GEOLOGY of the Philippines

Second Edition



MINES AND GEOSCIENCES BUREAU Department of Environment and Natural Resources

2010

COPYRIGHT, JUNE 2010

ΒY

MINES AND GEOSCIENCES BUREAU

Second Edition 2010

© 2010 Mines and Geosciences Bureau North Avenue, Quezon City, Philippines www.mgb.gov.ph

FOREWORD

This volume of the **Geology of the Philippines, Second Edition** comes at an opportune time when the Philippines has become once more a beehive of activities by geologists owing to the efforts of government to promote the revitalization of the mining industry. This edition is a timely reference material that gives the reader an overview of the geology of the Philippines, as well as the stratigraphic make-up of local areas. Although this contains updated geologic data since the First Edition was published in 1981, it is by no means a definitive volume. Much research remains to be done to fill in the gaps in geological knowledge, but this volume can provide the starting point for further researches.

This volume is also timely in the sense that the Philippine Stratigraphic Guide came out while it was being prepared, so that those involved in preparing the revised edition were able to apply the Guide in the nomenclature of rock formations. In addition, this edition was able to use another new yardstick in the form of the Geologic Time Scale 2009 by which the editors were able to stack stratigraphic formations in accordance with the new time scale.

It is hoped that this volume can serve the needs of various users – researchers, exploration geologists, faculty and students of academe and other practitioners. At a time when government is promoting the revitalization of the mining industry, we hope that this can help in some way in delineating more prospective areas for economic mineral exploration and development.

I commend the geoscientists of the Bureau who have contributed their knowledge, time and effort to come up with this manuscript and ensure its publication.

HORACIO C. RAMOS Director Mines and Geosciences Bureau

Diliman, Quezon City Philippines June 2010

PREFACE

Since the publication of the Geology and Mineral Resources of the Philippines, Volume 1 (Geology) in 1981, much information on Philippine geology has accumulated. A wealth of data have accrued from the geological studies undertaken through cooperation with geoscientists from Japan, France, Korea and other countries, as well as from sustained researches by the geologists of the Mines and Geosciences Bureau, Department of Energy, Philippine Institute of Volcanology and Seismology, Philippine National Oil Corporation, UP National Institute of Geological Sciences, private companies and other institutions and agencies.

Compiling these new findings is a Herculean task by itself, which had to be matched with a new format of presenting geological data. This required the adoption of a new framework for the updating of geological data.

In line with the new framework, the task of compiling and collating of information was undertaken through appropriate working groups. The work was started in 1995 and after a series of discussion meetings on the respective assignments of the working group members; an initial draft was prepared by the editors. In the course of editing the initial draft, more data was considered for inclusion. However, we have seen fit to draw a cut-off date of end of 2004 for inclusion of new data, as otherwise this will remain a work in unending progress. In doing so, we recognize that gaps remain in our present knowledge and understanding of the geology of certain areas and of the archipelago as a whole.

We do hope however that this volume will stimulate researches that will further enrich our understanding of the geology of the Philippines. Further, it is hoped that this publication will serve the needs of mining investors as they pursue activities in line with the program of the government for the revitalization of the mineral industry.

Finally, having been associated with this volume through much of its preparation, I would like to take this opportunity to express my appreciation to those who have contributed to its completion, particularly to Romeo L. Almeda, former Chief of the Lands Geological Survey Division (LGSD) for initiating work on the project and Antonio N. Apostol, Jr., Officer-in-Charge, of LGSD for seeing the work through to its end, as well as to the personnel of this Division and other officials and personnel of the Bureau. My gratitude also goes to the Department of Science and Technology for providing funding support to this project.

EDWIN G. DOMINGO Assistant Director Mines and Geosciences Bureau

Diliman, Quezon City Philippines June 2010

TECHNICAL WORKING GROUP

CONTRIBUTORS

- Tectonics
- Stratigraphy

Mario A. Aurelio Rolando E. Peña

Yolanda Maac-Aguilar Mario A. Aurelio Editha A. Amiscaray Mary Antonette A. Beroya Elmer C. Billedo Sevillo D. David, Jr. Ernesto A. Espiritu Digna G. Evangelista Marianne V. Fernandez Alvin Lucio M. Fernando Fe Tumanda-Mateer Dilson B. Montano Elsa Y. Mula Karlo L. Queaño Ramon D. Quebral Jerry Hervacio G.Salvador Marietta N.Tan Ma. Malyn L. Tumonong Maybellyn Agadier-Zepeda

TECHNICAL SUPPORT GROUP

Edward B. Aguinaldo Saturnino Y. Camangonan Melanio O. Dones, Jr. Aurelio M. Gutierrez Bernard S. Lanuza Enrique S. Maglanque Jose Claro C. Manipon Nympha R. Pajarillaga Marie Iris P. Villanueva

PUBLICATION STAFF

Ma. Elveta C. Comsti, Maria Sally P. Sagragao and Angelica B. Sajona

EDITORS

Mario A. Aurelio and Rolando E. Peña

CONTENTS

	Page
Foreword	iii
Preface	V
Introduction	xxxiii

TECTONICS

Chapter 1 REGIONAL GEODYNAMIC SETTING 1

WESTERN PACIFIC DOMAIN	1
Pacific Plate	1
Eurasian Plate	2
Indo-Australian Plate	2
SOUTHEAST ASIAN TECTONIC REGION	3
Philippine Sea Plate	3
Ocean Basins	3
Submarine Ridges	6
Tectonic Nature of the Boundaries of the Philippine	
Sea Plate	6
Kinematics of the Philippine Sea Plate	7
Present-day kinematics	7
Old kinematics	8
Southeast Asian Margin	11
South China Sea Basin and Continental Blocks	11
Sulu Sea - Cagayan Ridge - Sulu-Zamboanga	
Arc -Celebes Sea System	14
Sulu Sea Basin and Cagayan de Sulu Ridge	14
Sulu-Zamboanga Arc and Celebes Sea Basin	14
Synthesis	15
Origin of marginal basins: existing models	15
Back-arc basin	15
Continental domain basin	15
Extrusion tectonic basin	16
Trapped basin	16
Complexity of tectonic processes along plate	
boundaries	17

Chapter 2 THE PHILIPPINES: A COMPLEX PLATE BOUNDARY

GEODYNAMIC FRAMEWORK OF THE	
PHILIPPINES	18
Subduction zones	18
West-dipping subduction zones	18
Philippine Trench (4°N - 15°)	18
East Luzon Trough (16°N - 18°N)	21
East-dipping subduction zones	21
Manila Trench (22°N - 13°N)	21
Negros Trench (10°N)	21
Cotabato Trench (6°N)	23
Collision zones	23
Taiwan: continent-arc collision	24
Mindoro-Panay: arc-continent collision	24
Moluccas Sea: arc-arc collision	24
PHILIPPINE GEOLOGY: AN OVERVIEW	25
Metamorphic rocks	27
Ophiolites and ophiolitic rocks	27
Magmatic arcs	32
Ancient arc	32
Active volcanic arcs	34
Sedimentary basins: stratigraphic and structural	
overview	38
Ilocos - Central Luzon Basin	39
Cagayan Valley Basin	39
Southern Luzon - Bicol Basin	40
Mindoro Basin	41
Iloilo Basin	42
Visayan Sea Basin	42
Samar Basin	43
Agusan-Davao Basin	44
Cotabato Basin	44
THE PHILIPPINE FAULT	44
Extent of the fault and morphologic evidence	48
Activity	48
Seismicity	49
Extent of displacement, slip rate and age of the fault	50
Structural regime variations along the Philippine Fault:	53
the three segments	50
Northern Segment: NVV Luzon to Lamon Bay	53
Central Segment: Bondoc Peninsula to Leyte	54
Southern Segment: Mindanao and the Moluccas	54
	55
OTHER ACTIVE FAULTS	55
Marikina Valley Fault System	55
Macolod Corridor	56
Lubang-Verde Passage Fault System	5/
iviindoro/Agiubang Fault	57

71

Sibuyan Sea Fault Legaspi Lineament Tablas Lineament Mindanao Fault Offshore Cebu-Bohol faults	57 57 58 58 58
PRESENT-DAY PLATE MOTIONS IN AND AROUND THE PHILIPPINES Southern Philippines Central Philippines	59 59 60
Chapter 3 SUMMARY OF SIGNIFICANT TECTONIC EVENTS IN THE PHILIPPINES	64
Origin of Basement Rocks Continental Basement Oceanic Basement Arc Basement Formation of Sedimentary Basins in the Neogene Magmatism since Cretaceous Miocene Collision Recent Tectonic Deformation	64 64 65 65 65 65 65

STRATIGRAPHY AND PETROLOGY 67

Chapter 1 L U Z O N

	74
ILUCUS (SG 1)	11
Suyo Schist	71
Ilocos Peridotite	71
Bangui Formation	73
Magabbobo Limestone	73
Bojeador Formation	74
Dagot Limestone	75
Pasaleng Quartz Diorite	75
Batac Formation	76
Pasuquin Limestone	76
Laoag Formation	77
Uplifted Coral Reefs	77

CENTRAL LUZON BASIN - WEST SIDE (SG 1)	78
Aksitero Formation	78
Moriones Formation	79
Malinta Formation	80
Tarlac Formation	81
Amlang Formation	82
Cataguintingan Formation	83
Damortis Formation	84
Bamban Formation	84
CENTRAL LUZON BASIN - EAST SIDE (SG 1)	85
Barenas-Baito Formation	85
Bayabas Formation	85
Angat Formation	86
Madlum Formation	87
Clastic Member	88
Alagao Volcanics	88
Buenacop Limestone	88
Lambak Formation	89
Makapilapil Formation	90
Tartaro Formation	90
Guadalupe Formation	91
Alat Conglomerate	91
Diliman Tuff	91
CENTRAL CORDILLERA (SG 2)	92
Pugo Formation	92
Malitep Formation	94
Sagada Formation	95
Central Cordillera Diorite Complex	96
Zigzag Formation	97
Kennon Limestone	98
Itogon Quartz Diorite	99
Klondyke Formation	100
Mirador Limestone	101
Daguio Formalion Black Mountain Quartz Diarita	102
Balachae Andosite	103
Mankayan Dacitic Complex	104
Malava Formation	104
Pleistocene - Recent Volcanic Centers	100
	100
	107
SUB-PROVINCE (SG 2)	107
Batan Island	107
Sabtang Island	108
Babuyan de Claro Island	108
Califiguiti Island	100
Calayan Islanu Mt. Cogue Veleene	100
	109
Abuen Formation	109
ADUAN FORMATION	109
Ibulaal Formation	110
Sicalao Limestono	11Z
	112

Lubuagan Formation	113
Asiga Member	113
Balbalan Sandstone Member	113
Buluan Member	114
Callao Formation	114
Cabagan Formation	115
Ilagan Formation	115
Awiden Mesa Formation	116
NORTHERN SIERRA MADRE - CARABALLO	
	440
(56 4)	116
Isabela Ophiolite	116
Dibuakag Volcanic Complex	118
Lubingan Formation	119
Dinalungan Diorite Complex	120
Caraballo Formation	120
Dupax Diorite Complex	121
Mamparang Formation	122
Cordon Syenite Complex	123
Sta. Fe Formation	123
Kanaipang Limestone	124
Palali Formation	124
Aglipay Limestone	125
Palanan Formation	126
Pantabangan Formation	126
ZAMBALES RANGE (SG 5)	127
Zambales Ophiolite Complex	127
Coto block	127
Acoie block	120
Balog-Balog Diorite	129
Aksitero Formation	130
Cabaluan Formation	130
Sta Cruz Formation	101
Balinaa Limaatana	102
Botaan Valaania Ara Compley	100
Mostern Volcanic Alt Complex	100
Relatibel Valaania Complex	104
Marivalas Valaania Complex	100
Directulo Volcanic Complex	135
Pinatubo Volcanic Complex	135
	130
Mt. Arayat	136
Mt. Amorong	137
Mt. Balungao	137
Mt. Cuyapo	137
SOUTHERN SIERRA MADRE (SG 6)	137
Polillo Island Group - Infanta Strip	138
Buhang Ophiolitic Complex	138
Quidadanom Schist	139
Anawan Formation	140
Babacolan Formation	141
Polillo Diorite	141
Bordeos Formation	142
Langoyen Limestone	143
Patnanongan Formation	143

Karlagan Formation	144
Southern Sierra Madre Mainland	144
Montalban Ophiolitic Complex	144
Kinabuan Formation	145
Maybangain Formation	146
Sta Ines Diorite	148
Binangonan Formation	149
Anget Formation	150
Madlum Formation	151
Clastic Member	152
Alagao Volcanice	152
Ruenacen Limestene	152
Guadalupa Formation	153
Alet Conglemente	155
Alat Congiomerate	104
Diliman Tuli Antinala Dasalt	154
Antipolo Basalt	154
Manila Formation	155
SOUTHWEST LUZON UPLANDS (SG 7)	155
San Juan Formation	155
Tolos Quartz Diorite	157
Looc Volcanic Complex	157
Dagatan Wacke	158
Corregidor Formation	159
Calatagan Formation	160
Pinamucan Formation	160
Mataas na Gulod Volcanic Complex	161
Macolod Volcanic Complex	161
Taal Volcano	162
Makiling – Malepunyo	163
Laguna de Bai	163
Banahaw Volcanic Complex	164
MARINDUOLE ISLAND (SG 7)	16/
Marinduque Termetien	104
Mannouque Formation	164
Magapua Limestone	105
l aluntunan- i umicob Formation	166
San Antonio Formation	166
	167
Lobo Quartz Diorite	168
Porvado Conglomerate	168
Gasan Formation	169
Boac Formation	169
Malindig Volcanic Complex	169
BONDOC PENINSULA (SG 8)	170
Gumaca Schist	170
Unisan Formation	170
Panaon Limestone	171
Vigo Formation	171
Canquinsa Formation	172
Hondagua Formation	172
Viñas Formation	173
Malumbang Formation	173
SOUTHEASTERN LUIZON (SC 0 SC 10)	17/
Ouezon Comprises Marte	475
	C/1

Malaguit Schist	175
Cadig Ophiolitic Complex	175
Tigbinan Formation	176
Tumbaga Formation	177
Larap Volcanic Complex	178
Bosigon Formation	178
Paracale Granodiorite	179
Tamisan Diorite	180
Sta. Elena Formation	180
Viñas Formation	181
Caramoan Peninsula	181
Siruma Schist	181
Lagonoy Ophiolite	182
Pagsangahan Formation	183
Garchitorena Formation	183
Guijalo Limestone	184
Caramoan Formation	185
Tabgon Flysch	185
Ragas Point Olistostrome	185
Tambang Diorite	186
Del Pilar Formation	186
Labuy Formation	187
Catanduanes Island	187
Yon Formation	187
Codon Formation	188
Pavo Formation	180
Manamrag volcanics and volcaniclastics	100
facies	180
Hilawan Limestone	189
Batalay Diorite	109
Bote Limestope	190
San Vicente Conglemerate	190
Sta Dominga Limostono	101
Viga Conglomorato	191
Viga Congiomerate Cograrov, Poton, Pony Pony Jolanda	191
Caylalay, Dalali, Kapu-Kapu Islahus	192
Rapu-Rapu Schist	192
Liber Formation	192
Libog Formation	192
Sula Formation Cool Herber Limestone	193
Liguen Formation	193
Liguan Formation	194
	194
	194
Hill Limestone	194
Caracaran Siltstone	195
Bilbao Formation	195
Lower Limestone Member	195
Galicia Sandstone	195
Gaba Coal Measures	196
Upper Limestone Member	196
Southern Bicol Peninsula	196
Panganiran Peridotite	196
Pantao Limestone	196
Ragay Andesite	197

Maonon Diorite	197
Tinalmud Formation	198
Talisay Formation	198
Ligao Formation	200
Bicol Volcanic Arc Complex	200
Susong Dalaga Volcanic Complex	201
Macogon Formation	201
Bagacav Andesite	201
Polangui Volcanic Complex	202
Isarog Volcanic Complex	202
Labo Volcanic Complex	203
Pocdol Volcanic Complex	204
Bulusan Volcanic Complex	205
Iriga Volcano	206
Mayon Volcano	206
MASBATE GROUP OF ISLANDS (SG 8 SG 15)	206
Machate Mainland	207
NidSDale Mainianu Rolono Sobiet	207
Daleno Schist Mananaa Basalt	207
Manapao Basai	200
	208
Kaal Formation	209
Aroroy Quartz Diorite	209
Nabangig Formation	210
Mountain Maid Limestone	210
Lanang Formation	211
Mobo Dione Buyon Formation	212
Duyay Formation Nebengeuren Andesite	212
Dort Porroro Formation	210
Machata Limostona	213
Ticoo Island	214
Talisay Schiet	214
Nan Conglomerate	215
Pilar Formation	215
Ticao Limestone	210
San Jacinto Formation	216
Matabao Formation	210
Burias and Adjacent Islands	217
Makalawang Limestone	217
Quilla Formation	217
San Pascual Formation	218
Baybay Limestone	220
MINDOPO ISLAND (SG 7 SG 11)	220
Southwastern Mindera	220
Mancalay Formation	220
Adbabag Conglomerate	220
	221
Buatona Formation	222
Tangon Formation	223
Nanisian Formation	224
Pocanil Formation	224
Punso Condomerate	220
Famnoan Formation	220
	220

Sagasa melange	200
Sagasa Mélange	259
Pandian Formation	258
Sumbling Limestone	257
Fallas Fullianuli	207
Panac Formation	250
Dalrympole Amphibolite	256
Espina Formation	255
Stavely Gabbro	254
Beaufort Ultramafic Complex	253
Palawan Ophiolite	251
Central and Southern Palawan and Balabac Island	251
Manguao Basalt	250
Piedras Andesite	250
Kapoas Granite	249
St. Paul Limestone	248
St. Doublimestone	247
Mavtiguid Limestone	240
Boavan Formation	246
Concepcion Phyllite	245
Caramay Schist	244
Barton Group	243
Paly Serpentinite	243
Guinlo Formation	242
Coron Formation	241
Liminangcong Formation	239
Minilog Limestone	238
Bacuit Formation	237
Malampaya Sound Group	237
Northern Palawan	237
PALAWAN ISLAND (SG T1, SG T2)	230
	000
Dumair voicanic Complex	234
	204
Luminiao Dasait San Taadara Valaania Camplay	233
Annay Opnone	200
Ampor Ophiolito	202
Paghahan Granodiorite	231
Lasala Formation	231
Abra de llog	231
Metasedimentary and metavolcanic rocks	230
Camarong Gneiss	229
Burburungan Metaophiolite	229
Halcon Metamorphic Complex	228
Northeastern Mindoro	228
Oreng Formation	228
Balanga Formation	227

Panoyan Limestone Tagburos Opalite	264 265
Chapter 2	
VISAYAS	267
PANAY ISLAND (SG 11, 13, 14, 15)	267
Buruanga Peninsula	267
Buruanga Metamorphic Complex	267
Patria Quartz Diorite	268
Fragante Formation	269
Libertad Formation	269
Western Panay – Antique Range	270
Antique Ophiolite	270
Cabariohan Limestone	271
	272
Baloy Formation	272
Mayos Formation	273
Pakoi Diorite	273
Paniciuan Melange	274
Lagoo Formation	274
Apoo Formation Control Donov Illoito Posin	275
Demographic Formation	275
Singit Formation	275
Singit Formation Sowaragan Mombor	270
Tanjan Limostono Mombor	270
Intelencen Shale	270
Barasan Sandstone	277
Tarao Formation	277
Tubungan Siltstone Member	277
Guimbal Mudstone Member	278
Iday Formation	278
Illian Formation	279
Cabatuan Formation	279
Balic Clay Member	279
Maraget Sandstone	280
Sta. Barbara Member	280
Eastern Panav Magmatic Arc	280
Sibala Formation	280
Guimaras Diorite	280
Sara Diorite	281
Pilar Formation	281
Passi Formation	282
Salngan Member	282
Assisig Member	283
Agudo Basalt	283
Dingle Formation	283
Aglalana Limestone Member	284
Summit Clastic Member	284
Sto. Thomas Limestone Member	284
Ulian Formation	285

Odiongan Andesite	285
Cabatuan Formation	285
ROMBLON ISLAND GROUP (SG 11)	286
Romblon Metamorphic Complex	286
Carabao Sandstone	288
Pacul Limestone	288
Sibuyan Ophiolitic Complex	289
Tablas Volcanic Complex	290
Calatrava Quartz Diorite	290
Bailan Limestone	291
Binoog Formation	292
Tuguis Limestone	292
Cogon Member	292
Anahao Formation	293
Banton Volcanic Complex	293
Peliw Formation	294
Mayha Clastic Member	294
Looc Limestone	295
NEGROS ISLAND (SG 15, 16, 17)	295
Basak Formation	295
Isio Limestone	297
Pangathan Diorite	297
Escalante Formation	297
Tabu Formation	298
Malahago Formation	299
Vista Alegre Dacite Porphyry	300
Dacongcogon Formation	300
Macasilao Formation	301
Canturay Formation	302
Talave Formation	302
Magsinulo Andesite	303
Kalumbuvan Formation	303
Amlan Conglomerate	304
Caliling Formation	304
Calaogao Pyroclastics	305
Canlaon Volcanic Complex	305
CEBUISI AND (SG 17)	306
Northern and Central Cebu	307
Tunloh Schists	307
Mananga Group	308
Tuburan Limestone	309
Cansi Formation	310
Pandan Formation	311
Bantoon Peridotite	311
Lutopan Diorite	312
Bave Limestone	313
Lutak Limestone	313
Talamban Diorite	314
Naga Group	314
Cebu Formation	314
Lower Coal Measures	315
Ilag Limestone	315
Malubog Formation	316
~	

Uling Limestone	317
Luka Formation	317
Bulacao Andesite	318
Talavera Group	318
Toledo Formation	318
Maingit Formation	319
Barili Formation	320
Lower Limestone Member	320
Bolok-bolok Member	321
Carcar Limestone	321
Southern Cebu - Siguijor Island	322
Pandan Formation	322
Argao Group	323
Calagasan Formation	323
Butong Limestone	324
Linut-od Formation	324
Signific Island	325
Kanglasog Volcanic Complex	325
Basac Formation	325
Lazi Mombor	320
	320
Siguijor Limestono	320
	327
BURUL ISLAND (SG 17)	321
Alicia Schist	327
Bonoi Opniolite	329
Ubay Formation	330
Jetale Andesite	331
	აა∠ ეეე
	333
Jagna Andesite	333
Wanig Formation	334
Carmen Formation	335
Sierra Bullones Limestone	336
Maribojoc Formation	337
l ubigon Congiomerate	337
Sevilla Mari	338
Cortes Limestone	339
LEYTE ISLAND (SG 17, 19, 20)	339
Western Leyte and Camotes Island	339
Malitbog Ophiolite	340
Lawagan Gabbro	341
Cagbaong Basalt	341
Tigbauan Formation	342
Amontay Sandstone	343
Gilonon Formation	343
Kantaring Limestone	344
Batang Formation	345
Taog Formation	346
Laboon Conglomerate	346
Calubian Limestone	347
Tagnocot Formation	348
Kadlum Conglomerate	348
Bata Formation	349

371

Hubay Limestone	350
Inopacan Formation	351
Tuktuk Formation	351
San Isidro Limestone	352
Leyte Central Highland	353
Albuera Diorite	353
Kanturao Volcanic Complex	353
Pangasugan Formation	354
Dolores Formation	355
Visares Limestone	355
Leyte Volcanic Arc Complex	356
Cabalian Volcanic Complex	356
Biliran Volcanic Complex	356
Cancajanag Volcanic Complex	357
Eastern Leyte	357
Tacloban Ophiolite	357
Tagawili Ultramafic Complex	358
Tigbao Gabbro	358
Paglaum Diabase Complex	359
Caibaan Basalt	359
Palanog Formation	360
San Jose Formation	360
San Ricardo Formation	361
Bagahupi Formation	361
SAMAR ISLAND (SG 18, 20)	362
Samar Ophiolite	362
Giporlos Ultramafic Complex	362
Camcuevas Volcanic Complex	364
Anagasi Formation	364
Balo Formation	365
Lawaan Formation	366
Mapanas Limestone	367
Daram Formation	367
Hagbay Formation	368
Catbalogan Formation	368
Calicoan Formation	369

Chapter 3 MINDANAO

DINAGAT GROUP OF ISLANDS (SG 20)	371
Nueva Estrella Schist	371
Dinagat Ophiolite	372
Madanlog Formation	374
Bacuag Formation	374
Mabuhay Formation	375
Timamana Limestone	375
Loreto Formation	376
Siargao Limestone	376
Recent Deposits	377
SULU ARCHIPELAGO (SG 21)	377

Sulu Serpentinite	377
Sibutu Diorite	377
Bongao Formation	378
Jolo Volcanic Complex	379
ZAMBOANGA – MISAMIS OCCIDENTAL (SG 21)	379
Zamboanga Peninsula	379
Tungayan Schist	370
Bungiao Mélange	381
Sirowai Formation	201
Anungan Formation	201
Anungan Formation Selenten Veleenie Complex	302
Solepiep voicanic Complex	383
Vitali Dionte	383
Curuan Formation	384
Panganuran Formation	385
ligpalay Conglomerate	386
Sta. Maria Volcanic Complex	386
North – Central Zamboanga	386
Dansalan Metamorphic Complex	386
Polanco Ophiolite Complex	387
Sindangan Basalt	388
Gunyan Mélange	388
Tampilisan Mélange	389
Camanga Formation	389
Pictoran Formation	390
Timonan Formation	391
Aurora Formation	391
Sibuguey Peninsula – Olutanga Island	392
Mangabel Formation	392
Sibuguey Formation	392
Lumbog Formation	393
Lalat Member	393
Gotas Member	394
Dumagok Member	394
Dumaguet Sandstone	394
Midsalin Diorite	395
Colov Formation	395
Olutanga Limestone	396
Zamboanga Volcanic Complex	396
Labangan Formation	307
	200
CENTRAL WINDANAO (36 22)	330
Misamis Oriental – Bukidnon – Lanao	398
l ago Schist	398
Awang Ultramatic Complex	399
Himalyan Formation	400
Balongkot Limestone	400
Luod Formation	401
Maniki Diorite Complex	402
Opol Formation	402
Indahag Limestone	403
Iponan Formation	404
Bukidnon Formation	404
Cagayan Gravel	404
Mindanao Central Cordillera	405

Tago Schist	405
Pantaron Ophiolitic Complex	406
Nilabsan Formation	406
Umayam Limestone	407
Kilapagan Formation	407
Kalagutay Formation	408
Tagbacan Formation	409
Locawan Diorite	409
Lumbayao Formation	410
Malambo Andesite	410
Koronadal Formation	411
Cabanglasan Gravel	411
Central Mindanao Volcanic Zone	412
Mambuaya Andesite	412
Lanao Volcanic Complex	412
Ragang Volcanic Complex	412
Parker Volcanic Complex	413
Apo Volcanic Complex	414
Malindang Volcanic Complex	414
Katanglad Volcanic Complex	414
Matutum Volcanic Complex	415
Camiguin Volcanic Complex	415
Musuan Volcano	416
AGUSAN – DAVAO BASIN (SG 23)	416
Agusan Basin	418
Addaon Formation	418
Wawa Formation	419
Recent Deposits	420
Davao Basin	420
Kabagtican Formation	420
Upian Limestone	421
Masuhi Formation	422
Mandog Sandstone	422
Mawab Formation	423
Bunawan Limestone	424
Tigatto Terrace Gravel	424
Davao Gulf and Samal Island	425
Tagbobo Conglomerate	425
Samal Limestone	425
MINDANAO PACIFIC CORDII I FRA (SG 24)	426
Northern Pacific Cordillera and Masapelid Island	426
Dinagat Ophiolite	426
Schoton Greenschist	427
Madanlog Formation	427
Bacuag Formation	428
Asiga Diorite	429
Mabuhay Formation	430
Alipao Andesite	430
Timamana Limestone	431
Tugunan Formation	431
Inil Andesite	432
Bad-as Dacite	433
Manjavao Andesite	434
Manayao / Macono	-0-1

Mainit Formation	101
	434
Hinatigan Limestone	435
Placer Conglomerate	435
Central Pacific Cordillera	435
Anoling Volcanics	435
Baggao Limestone	436
Diwata Diorite	436
Bislig Formation	436
Rosario Limestone	438
Hinatuan Limestone	438
Southern Pacific Cordillera	439
Barcelona Formation	439
Tagabakid Formation	440
Cateel Quartz Diorite	440
Agtuuganon Limestone	441
Taragona Conglomerate	441
Manay Formation	442
Amacan Volcanic Complex	442
DAGUMA RANGE (SG 25)	443
Salbuvon Schist	443
Kiamba Formation	444
Daguma Diorite	445
Maganov Formation	446
Nakal Formation	446
Cablacan Formation	447
Tual Quartz Diorite	448
Tampanan Limestone	449
Siguil Formation	440
Allah Formation	450
Kamanga Limestone	450
Matulas Gravel	450
	451
COTADATO DASIN (SG 20)	431
Patut Formation	452
Dinganen Formation	453
Nicaan Formation	453
Marbel Formation	454
Kilada Formation	454
Omanay Marl	455
SARANGGANI PENINSULA (SG 27)	455
Malita Formation	455
Latian Limestone	455
Pangyan Formation	456
Glan Formation	456
Sulop Formation	457
Buayan Formation	458
Gumasa Formation	458
Balut Volcano	460
PUJADA PENINSULA (SG 28)	460
Pujada Ophiolite	460
Ansuwang Amphibolite	460
Magnapangi Greenschist	462
Suron Peridotite	462
Nagas Peridotite	463
ragao i onaomo	

Matalao Gabbro	463
Lumao Diabase	464
Kalunasan Basalt	464
Iba Formation	464
Basiaw Limestone	465
Sanghay Formation	466
Sigaboy Formation	466
Maco Limestone	467
References Index of Stratigraphic Names	469 509
index of Stratigraphic Names	509

GEOLOGY OF THE PHILIPPINES

FIGURES

1.1 Geodynamic setting of the Southeast Asia – West Pacific Domain. Numbers beside arrows indicate rates of plate motion in cm/yr relative to Eurasia. Modified from Barrier, 1985

1.2 Bathymetric features of the Philippine Sea Plate. Modified from Ringenbach, 1992

1.3 Paleomagnetic signature of the West Philippine Sea basin. From Hilde and Lee, 1984

1.4 Evolution of the Philippine Sea Plate according to Uyeda and Avraham, 1972

1.5 Kinematics of the Philippine Sea Plate according to different authors. Adopted from Seno and Eguchi, 1983 and Barrier, 1985

1.6 Kinematics of the Philippine Sea Plate with respect to Eurasia. Numbered arrows represent relative plate motion in cm/yr. Adopted from Seno, 1977

1.7 Evidence of kinematic reorganization (40-deg counterclockwise rotation) of the Philippines Sea Plate in Taiwan that occurred about 5Ma. Modified from Barrier, 1985 and Huchon, 1985

1.8 Evidence of kinematic reorganization of the Philippines Sea Plate in Japan that occurred about 5Ma. Modified from Huchon, 1985 and Angelier and Huchon, 1985

1.9 Terrane affinity map of the Philippines according to Rangin et al., 1990

1.10 Paleomagnetic signature and structural synthesis of the South China Sea basin and neighboring areas. Adopted from Taylor and Hayes, 1983

1.11A Structure of the Sulu Sea Basin deduced from magnetic data. Modified from Murauchi, et al., 1973

1.11B Structure of the Cagayan Ridge from seismic data. Adopted from Rangin, 1989

1.12 Basin evolution models for West Pacific – Southeast Asia regions. (a) Back-arc spreading, (b) Atlantic-type spreading, (c) Basin formation by extrusion tectonics, (d) Trapped basin. Modified from Silver and Rangin, 1991

1.13 Simplified tectonic map of the Philippines. Adopted from Aurelio, 1992

1.14 Distribution of earthquake epicentres in the Philippines from 1900 to 1992. Locations of diagrams in Fig. 1.15 are indicated. Adopted from Aurelio, 1992

1.15 Geometry of seismogenic plates underneath the Philippines, deduced from Benioff zones from Fig. 14. Adopted from Aurelio, 1992

1.16 Structure of the old subduction zone west of the East Luzon Trough established from seismic profiles. Adopted from Lewis and Hayes, 1983

1.17 Structure of the accretionary prism of the Manila Trench from seismic profiles (A), and of the subducting slab and over-riding plate established from gravimetric data. Adopted from Hayes and Lewis, 1984 and Pinet, 1990

1.18 Lithospheric structure in the Taiwan region showing collision of the Luzon Arc with the Eurasian plate. Original drawing by J. Angelier, 1985

1.19 Simplified tectonic map of the collision zone involving the North Palawan continental block and the western central Philippine arc (Mindoro-Panay). Adopted from Marchiadier, 1988

1.20 Lithospheric structure in the Mollucas Sea region, showing the incipient arc-arc collision between Sangihe (1) and Halmahera (2). From Roeder, 1977

1.21 Tectonic and structural features of the Philippine archipelago. Circles are active volcanoes while triangles are GPS observation stations discussed in text. Modified from Aurelio, 2000

1.22 Generalized distribution map of metamorphic rocks in the Philippines. (1) island arc affinity, (2) continental affinity

1.23 Generalized distribution map of ophiolites and ophiolitic rocks in the Philippines

1.24 Generalized distribution map of Cretaceous-Paleogene intrusions in the Philippines

1.25 Generalized distribution map of Oligocene-Miocene magmatic belts in the Philippines

1.26 Generalized distribution map of active and potentially active volcanoes, and other Recent volcanic belts in the Philippines

1.27 Generalized distribution map of Philippine sedimentary basins. Location of Figs. 1.28 to 1.35 indicated

1.28 Schematic cross sections across the Ilocos Basin according to Pinet and Stephan, 1990

1.29 E-W schematic section across the asymmetric Cagayan Valley Basin. Modified from MGB 1982 **1.30** E-W schematic section across Mindoro and Tablas Islands, showing structural position of Mindoro Basin with respect to juxtaposed ophiolites, volcanic arcs and continental rocks. From Marchiadier and Rangin, 1989

1.31 E-W schematic section across Panay Island and summary of stratigraphy of different terrane units. From Rangin and others, 1991

1.32 Synthetic profile across Panay, Negros, Cebu and Bohol Islands, showing structural relationship between the continental platform and the Visayan Sea Basin. Modified from Rangin and others, 1989

1.33 Structural sketch map (A) and schematic sections (B) across Samar Island. From Aurelio, 1992

1.34 Schematic section across the Agusan-Davao Basin showing the Philippine Fault Zone as a terrane boundary according to Hawkins and others, 1985. Read later interpretation by Pubellier and others, 1991

1.35 Schematic section across the Cotabato Basin flanked to the west by the Daguma Range and to the east by the Central Mindanao volcanic Arc. Modified from Letouzey and others, 1987; according to Pubellier, unpublished data

1.36 Morphological expression of the Philippine Fault cutting through eroded volcanic edifices in northern Leyte. Photo by C. Allen, 1962

1.37 Left-laterally displaced drainage patterns in Digdig, Masbate and Leyte. From Allen, 1962

1.38 Intensity isoseismal map of the Ms 7.3 Ragay Gulf earthquake of 1973, showing the elongation of the source: Philippine Fault. From Garcia and others, 1985

1.39 Focal mechanism solutions of major earthquakes (>Ms 5.0) related to the Philippine Fault from 1964 to 1991. Replotted from Aurelio, 1992

1.40 Diagram explaining the concept of shear partitioning as originally proposed by Fitch in 1972

1.41 Motion vectors in the Philippines deduced from GPS measurements. From Aurelio and others, 1998

1.42 Block rotation rates in the Philippines deduced from GPS measurements. From Aurelio and others, 1998

1.43 Strain rates in the Philippines deduced from GPS measurements. From Aurelio and others, 1998

GEOLOGY OF THE PHILIPPINES

TABLES

1.1 List of Active Volcanoes of the Philippines according to PHIVOLCS (2002)

1.2 List of Potentially Active Volcanoes of the Philippines according to PHIVOLCS (2002)

1.3 Estimates of extent of displacement slip rate and age of the Philippine Fault according to various authors

- 2.1 Stratigraphic groupings
- 2.2 Stratigraphic column for llocos
- 2.3 Stratigraphic column for Central Luzon Basin
- 2.4 Stratigraphic column for Central Cordillera and Batanes
- 2.5 Stratigraphic column for Cagayan Valley Basin
- 2.6 Stratigraphic column for Northern Sierra Madre-Caraballo
- 2.7 Stratigraphic column for Zambales Range
- 2.8 Stratigraphic column for Southern Sierra Madre
- 2.9 Stratigraphic column for Southwest Luzon
- 2.10 Stratigraphic column for Marinduque Island
- 2.11 Stratigraphic column for Southeastern Luzon
- 2.12 Stratigraphic column for Masbate, Ticao and Burias Islands
- 2.13 Stratigraphic column for Mindoro Island
- 2.14 Stratigraphic column for Northern Palawan
- 2.15 Stratigraphic column for Central and Southern Palawan
- 2.16 Stratigraphic column for Panay Island
- 2.17 Stratigraphic column for Romblon Island Group
- 2.18 Stratigraphic column for Negros Island
- 2.19 Stratigraphic column for Cebu and Siquijor Islands

- 2.20 Stratigraphic column for Bohol Island
- 2.21 Stratigraphic column for Leyte Island
- 2.22 Stratigraphic column for Samar Island
- 2.23 Stratigraphic column for Dinagat Group of Islands
- 2.24 Stratigraphic column for Sulu Archipelago
- 2.25 Stratigraphic column for Zamboanga Misamis Occidental
- 2.26 Stratigraphic column for Central Mindanao
- 2.27 Stratigraphic column for Agusan Davao Basin
- 2.28 Stratigraphic column for Mindanao Pacific Cordillera
- 2.29 Stratigraphic column for Daguma Range
- 2.30 Stratigraphic column for Cotabato Basin and Saranggani Peninsula
- 2.31 Stratigraphic column for Pujada Peninsula

2.32 Comparison of attributes of Eastern and Western Volcanic Belts, Bataan Volcanic Belt

2.33 Petrologic characteristics of Volcanoes of Eastern Volcanic Belt, Bataan Volcanic Belt

2.34 Lithology and Age Dating of Units of the Podcol Volcanic Complex, Bicol Region

INTRODUCTION

This present edition of the *Geology of the Philippines* addresses a basic problem encountered by geoscientists and the general public, local and foreign alike, regarding the need of an updated reference on Philippine geology. This is a revised edition of the 30-year old first edition published by the then Bureau of Mines and Geosciences. Since then, developments in the earth sciences in general, and in geology in particular have accelerated considerably, thanks to numerous collaborative programmes among local and foreign institutions showing mutual interests in the different branches of the field. This book presents an update on the state of knowledge of Philippine Geology as a consequence of the rapid influx of information between 1981 and 2004.

This volume starts with an introductory chapter describing the regional tectonic setting of the Philippines, followed by a detailed and in-depth discussion of the stratigraphy and petrology of the various regions.

This edition differs from the first in the format of presentation. In the 1981 edition, the geology of the Philippines was grouped by physiographic provinces and was presented according to geologic age of formations. The present edition discusses geology by stratigraphic groupings. The work of updating this volume also involves the renaming of some stratigraphic units in order to conform to certain provisions of the Philippine Stratigraphic Guide (Peña and others, 2001). The adoption of a new Geologic Time Scale (Gradstein and others, 2004, International Commission on Stratigraphy, 2009) under the auspices of the International Union of Geological Sciences (IUGS) also allowed us to make necessary adjustments in preparing the stratigraphic columns and in the discussions of the stratigraphic positions of geologic units.

The project for the revision of the first edition was brought into fruition through the generous funding assistance of the Department of Science and Technology. In the work of revising the earlier edition, a Geology Working Group to prepare this volume was established. This working group was further subdivided into subgroups and a Technical Support Group was also organized in the preparation of the final product. However, more workers became involved as the tasks proved to be more demanding academically and technically.

Apart from the assistance provided by the Department of Science and Technology, gratitude is extended for the help and cooperation of the Energy Resources Development Bureau of the Department of Energy, the National Institute of Geological Sciences of the University of the Philippines, the Philippine Institute of Volcanology and Seismology and geologists from other institutions and the private sector. This project would not have been made possible without the full support of Mines and Geosciences Bureau Director Horacio C. Ramos, Assistant Director Edwin G. Domingo and former Lands Geological Survey Division Chief Romeo L. Almeda and his successor, Antonio N. Apostol, Jr.

TECTONICS

In June 1991, Mount Pinatubo awakened and recorded what later would be considered as the greatest volcanic eruption in the 20th century, causing destruction to human lives and property. A year earlier, on the 16th of July 1990, Northern Luzon was struck by a magnitude Ms 7.8 earthquake resulting in innumerable deaths and immense damage. These are natural phenomena that will remain in the Philippines for as long as the current geodynamics operate.

The following discussion is divided into three chapters. The first situates the Philippines in its *regional geodynamic setting*, while the second is a detailed discussion of the major *tectonic* features of the archipelago. The third chapter summarizes the significant tectonic events that transpired since the formation of the Philippine basement.



Philippine tectonics is indeed one of the most active in the world. The devastating Luzon Earthquake of 1990 and the catastrophic 1991 eruption of Mt. Pinatubo are but two of the most recent manifestations of this phenomenon. This tectonic activity is the result of the interaction of three major tectonic plates of the Western Pacific Domain, namely; the *Pacific*, the *Eurasian* and the *Indo-Australian* Plates (**Fig 1.1**).

WESTERN PACIFIC DOMAIN

Pacific Plate

The **Pacific Plate** is entirely composed of an *oceanic* lithosphere created since 150 Ma. It presently occupies almost a third of the total terrestrial surface, less than it did at 200 Ma (Le Pichon and Huchon, 1984). This plate has undergone a major kinematic reorganization at around 43 Ma, involving a 50-degree clockwise rotation with respect to hot spots (Clague and Jarrard, 1973). This rotation from a NNW to a WNW trajectory is presently manifested in the change of orientation of the Hawaiian - Emperor Islands volcanic chain from a WNW-ESE direction to the south to a NNW-SSE direction to the north. Another kinematic reorganization involving a 10-degree clockwise rotation about 5 Ma is mentioned by Cox and Engebretson (1985) and Seno and Maruyama (1984).

Fig. 1.1 Geodynamic setting of the Southeast Asia – West Pacific Domain. Numbers beside arrows indicate rates of plate motion in cm/yr relative to Eurasia. Modified from Barrier, 1985

Eurasian Plate

The **Eurasian Plate** (or **Eurasia**) extends for over 11,000 km from the Atlantic Ocean in the west, to the Pacific Ocean in the east. Unlike the Pacific Plate, the Eurasian Plate is basically *continental* in nature, except for marginal basins created along its edges. The movement of this plate with respect to hot spots is considered weak (Morgan, 1981) in the order of only a few millimetres per year (3 mm/yr), while the absolute velocities of the Pacific and Indo-Australian plates are 80 mm/yr and 107 mm/yr respectively. Consequently, most authors consider Eurasia as *fixed* since 50 Ma.

Indo-Australian Plate

The **Indo-Australian Plate** is composed of both *continental* and *oceanic* crusts. The continental crusts are presently represented by India and Australia, while the oceanic portion is represented by the Indian Ocean. The creation of the oceanic crust between India and Australia corresponds to the separation of the continental masses around 150 Ma. From 43 Ma, the mid-oceanic ridge separating the two continental blocks has become inactive. Since then, a single Indo-Australian Plate is moving northwards.

The interaction of these three major tectonic plates is governed by their nature (oceanic/continental) and their relative movements. The entirely

oceanic Pacific Plate subducts under the other plates: under the Eurasian Plate along the Japan Trench, under the Philippine Sea Plate along the Bonin-Marianas-Yap Trench System, and under the Indo-Australian Plate east of New Zealand. The mixed continental and oceanic crusts of the Indo-Australian Plate are presently colliding with the Eurasian Plate (in the Himalayas) and with a complex zone of insular arcs which have been active since the Mesozoic (in New Guinea, for example). Its oceanic portion is presently subducting under the Eurasian Plate along the Java Trench.

SOUTHEAST ASIAN TECTONIC REGION

The Southeast Asian Tectonic Region, here considered as the southwestern portion of the Western Pacific Domain, is essentially composed of the *Philippine Sea Plate* and the *southeastern edge* of the Eurasian Plate. The ensuing discussion describes these two tectonic plates in detail and serves as an introduction to the next chapter which will describe the complex tectonic zone created by their interaction. This complex zone *in fact* is the Philippine archipelago.

Philippine Sea Plate

The **Philippine Sea Plate** is developed at the western edge of the Pacific Plate. It is an oceanic crust composed of several *ocean basins* separated by *submarine ridges* (**Fig. 1.2**). It roughly takes the form of a diamond (long axis directed N-S) whose edges are defined by deep trenches including the Marianas Trench, the *deepest* in this planet.

Ocean Basins

The Philippine Sea Plate is basically composed of well individualized ocean basins with an average depth of 4 to 6 km. Except for the West Philippine Basin, the long axis of these basins is generally oriented N-S. They can be classified into two groups, namely; the *West Philippine Basin* and the *Other Basins*, the former being directly in contact with the Philippine archipelago.

The **West Philippine Basin** is the largest of its type in the region, occupying around 50% of the Philippine Sea Plate. It is characterized by the presence of several submarine plateaus (Benham Rise, Urdaneta Plateau and Anami and Oki-Daito Ridges) and a WNW-ESE lineament corresponding to the *Central Basin Fault* (**Fig. 1.2**). The age of this basin varies between 60 and 35 Ma from paleomagnetic data (Hilde and Lee, 1984) and between 53 and 42 Ma from Deep See Drilling (DSDP) data. The Central Basin Fault is composed of a series of *en echelon* ridges whose orientation makes an angle of around 15° (almost E-W) to its general direction (WNW-ESE). This structure represents an extinct midoceanic spreading ridge, cut transversely by a series of parallel faults oriented N-S (**Fig. 1.3**). This structural setting has brought Hilde and Lee (1984) to propose an opening model in two stages involving a first stage that occurred between 60 and 45 Ma whose direction of spreading was oriented NE-SW (half spreading rate = 4.4 cm/yr), and a second stage


Fig. 1.2 Bathymetric features of the Philippine Sea Plate. Modified from Ringenbach, 1992

occurring between 45 and 35 Ma the opening direction of which was oriented N-S (half spreading rate = 1.8 cm/yr).

In terms of the basin's origin, two models are generally distinguished. One is the model of a *trapped oceanic basin* invoked by Uyeda and Ben-Avraham (1972), Hilde and others (1977) and Hilde and Lee (1984). Another is the typical *back-arc basin* model of Karig (1975), Mrozowski and others (1982) and Seno and Maruyama (1984). In the back-arc basin model, the Oki-Daito Ridge would correspond to a relict volcanic arc that travelled to the NE during the opening of the basin (**Fig. 1.3**).

The **Other Basins** include the Parece Vela - Shikoku and the Marianas Basins (**Fig. 1.2**). Situated to the east of the West Philippine Basin, the Parece Vela - Shikoku Basin is an oceanic crust accreted on a N-S spreading axis. Its opening occurred in two stages, first in the Parece Vela



Fig. 1.3 Paleomagnetic signature of the West Philippine Sea Basin. From Hilde and Lee, 1984

at around 30 Ma, followed by the Shikoku area 10 Ma later (Mrozowski and Hayes, 1979; Kobayashi and Nakada, 1978). Oceanic accretion stopped at around 17 Ma. Similarly, the Marianas Basin corresponds to an oceanic crust with a spreading axis oriented N-S. It started opening around 6 Ma and is still presently active (Hussong and others, 1981).

The opening of these basins is usually associated with an eastward migration of the subduction of the Pacific Plate under the Philippine Sea Plate, probably by a mechanism involving the retreat of the subducting slab (Huchon, 1985; Le Pichon and others, 1985).

• Submarine Ridges

The oceanic basins are separated from each other by submarine ridges whose axes are generally oriented N-S which sometimes split into several branches. The four major ridges are the Palau-Kyushu, Izu Bonin, Marianas and West-Marianas Ridges (Fig. 1.2). Aside from these ridges, other bathymetric highs such as the Benham Rise or the Oki-Daito Platform are also present.

The **Palau-Kyushu Ridge** divides the West Philippine Basin from the Parece Vela - Shikoku Basin. Generally oriented N-S, it traverses the longer diagonal of the Philippine Sea Plate for around 2,500 km. This ridge is considered as a relict volcanic arc of Middle Eocene to Oligocene age (Ozima and others, 1977; Scott and Kroenke, 1980; Meijer, 1980). Following the model of a "trapped basin", the Palau-Kyushu Ridge would represent the volcanic arc formed by the transformation of an old transform fault into a subduction zone arising from the kinematic reorganization of the Philippine Sea Plate at around 43 Ma (**Fig. 1.4**). As the subduction zone retreated eastward at 30 Ma, activity on this arc stopped and the Parece Vela - Shikoku Basin started to open.

The **Izu-Bonin Ridge** defines the eastern limit of the Shikoku Basin. It represents the volcanic arc of the presently active Bonin Trench. This ridge is presently colliding with the Japanese margin. Manifestations of this collision can be observed on the Izu Peninsula in central Japan (Huchon, 1985; Angelier and Huchon, 1986).

The Izu-Bonin Ridge splits into two branches towards the south, namely; the **West** and **East Marianas Ridges**. These ridges define respectively the western and eastern limits of the Marianas Basin. The West Marianas Ridge is considered as an ancient volcanic arc active between 20 and 9 Ma (Scott and Kroenke, 1980) while the East Marianas Ridge represents the volcanic arc of the presently active Marianas Trench. In a backarc basin model, the West Marianas Ridge would correspond to the relict volcanic arc left inactive after opening of the Marianas Basin.

• Tectonic nature of the boundaries of the Philippine Sea Plate

The Philippine Sea Plate is *entirely* surrounded by subduction zones (**Fig. 1.2**). To the east, the edge of the Philippine Sea Plate is defined by the Bonin-Marianas-Yap Trench System. To the northwest, the plate subducts under the Japanese archipelago along the Nankai and Ryukyu Trenches and enters into collision with the Eurasian margin in Taiwan. To the southwest, the plate is subducted into the Philippine archipelago along the Philippine Trench System.



Fig. 1.4 Evolution of the Philippine Sea Plate according to Uyeda and Avraham, 1972

• Kinematics of the Philippine Sea Plate

In terms of its kinematics, the Philippine Sea Plate poses several problems due to the tectonic complexity of its boundaries. The plate's boundaries are very well defined *but* they are largely manifested as subduction zones, except in the Ayu Basin, a poorly known portion on the southern extremity of the plate, where oceanic accretion appears to be occurring. There are *no* magnetic anomalies that would allow for the computation of the plate's kinematics. The oceanic basins that are presently accreting can be simply considered as marginal basins related to anomalies in subduction zones.

Present-day kinematics: NW displacement direction

Due to the absence of magnetic anomalies, computations for the present-day kinematics of the Philippine Sea Plate are solely based on slip vectors calculated from earthquakes occurring along subduction zones (Fitch, 1972; Morgan, 1972; Karig, 1975; Seno, 1977; Chase, 1978; Minster and Jordan, 1979 a & b; Ranken and others, 1984; Huchon, 1986). Plate motion parameters including the pole and rate of rotation and the instantaneous velocity computed by different authors vary slightly (**Fig. 1.5**). More recent works on Philippine kinematics have adopted or improved the rotation parameters by Seno (1977) (**Fig. 1.6**). The following

are the three main kinematic parameters of the Philippine Sea Plate computed with respect to Eurasia:

- a Philippine Sea Plate/Eurasia **rotation pole** located NE of Japan.
- a Philippine Sea Plate/Eurasia relative **displacement rate** that varies from north to south along the western edge of the Philippine Sea Plate, from 3.0 cm/yr in the latitude of the Nankai Trough to around 9.0 cm/yr on the southern end of the Philippine Trench.
- a Philippine Sea Plate/Eurasia relative displacement direction whose azimuth is directed N55°W near Taiwan with a linear velocity of around 7.0 cm/yr. This azimuth varies by several degrees from north (clockwise addition) to south (counter clockwise addition).



Fig. 1.5 Kinematics of the Philippine Sea Plate according to different authors. Adopted from Seno and Eguchi, 1983 and Barrier, 1985

It can be observed that this direction of convergence is coherent with the direction of slip vectors along subduction zones with the exception of the Philippine Trench. Seno (2000) shows that the northwestward motion of the Philippine Sea Plate cannot be explained simply by a slab pull – ridge push mechanism. This author emphasizes the influence of plume convection induced by mantle upwelling in the back-arc area of the Kyushu – Ryukyu arc system in southern Japan.

Old kinematics: 4 Ma plate reorganization

Stress field orientation studies in the collision zones of Taiwan (Barrier, 1985; Angelier and others, 1986, 1990; Chu, 1990) and the Izu-Miura-Boso region of Japan (Huchon, 1985; Angelier and Huchon, 1986) show that the

Fig. 1.6 Kinematics of the Philippine Sea Plate with respect to Eurasia. Numbered arrows represent relative plate motion in cm/yr. Adopted from Seno, 1977

direction of the Philippine Sea Plate/Eurasia relative movement has changed from NNW to WNW since 5 Ma. In Taiwan, this kinematic reorganization, dated at 4 to 6 Ma is manifested by a 40-degree counterclockwise rotation of the stress fields (Fig. 1.7). This observation is consistent with results of paleomagnetic studies performed in the island 1989; Lee and others, 1990). In Japan, a 30-degree (Lee, counterclockwise rotation occurred around 2 to 3 Ma (Huchon, 1985; Angelier and Huchon, 1986) (Fig. 1.8). The origin of this kinematic reorganization is still poorly understood, but it appears to be a major event in the evolution of the western boundary of the Philippine Sea Plate. Recently, Kamata (1999) and Kamata and Kodama (1999) presented arguments from volcanic events that this plate reorganization had been evident in Japan between 2 and 4 Ma.



Fig.1.7 Evidence of kinematic reorganization (40-deg counterclockwise rotation) of the Philippines Sea Plate in Taiwan that occurred about 5Ma. Modified from Barrier, 1985 and Huchon, 1985

The above-observations strengthen the arguments presented earlier by Seno and Maruyama (1984) that prior to its present-day kinematics, the Philippine Sea Plate was moving northwardly. These authors estimate that this directional change from NNW to WNW (around 45-degree counterclockwise rotation) could have happened between 4 and 6 Ma. Paleomagnetic studies in the Benham Rise, dated Eocene in age and presently located between 15° and 16° North Latitude, show that during Eocene times, this ridge was located in sub-equatorial latitudes (Louden, 1977). This strongly supports the importance of the northward component of the plate's movement between Eocene and Pliocene.



Fig. 1.8 Evidence of kinematic reorganization of the Philippines Sea Plate in Japan that occurred about 5 Ma. Modified from Huchon, 1985 and Angelier and Huchon, 1985

Southeast Asian Margin

The boundary between the southwestern margin of the Eurasian Plate and the Philippine Sea Plate is active from Japan to the Philippines. To the north, this boundary is marked by subduction zones along the Nankai and Ryukyu Trenches and by an arc-continent collision zone in Taiwan. To the south, this boundary is defined by subduction zones, punctuated by collision zones bordering the western margin of the Philippine archipelago. This portion of the Eurasian margin is basically composed of *marginal basins* that successively *opened* in several phases within Neogene times. The lithospheric plate is thus thinned (*thinned margin*) as a consequence of the creation of new oceanic crust. The resulting marginal basins are represented by the *South China*, the *Sulu* and the *Celebes seas*. These basins are bordered by the continental blocks of Taiwan (true continental margin) and North Palawan (rifted from the Asian continental margin) and by the volcanic arcs of Sulu and North Sulawesi (**Fig. 1.9**).

South China Sea Basin and Continental Blocks

The South China Sea Basin bounds the Philippine archipelago to the NW. It is an oceanic basin whose axis is oriented NE-SW with average depths of 4 km. Since the works of Taylor and Hayes (1980, 1983), knowledge on its general structure and opening mechanism has considerably advanced. On the basis of magnetic anomalies, these authors have proposed an accretion model where opening is symmetric between



Fig. 1.9 Terrane affinity map of the Philippines according to Rangin et al., 1990

32 and 17 Ma (**Fig. 1.10**). This oceanic accretion along an E-W axis is presently manifested by an alignment of submarine mountains at around 15° North latitude. The opening was preceded by rifting that could have taken place between the Late Cretaceous and Late Eocene.

More recent data however, tend to modify this model. Morphological studies show the dominance of normal faults oriented N50°E on the southern portion of the basin which would correspond to a NW-SE opening direction. This observation has led Pautot and others (1986) to propose two stages of opening, namely: 1) a first stage between 32 and 17 Ma along an E-W axis followed by, 2) a second stage between 20 and 17 Ma



Fig. 1.10 Paleomagnetic signature and structural synthesis of the South China Sea basin and neighboring areas. Adopted from Taylor and Hayes, 1983

along a NE-SW axis. Briais (1989) and Briais and others (1988 and 1989) give further support to this modified model and apply it to the whole basin. Consequently, the sub E-W anomalies recorded on the northern portion of the basin would represent an "artifact" produced by a dense network of transform faults. Briais and others (1989) suggest then that the general opening direction is oriented NW-SE.

A direct consequence of the opening of the China Sea is the separation of a microcontinental block from mainland China. This block corresponds *today* to the Palawan-Mindoro microcontinent (**Fig. 1.9**). The tectonic history of this block is discussed in a later section.

• Sulu Sea - Cagayan Ridge - Sulu-Zamboanga Arc –Celebes Sea System

Southeast of the North Palawan Block, a series of oceanic basins and ridges generally oriented along a NE-SW axis is manifested. From the NE, one can encounter the Sulu Sea Basin, divided into two by the Cagayan de Sulu Ridge, the Sulu-Zamboanga Ridge, and the Celebes Sea Basin.

Sulu Sea Basin and Cagayan de Sulu Ridge

The Sulu Sea is a small marginal basin located immediately to the SE of the North Palawan Block (**Fig. 1.9**). It is subdivided into two subbasins by the Cagayan Ridge.

- The **NW subbasin** is an asymmetric basin whose western flank is more inclined towards Palawan than does the eastern flank towards the Cagayan Ridge (**Fig. 1.11A**). The thickness of the sedimentary fill is between 6 and 8 km (Murauchi and others, 1973). The basement is either volcanic or continental (or both) in nature (Mascle and Biscarrat, 1978; Murauchi and others, 1973).

- The **Cagayan Ridge** is composed of volcanic material dated 14.7 Ma (Kudrass and others, 1986; 1990). It corresponds to a volcanic arc that was active until the end of early Miocene (Rangin and others, 1989a). Its southern flank is characterized by the presence of SE-dipping normal faults which define its contact with the SE subbasin (**Figs. 1.11A** and **B**).

- The **SE subbasin** is composed of an oceanic basement covered with a thin (1 to 2 km) sedimentary fill (Mascle and Biscarrat, 1978). The basalts of the upper part of the oceanic crust present intermediate characteristics between MORB and arc tholeiites. Heat flow data (2.4 HFU on the average) indicate a relatively young crust. The oldest known sediments have been dated late Late Miocene to early Middle Miocene (Rangin and others, 1989b) while volcanic ash appeared at around 6 Ma.

Sulu-Zamboanga Arc and Celebes Sea Basin

The **Sulu-Zamboanga Arc** separates the Sulu Sea Basin from the Celebes Sea Basin. It is manifested as a group of islands in which some are classified as Pleistocene-Holocene with one active volcano (Cruz, 1987). However, there is no well-defined seismic zone along the Sulu Trench. It is a volcanic arc considered to be in its solfataric stage.

The Celebes Sea Basin, located SE of the Sulu-Zamboanga Arc, also represents an oceanic crust. Magnetic anomalies (An 18-20) and heat flow data (1.58 +/- 0.25 HFU) indicate an Eocene age (Weissel, 1980; 1981). This age is consistent with the findings of Leg 124 of the Ocean Drilling Program (ODP, 1991) in which radiolaria-bearing muds covering the MORB basement have been dated Middle Miocene.

Lee and McCabe (1986) propose a trapped basin mechanism for the origin of the Basin. Results of ODP 124, however, indicate that the Celebes Sea was formed in an open ocean setting with a basalt characterized as N-

MORB, and that it could have split off as a basin from a previously larger Molucca Sea Plate, although rifting from the outermost part of the Eurasian margin remain a possibility (Silver and Rangin, 1991)

Synthesis

The Southeast Asian Region is the site of interaction between an essentially oceanic plate, the Philippine Sea Plate, and a thinned crust, the Southeast Eurasian Margin. In such a plate boundary setting, three types of plate interaction are possible, namely: *oceanic-oceanic, oceanic-continental* and *continental-continental*. Furthermore, volcanic arcs may also develop over either oceanic or continental crust, which in turn modifies the character of the possible plate interaction combinations. This geographic setting gives rise to a complex plate boundary governed by subductions, collisions, transcurrent faulting and basin openings.

• Origin of marginal basins: existing models

The term "marginal basin" generally refers to an *oceanic* basin formed on the edge (margin) of a *continental* crust (Packham and Falvey, 1971). Since the early 1970s, a great number of models of the origin of marginal basins have been proposed (eg. Packham and Falvey, 1971; Karig, 1971; Uyeda and Ben-Avraham, 1972; Cooper and others, 1976; Weissel and Hayes, 1977; Chase, 1978; Mrozowski and Hayes, 1979; Weissel and Watts, 1979; Curray and others, 1982; Jolivet and others, 1989; Tapponier and others, 1982; Taylor and Karner, 1983; Silver and others, 1985; Lee and McCabe, 1986; Uyeda, 1986; Sarewitz and Lewis, 1991). The following discussion presents some generally accepted models which are more applicable to the basins previously discussed.

Back-arc basin

A **back-arc basin** is formed *behind* a subduction zone (eg. Packham and Falvey, 1971; Karig, 1971; Chase, 1978; Taylor and Karner, 1983). Its formation involves a process that creates an extensional regime oriented perpendicular to the subduction zone which consequently gives rise to the formation of a basin in an oceanic or a continental domain (**Fig. 1.12a**). Classic examples of this type are the Marianas (Karig, 1971) and the Parece Vela - Shikoku (Mrozowski and Hayes, 1979) basins. In a continental setting, an example is the Okinawa Basin formed behind the Ryukyu Trench (Jolivet, 1988; Jolivet and others, 1989).

Continental domain basin

A basin in a **continental domain** results from an opening whose mechanism is independent of any other processes. In this model, opening is preceded by rifting in a continental domain (typical example: Atlantic Ocean) (**Fig. 1.12b**). The South China Sea Basin, according to Taylor and Hayes (1980, 1983) belongs to this type.

Extrusion tectonics basin

Unlike Taylor and Hayes' (1980, 1983) model, the South China Sea, according to Tapponier and others (1982, 1986) is a consequence of extrusion tectonics, particularly the collision of India with Eurasia. In this model, India would impinge northwards against Eurasia which would cause the southeastward expulsion of the Indo-Chinese Block along large strikeslip faults where pull-apart extensional zones may be created and form basins (**Fig. 1.12c**). This model applies to areas where strike-slip faults play a major role.

Trapped basin

The formation of a trapped basin occurs in two stages, namely; 1) emplacement of an oceanic basin, and 2) individualization/isolation of a portion of the oceanic crust from the rest of the basin (**Fig. 1.12d**). For this type, the West-Philippine Basin is considered by some authors as an example (Uyeda and Ben Avraham, 1972; Hilde and others, 1977; Hilde and Lee, 1984). In this model, the West-Philippine Basin was originally a part of the Pacific Plate which was isolated during the kinematic reorganization at 43 Ma (see also **Fig. 1.4**).

Fig. 1.11A Structure of the Sulu Sea Basin deduced from magnetic data. Modified from Murauchi, et al., 1973



Fig. 1.11B Structure of the Cagayan Ridge from seismic data. Adopted from Rangin, 1989



Fig. 1.12 Basin evolution models for West Pacific – Southeast Asia regions. (a) Back-arc spreading, (b) Atlantic-type spreading, (c) Basin formation by extrusion tectonics, (d) Trapped basin. Modified from Silver and Rangin, 1991

Complexity of tectonic processes along plate boundaries

The tectonic character of plate boundaries is basically governed by the nature of the plates. It has been mentioned for example, that the opening of a back-arc basin involves the formation of a basin behind a subduction zone. In the West Pacific Domain, the tectonic character of plate boundaries is as diversified as the nature of the plates themselves. For instance, an arc collides with another arc (Izu-Bonin collision, Japan), an arc collides with a continental crust (Taiwan) or simply an oceanic crust subducts into another or into a continental crust. The co-existence of oceanic crusts and continental blocks along a single margin demonstrates the complexity of tectonic processes along a plate boundary. This complexity is usually expressed as a system of subduction zones sometimes with opposing polarities, continuously interrupted by collision zones. Such is the case in the Philippines.



The Philippines: A Complex Plate Boundary

The boundary between the Philippine Sea Plate and the eastern margin of the Eurasian Plate is a complex system of subduction zones, collision zones and marginal sea basin openings. In between these two plates, an actively deforming zone is created. This zone represents the Philippine Mobile Belt (**Fig. 1.13**), a term first defined by Gervasio (1966). The following discussion is divided into three subtopics. The first presents the *general geodynamic framework* of the Philippines while the second is a *geologic overview* of the archipelago. The third subtopic is a separate discussion on the Philippine Fault, a structure that plays significant role in the Neogene tectonic evolution of the archipelago.

GENERAL GEODYNAMIC FRAMEWORK OF THE PHILIPPINES

The Philippines is generally interpreted as a collage of insular arcs, ophiolitic suites and continental rocks of Eurasian affinity. The formation of this belt is controlled by subductions, collisions and major strike-slip faults.

Subduction zones

The Philippine Mobile Belt is surrounded by subduction zones with opposing polarities (**Fig. 1.13**). Subduction zones east of the mobile belt have westward vergence while those on the west are subducting eastward. The result is an actively deforming zone between two active subduction systems.

West-dipping subduction zones

• Philippine Trench (4°N - 15°)

The Philippine Trench is the morphological expression of the westward subduction of the Philippine Sea Plate under the eastern Philippine Arc (**Fig. 1.13**) (Cardwell and others, 1980; Fitch, 1970; Hamburger and others, 1983). The corresponding Benioff zone is slightly inclined (20°) to the north



Fig. 1.13 Simplified tectonic map of the Philippines. Adopted from Aurelio, 1992

but plunges to over 45° to the south (**Figs. 1.14** and **1.15**). The southern closure of this trench is still poorly known. Seismic reflection profiles and bathymetric data (Karig and Sharman, 1975; Karig, 1975) do not show a well-developed accretionary prism which abruptly diminishes



Fig. 1.14 Distribution of earthquake epicentres in the Philippines from 1900 to 1992. Locations of diagrams in Fig. 1.15 are indicated. Replotted from Aurelio, 1992

towards the south. This observation, combined with the shallow Benioff zone that corresponds to a maximum of 250 km for the length of the subducted slab suggest that this subduction zone is young and is presently propagating to the south. Its southern termination was recently studied by Nichols and others (1990) by conducting a marine geophysical survey with GLORIA, and an onshore fieldwork in Halmahera Island. These recent data appear to confirm the southward propagation of the trench towards the Moluccas Collision Zone.

The volcanic arc corresponding to the Philippine Trench can be traced from Bicol to Leyte but in Mindanao, it becomes unclear. This trench is generally considered young, created not earlier than 5 Ma. This estimate is based on the consideration of the length of the subducting slab and the displacement rate of the Philippine Sea Plate (to completely consume 250 km of slab subducted at 8 cm/yr would take 3.1 Ma).

• East Luzon Trough (16°N - 18°N)

The propagation of the Philippine Trench is arrested at a still poorly understood feature which appears in most maps as a transform fault. Farther to the north, however, east of Luzon Island, is a linear feature designated as East Luzon Trough. Compressive structures that would correspond to the subduction zone are generally absent on the eastern flank of the island, and in very isolated cases where they exist, the degree of deformation decreases from 16°N to 18°N latitude, and seem to completely disappear to the north. The corresponding volcanic arc does not exist. Basing from seismic and bathymetric data; Lewis and Hayes (1983) have proposed that this is a nascent subduction zone propagating northwards. Barrier and others (1990) however present later a kinematic explanation to the trough's disappearance to the north. The trough is flanked to the east by the Benham Rise (Fig. 1.13). At this point, it is important to note the existence of an inactive accretionary prism to the west of the present location of the trough with the attendant rafting of Benham Rise towards Luzon (Fig. 1.16) that would indicate the existence of an ancient subduction zone, an idea that has always been maintained by Balce and others (1979). Other evidences such as the presence of subduction-related magmatism in East Luzon which ceased at the onset of Early Miocene and the accretion of Benham Rise to Luzon tend to bolster this idea.

East-dipping subduction zones

• Manila Trench (22°N - 13°N)

Located west of Luzon Island opposite the East-Luzon Trough, the Manila Trench represents the morphologic expression of the subduction of the oceanic crust of the South China Sea under the Luzon Arc (Karig, 1973; Cardwell and others, 1980). It is an elongated bathymetric depression that reaches depths of 5,100 m in the latitude of Manila (Ludwig and others, 1967). Thickness of the sedimentary fill varies between 250 and 2,600 m. The corresponding Benioff Zone is steep on its southern portion, but flattens off towards the north (**Fig. 1.15 [1] and [2]**). The southern termination of this subduction zone passes into the Collision Zone of Mindoro-Panay (Stephan and others, 1986; Marchadier, 1988; Rangin and others, 1988a; Marchadier and Rangin, 1988, 1989, 1990).

Unlike the Philippine Trench, the Manila Trench possesses a welldeveloped accretionary prism (**Fig. 1.17**) (Hayes and Lewis, 1984). Gravimetric and seismic reflection data, as well as acoustic velocities measured with the prism, suggest that it is entirely composed of sediments. From seismic reflection profiles and bathymetric data, it is apparent that a forearc basin is developed between the accretionary prism and Luzon Island.

• Negros Trench (10°N)

The Negros Trench runs parallel to the western coasts of the islands of Panay and Negros. It is here that the oceanic crust of the Sulu Sea Basin is being consumed, although the corresponding Benioff Zone is poorly manifested. The subducted oceanic slab does not seem to exceed 100 km in depth and it dips slightly under Negros and Panay. An active volcanic chain can however, be traced in these islands (eg. Canlaon Volcano). The bathymetric link between the Negros Trench and the Manila Trench is represented by a shallow trough that passes northeast off Palawan Island.

Fig. 1.15 Geometry of seismogenic plates underneath the Philippines, deduced from Benioff zones from Fig. 14. Adopted from Aurelio, 1992

Fig. 1.16 Structure of the old subduction zone west of the East Luzon Trough established from seismic profiles. Adopted from Lewis and Hayes, 1983

Fig. 1.17 Structure of the accretionary prism of the Manila Trench from seismic profiles (A), and of the subducting slab and over-riding plate established from gravimetric data. Adopted from Hayes and Lewis, 1984 and Pinet, 1990

• Cotabato Trench (6°N)

Subduction along the Cotabato Trench is young as shown by a poorly developed Benioff Zone. This poorly known structure seems to even disappear southwards into the Moluccas Sea (Silver and others, 1983). The corresponding volcanic arc is active on the western margin of Mindanao (Divis, 1983; Cruz, 1987). A left-lateral strike-slip feature (Cotabato Fault) cutting across the Zamboanga Peninsula appears to link the Cotabato Trench with the Negros Trench (Pubellier and others, 1991; 1993).

Collision zones

The northern and southern extremities as well as the western margin of the Philippines are marked by active collision zones, namely, *Taiwan*, *Mindoro-Panay* and *Moluccas Sea*. These are three collision zones governed by three different geodynamic processes.

• Taiwan: continent-arc collision

Taiwan is a 400 km-long island dominated by mountain ranges that reach altitudes of around 4 km in its central portion. It represents an active orogenic belt resulting from the collision of the western edge of the Philippine Sea Plate where the Luzon arc has developed, with the continental margin of Eurasia (**Fig. 1.18**). The start of this collision is associated with the kinematic reorganization of the Philippine Sea Plate at around 4 Ma, involving a change in the direction of its movement from a northerly to a northwesterly motion (Barrier, 1985). This collision zone passes into the Manila Trench - Luzon Arc system which in turn passes into the Mindoro - Panay collision zone. This setting gives rise to a system called the Taiwan-Luzon-Mindoro Belt (Pelletier, 1985; Stephan and others, 1986; Dario, 1987; Maleterre, 1989; Pinet, 1990).

• Mindoro-Panay: arc-continent collision

The southern termination of the Manila Trench is characterized by the transformation of the subduction of the South China Sea Plate under the Luzon Arc into an arc-continent collisional deformation within Mindoro Island (Marchadier, 1988; Marchadier and Rangin, 1989; 1990). Here, the Palawan-Mindoro microcontinent enters into collision with the central portion of the Philippine Mobile Belt (**Fig. 1.19**). Paleomagnetic data (McCabe and others, 1985; 1987), stratigraphic and tectonic analysis (Marchadier, 1988; Marchadier and Rangin, 1989; Faure and others, 1985; 1987), stratigraphic and tectonic analysis (Marchadier, 1988; Marchadier and Rangin, 1989; Faure and others, 1988, 1989; Faure and Ishida, 1990), as well as bathymetric and offshore geophysical studies west of Mindoro (Rangin and others, 1988a), show that this collision was initiated within Miocene time, right after the cessation of the accretion of the South China Sea oceanic crust between 32 and 17 Ma. Effects of this event are felt down to the island of Panay (Rangin and others, 1991), but observations on Mindoro Island indicate that the intensity of collision appears to have decreased since Pliocene (Marchadier, 1988).

Moluccas Sea: arc-arc collision

South of Mindanao Island in the Moluccas Sea, an oceanic plate is presently subducting in two directions: to the east and to the west (**Fig. 1.20**) (Roeder, 1977; Silver and Moore, 1978 a and b; Cardwell and others, 1980). This double-vergent subduction causes consequently the convergence/collision of the two corresponding active volcanic arcs. This active collision represents, according to McCaffrey (1991), a present-day example of the emplacement of ophiolites by slivers (obduction) developed from the curvature of the fold axis of the oceanic plate.

Field data inland and offshore Mindanao (Roeder, 1977; Silver and Moore, 1978 a and b; Moore and Silver, 1983; Cardwell and others, 1980; Hawkins and others, 1985; Florendo, 1987) all suggest a Late Miocene age for the start of collision. The western slab dives down to depths of more than 600 km, one of the deepest in the world, while the eastern slab subducts to only about 200 km. The corresponding arcs, Sangihe and

Halmahera, are presently separated by at least 100 km. The Moluccas Sea Plate has thus an E-W dimension of at least 900 km.

Fig. 1.18 Lithospheric structure in the Taiwan region showing collision of the Luzon Arc with the Eurasian plate. Original drawing by J. Angelier, 1985

PHILIPPINE GEOLOGY: AN OVERVIEW

In general, the Philippine archipelago can be divided into two geologic entities, namely: the Philippine Mobile Belt (Gervasio, 1966) and the Palawan-Mindoro microcontinent. The Palawan-Mindoro microcontinent is a geological block that was rifted from the Asian mainland during Late Cretaceous-Late Eocene time and drifted to approximately its present position with the opening of the South China Sea basin. The Philippine Mobile Belt is the group of land masses that apparently originated from sub-equatorial regions to its present position with the rotation and spreading of the Philippine Sea Plate during Eocene to Miocene times. Each of these two entities is composed of different types of lithologic units that can be classified into four general groups, namely: 1) metamorphic rocks, 2) ophiolites and ophiolitic rocks, 3) magmatic rocks and active volcanic arcs, and 4) sedimentary basins. The metamorphic and ophiolitic rocks normally represent the pre-Tertiary basement of the Philippines.



Fig. 1.19 Simplified tectonic map of the collision zone involving the North Palawan continental block and the western central Philippine arc (Mindoro-Panay). Adopted from Marchiadier, 1988

Metamorphic rocks

Metamorphic rocks present in the Philippines can be divided into two categories, namely: 1) pre-Cretaceous metamorphic rocks of continental origin, and 2) Cretaceous metamorphic rocks of insular arc affinity.

The first category is represented by metamorphic formations located in North Palawan, Mindoro, Panay and neighboring islands (**Fig. 1.22**) belonging to the Palawan-Mindoro microcontinent. These formations include the Caramay Schist in Palawan, Halcon Metamorphic Complex in Mindoro, Romblon Metamorphic Complex in Romblon, Buruanga Metamorphic Complex in Panay and Tungauan Schist in Zamboanga. This metamorphic group is characterized petrographically by the abundance of silica (continental provenance) and geographically by its restricted distribution in the western central Philippines.

Rocks belonging to the second group are distributed sporadically within the whole archipelago (**Fig. 1.22**). They are essentially basic to ultrabasic in character, which suggest that they have most likely originated from old island arcs. Considered post Jurassic (Gervasio, 1966; BMG, 1982), the age of these rocks do not extend beyond Paleogene. Metamorphosed ophiolitic rocks of Eocene age are present in eastern Luzon (Hashimoto and others, 1978; Aurelio and Billedo, 1988; Geary, 1986; Geary and others, 1988; JICA-MMAJ-MGB, 1990; Billedo, 1994), in the Caramoan Peninsula in Bicol (Geary and others, 1988; David, 1994) and in eastern Mindanao (Hamilton, 1979; Hawkins and others, 1985; Pubellier and others, 1991, 1993; Quebral, 1994).

Ophiolites and ophiolitic rocks

Ophiolites and ophiolitic rocks (collectively called *ophiolitic rocks* hereunder) in the Philippines are widespread in the whole archipelago (**Fig.1.23**).Usually occurring together with the pre-Tertiary metamorphic rocks, the ophiolitic rocks represent basement on which magmatic arcs were developed. Complete ophiolite sequences can be found in Zambales, Isabela, southern Palawan and Pujada Peninsula where the series includes tectonized peridotites progressing to gabbro, diabase, pillow basalts and finally to the pelagic sediments.

Dating of these ophiolitic rocks is essentially based on the ages of pelagic sediments covering them. Ages of these sediments vary from Early-Late Cretaceous (eg. NE Luzon: Aurelio and Billedo, 1988; JICA-MMAJ-MGB, 1990; Montalban: Yumul and Datuin, 1991; Arcilla, 1991; Encarnacion and others, 1993) to Eocene (eg. Palawan: Santos, 1988; JICA-MMAJ-MGB, 1990; Zambales: Villones, 1980; Schweller and others, 1983, 1984; Yumul and Datuin, 1990) to as young as Oligocene (eg. Mindoro: Rangin and others, 1985; Sarewitz and Karig, 1986; Marchadier, 1988). Portions of these ophiolitic bodies have undergone varying degrees of metamorphism, and in pre-1980 literature, they were previously referred to as ultramafic complexes or undifferentiated Cretaceous-Paleogene basement.

Fig. 1.20 Lithospheric structure in the Mollucas Sea region, showing the incipient arc-arc collision between Sangihe (1) and Halmahera (2). From Roeder, 1977

In terms of their structural nature, the ophiolitic rocks are generally thrust over Paleogene sequences as in NE Luzon (Aurelio and Billedo, 1988; JICA-MMAJ-MGB, 1990), in Mindoro (Rangin and others, 1985; Sarewitz and Karig, 1986; Marchadier, 1988), in Zambales (Schweller and others, 1983, 1984; Yumul and Datuin, 1990), in Palawan (Santos, 1988), in Panay (McCabe and others, 1982; Mitchell and others, 1986; Rangin and others, 1991), in Leyte (Florendo, 1987; Aurelio, 1992) and in eastern Mindanao (Hawkins and others, 1985). Their origin and mode of emplacement are still the subject of controversy. Consider for example the two most structurally studied areas: Zambales and Mindoro-Panay. The Eocene age of the Zambales ophiolites has led Hawkins and Evans (1983) to disregard the possibility that they have originated from the South China Sea which is of Oligocene to Miocene age (see previous discussion). Using structural and geochemical arguments, Yumul and Datuin (1990) however, consider that these ophiolites belong to a proto South China Sea of Paleocene-Eocene age. But whether this proto South China Sea really existed (which in present-day setting, has already completely disappeared) is still a matter of great debate. The history of the ophiolitic rocks of Mindoro-Panay appears to be more coherent. With their Oligocene age, they can be easily correlated to a crust of the South China Sea which was jammed into Cenozoic sequences during the onset of collision between the Palawan-Mindoro microcontinent and the Philippine Mobile Belt sometime



Fig.1.21 Tectonic and structural features of the Philippine archipelago. Circles are active volcanoes while triangles are GPS observation stations discussed in text. Modified from Aurelio, 2000

in the Miocene (Rangin and others, 1985; Mitchell and others, 1986; Sarewitz and Karig, 1986; Marchadier, 1988).



Fig. 1.22 Generalized distribution map of metamorphic rocks in the Philippines

CHAPTER 2, TECTONICS, THE PHILIPPINES: A COMPLEX PLATE BOUNDARY



Fig. 1.23 Generalized distribution map of ophiolites and ophiolitic rocks in the Philippines

Magmatic arcs

The presence of magmatic arcs that cannot be associated with any of the active subduction zones indicates that the evolution of the Philippine archipelago is characterized by a relatively continuous volcanic activity throughout the Cenozoic. Their geodynamic origin (eg. polarity of corresponding subduction) is still however, poorly understood. They are briefly presented here according to their ages and their spatial distribution.

• Ancient arcs

The oldest known magmatic rocks in the Philippines are found in Cebu Island, where dioritic rocks have been dated Late Cretaceous (Walther and others, 1981). Similar rocks of Paleogene age have been recognized in neighbouring Bohol Island (Zanoria and others, 1984; JICA-MMAJ, 1985), Negros, Panay and Masbate. Magmatic formations dated Early Eocene to Oligocene extends from Sierra Madre Range in Luzon (Wolfe, 1981; Ringenbach, 1992; Billedo, 1994) down to Bicol in southern Luzon, Leyte in the Visayas and the Pacific Cordillera in eastern Mindanao.

In Luzon, the Middle Oligocene to Late Miocene age of the arc is well constrained stratigraphically as well as radiometrically (Maleterre, 1989; Wolfe, 1981). Most of the intrusive rocks are dioritic in composition, although alkali rocks (e.g. Cordon Syenite Complex) also occur. In the Central Cordillera of Luzon, intrusive rocks include Paleogene rocks related to an ancient arc and Neogene intrusive and volcanic rocks related to eastward subduction from the Manila Trench, The general distribution of Cretaceous-Paleogene intrusions is shown on **Fig. 1.24**.

Magmatic belts associated with Miocene arcs include those on western Luzon, southwest Luzon, Panay, Negros, Zamboanga and South Cotabato in western Philippines. Miocene to Pliocene magmatic arcs in eastern Philippines are present in southeastern Luzon, Leyte and the Pacific Cordillera of eastern Mindanao (**Fig. 1.25**). In Mindanao, interpretation of the age of these rocks is further complicated by their petrographic diversity. Sajona and others (1993) analyzed Plio-Pleistocene adaktic rocks in the Zamboanga Peninsula and in eastern Mindanao. They mention a possible association of adakite formation with activity along the Philippine Fault in Surigao and northern Davao.

It is important to note that Zanoria and others (1984) estimate that 90% of all auriferous deposits in the Philippines are associated with Late Neogene hypabyssal intrusions and volcanism.

CHAPTER 2, TECTONICS, THE PHILIPPINES: A COMPLEX PLATE BOUNDARY



Fig. 1.24 Generalized distribution map of Creataceuos-Paleogene intrusions in the Philippines



Fig. 1.25 Generalized distribution map of Oligocene-Miocene magmatic belts in the Philippines

• Active volcanic arcs

The distribution of Philippine Pliocene-Holocene volcanoes (active, potentially active and inactive) generally reflects the activity along subduction zones presently bounding the archipelago (**Fig. 1.26**). Five distinct volcanic belts can be defined, namely: 1) the Luzon Volcanic Arc



Fig. 1.26 Generalized distribution map of active and potentially active volcanoes, and other Recent volcanic belts in the Philippines

corresponding to the Manila Trench, 2) the East-Philippine Volcanic Arc associated with the Philippine Trench, 3) the Negros-Panay Arc linked to the Negros Trench, 4) the Sulu-Zamboanga Arc formed by the Sulu Trench, and 5) the Cotabato Arc related to the Cotabato Trench. There is no volcanic arc corresponding to the East Luzon Trough. In a similar manner, the East Philippine Arc is well defined only from Bicol to Leyte but

cannot be traced in eastern Mindanao. In Mindanao, the active volcanic chain that includes the highest peak in the archipelago, Mount Apo and the other volcanic cones in central Mindanao, are located more than 100 km away from any active subduction zone (e.g. Philippine Trench). Sajona (1995) proposes that these volcanoes that were not produced by subduction are products of partial melting of a detached slab underneath Mindanao.

Considered by PHIVOLCS as most active volcanoes are those which have short response periods, namely: Mayon, Taal, Bulusan, Canlaon and Hibok-Hibok. Mount Pinatubo in 1991 was responsible for the largest eruption of the 20th century in terms of volume of ejecta and area covered with ashfall. PHIVOLCS (2002) currently lists 22 active (**Table 1.1**), 27 potentially active (**Table 1.2**) and 281 inactive volcanoes.

No.	Name of Volcano	No. of Historical Eruptions	Date of Last Eruption / Known Activity	Location
1	Babuyan Claro	4	1917	Babuyan Island
2	Banahaw	3	1843	Laguna-Quezon Province
3	Biliran	1	1939	Biliran Island
4	Bud Dajo	2	1897	Jolo Island, Sulu
5	Bulusan	15	1995	Sorsogon
6	Cagua	2	1907	Cagayan
7	Camiguin de Babuyanes	1	1857	Babuyan Island Group
8	Canlaon	25	1996	Negros Oriental
9	Didicas	6	1978	Babuyan Island Group

 Table 1.1 List of Active Volcanoes of the Philippines according to PHIVOLCS (2002)

CHAPTER 2, TECTONICS, THE PHILIPPINES: A COMPLEX PLATE BOUNDARY

10	Hibok-Hibok	5	1953	Camiguin Island
11	Iraya	1	1454	Batan Island, Batanes
12	Iriga	2	1642	Camarines Sur
13	Leonard		1,800 yrs ago by ¹⁴ C	Davao
14	Makaturing	10	1882	Lanao del Sur
15	Matutum	1	1911	South Cotabato
16	Mayon	49	2009	Albay
17	Musuan (Calayo)	2	1867	Bukidnon
18	Parker	1	1640	South Cotabato
19	Pinatubo	3	1991	Zambales- Pampanga- Tarlac
20	Ragang	8	1916	Lanao del sur- Cotabato
21	Smith	5	1924	Babuyan Island
22	Taal	33	1977	Batangas

 Table 1.2 List of Potentially Active Volcanoes of the Philippines according to PHIVOLCS (2002)

No.	Name of Volcano	Location
1	Аро	Davao
2	Balut	Davao
3	Cabalian	Southern Leyte

4	Cancajanag	Central Leyte	
5	Corregidor	Bataan	
6	Cuernos de Negros	Negros Oriental	
7	Dakut	Sulu	
8	Gorra	Sulu	
9	Isarog	Camarines Sur	
10	Kalatungan	Bukidnon	
11	Labo	Camarines Sur	
12	Lapac	Sulu	
13	Malinao	Albay	
14	Malindig (Marlanga)	Marinduque	
15	Mandalagan	Negros Occidental	
16	Maripipi	Leyte	
17	Mariveles	Bataan	
18	Natib	Bataan	
19	Negron	Zambales	
20	Parang	Sulu	
21	Parangan	Sulu	
22	Pitogo	Sulu	
23	San Cristobal	Laguna-Quezon	
24	Silay	Negros Occidental	
25	Sinumaan	Sulu	
26	Tukay	Sulu	
27	Tumatangas	Sulu	

Sedimentary basins: stratigraphic and structural overview

Since the discovery of oil in Nido, Palawan in 1976 (Hatley, 1977, 1978; Saldivar-Sali, 1978), knowledge on the Tertiary sedimentary basins of the Philippines has considerably improved. In 1986, the then Bureau of Energy Development (now Department of Energy) published a synthesis of previous works incorporated with recent geophysical and subsurface data collected in collaboration with other local and foreign firms. These works (e.g. Corby and others, 1951; Christian, 1964; Tamesis, 1976; BMG, 1976; Caagusan, 1977, 1981; Porth and Von Daniels, 1989) focused essentially on the hydrocarbon potentials of these basins. In the following discussion,

emphasis is given to their general stratigraphic and structural characteristics.

Nine individual basins can be distinguished within the Philippine Mobile Belt. A tenth one, whose elements were separately discussed Section 1.3.1, forms a vast basin over the thinned continental margin of Eurasia (**Fig. 1.27**).

The axis of the sedimentary basins of the mobile belt is generally oriented N-S, except for some located in the central Philippines like the Mindoro and Southern Luzon basins which have axes oriented more northwesterly, and the Panay and Visayan Sea basins with northeasterly axes. Thickness of the sedimentary cover ranges from 4,000 to 12,000 meters while their surface area is between 1 million m² and 4.7 million m² (Ranneft and others, 1960; BMG, 1976, 1982; Saldivar-Sali, 1978).

• Ilocos - Central Luzon Basin

Filled with a thick (8,000 m) sedimentary sequence (Saldivar-Sali, 1978), the Ilocos-Central Luzon Basin flanks western Luzon Island along a generally N-S axis. The northern part of the basin (llocos) is filled with Upper Oligocene - Middle Miocene marine detrital sediments (mostly conglomerates and sandstones) derived from the Luzon Central Cordillera Range located to the east. These sediments are overlain by an Upper Miocene - Pliocene sedimentary sequence dominated by sandstones, shales and shallow water carbonates and tuffaceous deposits. On the southern part, the eastern and western flanks of the Central Luzon Basin are stratigraphically distinguished from each other. Sediments on the east are characterized by a significant amount of volcanic sources (volcanic sandstones and shales, tuffs) and by a shallow marine depositional environment (carbonates). To the west, Neogene sediments dominated by Middle Miocene turbidites overlie directly the Eocene ophiolites of Zambales. The llocos - Central Luzon Basin is structurally controlled by main branches of the northern segment of the Philippine Fault, notably the Vigan-Aggao Fault (Fig.1. 28) (Maleterre, 1989; Pinet, 1990).

• Cagayan Valley Basin

Sitting on pre-Paleogene ophiolitic basement and Cretaceous-Paleogene arc sequences, the Cagayan Valley Basin is filled with a sedimentary sequence with a thickness of about 8,100 m. (Saldivar-Sali, 1978). These sedimentary formations, basically marine in nature, are intruded by Oligocene-Miocene plutonic rocks in portions of its flanks. The Late Oligocene - Early Miocene interval is represented by platform limestones and coarse-grained clastic deposits (conglomerates) while the Middle Miocene is characterized by turbiditic sequences with intercalated fine layers of coal-bearing carbonates. Upper Miocene - Pliocene deposits are essentially shallow marine (shelfal), upgrading into deltaic then fluviatile beds. With a N-S axis, the Cagayan Valley Basin is assymmetric, where bedding planes on its eastern flank dip gently to the west while formations on its western flank are highly deformed, sometimes resulting in overturned beds (**Fig.1.29**).


Fig. 1.27 Generalized distribution map of Philippine sedimentary basins

• Southern Luzon - Bicol Basin

The Southern Luzon - Bicol Basin is filled with a 4,600-m thick sedimentary sequence (BMG, 1981). The lower layers of the basin are composed mainly of Upper Oligocene - Lower Miocene platform limestones and highly deformed Middle Miocene turbidites. Plio-Pleistocene sequences are dominated by shallow water fine-grained deposits and reefal limestones. This basin has a NW-SE axis and is traversed longitudinally by the Philippine Fault. It is flanked to the NE by the East Philippine Volcanic Arc and by the Mindoro, Panay and Visayan Sea basins to the SW.



Fig. 1.28 Schematic cross sections across the Ilocos Basin according to Pinet and Stephan, 1990

Fig. 1.29 E-W schematic section across the asymmetric Cagayan Valley Basin. Modified from MGB 1982

• Mindoro Basin

Tertiary sedimentary formations in Mindoro are both thrust over continental type formations belonging to the North Palawan Block, and juxtaposed with South China Sea ophiolitic crust (Rangin and others, 1985; Marchadier, 1988). Along a NW-SE axis, the basin is developed only on the eastern part of the island, over arc volcanic sequences of tuffs, tuffites and volcanic conglomerates (**Fig.1.30**). In stricter terms, the true sedimentary fill is composed of lower-Miocene limestone (Marchadier, 1988), overlain by a Lower Miocene - early Upper Miocene volcaniclastic sequence becoming more carbonaceous towards the top. The Upper



Fig. 1.30 E-W schematic section across Mindoro and Tablas islands, showing structural position of Mindoro Basin with respect to juxtaposed ophiolites, volcanic arcs and continental rocks. From Marchiadier and Rangin, 1989

Miocene - Recent sedimentary cover envelops both the basin as well as the continental platform.

Iloilo Basin

The basement of the Iloilo Basin is represented by the Paleogene volcanic belt of Negros-Panay. The basin is asymmetric and filled with Oligocene to Recent deposits. Dips of the sedimentary beds increase from east to west, becoming steeper towards the volcanic basement. The Lower Oligocene - Miocene layers are uplifted and highly deformed, while the Pliocene-Quaternary deposits are generally undeformed. As in the Mindoro Basin, the Iloilo Basin is juxtaposed with other stratigraphic units (**Fig. 1.31**).

It is thrust over Middle to Upper Miocene volcaniclastics developed over an ophiolitic and melange basement (Rangin and others, 1991). Thickness of the sedimentary fill may attain 5,000 m (Saldivar-Sali, 1978).

• Visayan Sea Basin

The Visayan Sea Basin, installed unconformably over a deformed volcaniclastic basement, covers a portion of Negros, the whole of Cebu and a large part of Bohol (**Fig.1.32**).

The lower layers of the basin are dominated by Middle to Upper Oligocene platform limestones and clastic sequences, while the Plio-Pleistocene layers are characterized by a succession of volcaniclastics and carbonates, separated by at least three major unconformities (Porth and others, 1989; Müller and others, 1989 a and b). The youngest major unconformity separates Pleistocene formations from Upper Miocene – Lower Pliocene units. The second major unconformity, well developed in Fig. 1.31 E-W schematic section across Panay Island and summary of stratigraphy of different terrane units. From Rangin and others, 1991



Fig. 1.32 Synthetic profile across Panay, Negros, Cebu and Bohol islands, showing structural relationship between the continental platform and the Visayan Sea Basin. Modified from Rangin and others, 1989

the entire basin, is end of Middle Miocene. The basin axis is NNE-SSW and the sedimentary fill is around 4,000 m thick.

• Samar Basin

The Samar basin presents stratigraphic characteristics similar to those of the Visayan Sea Basin. Here, Upper Oligocene - Lower Miocene volcaniclastics unconformably overlie a mixed basement of ophiolites and metamorphic rocks (Letouzey and others, 1987) (**Fig. 1.33**). The Middle Miocene interval is represented by a widespread deformed limestone formation which presently covers almost 25% of Samar Island (Garcia and

Mercado, 1981). This limestone body is unconformably overlain by Upper Miocene - Pleistocene shales and carbonates. The basin axis is generally oriented N-S.

Agusan-Davao Basin

Among the sedimentary basins of the mobile belt, the Agusan-Davao basin has the thickest sedimentary fill, sometimes attaining a thickness of more than 12,000 m (Ranneft and others, 1960). It is formed over a mixed basement composed of ophiolitic and metamorphic rocks of unknown age, of pre-Oligocene arcs and Eocene limestones (**Fig. 1.34**) (Hawkins and others, 1985; Letouzey and others, 1987). The sedimentary fill is composed of Upper Oligocene - Lower Miocene limestones, followed by alternating layers of conglomerates, sandstones, shales and sometimes thin Middle Miocene carbonaceous layers. The Pliocene-Quaternary cover is dominated by shallow marine deposits upgrading into fluviatile facies. The Agusan Davao-Basin follows a N-S trending axis and is traversed longitudinally by the Philippine Fault.

Cotabato Basin

The Cotabato Basin is another sedimentary basin in the island of Mindanao. It is located between the active volcanic arcs of Cotabato and central Mindanao. The general stratigraphy is similar to that of the Agusan-Davao Basin, except that the Upper Miocene - Pleistocene units are more exposed. This sequence of the basin is composed mainly of relatively undeformed shallow marine deposits dominated by conglomerates, sandstones and shales, grading into deltaic and fluviatile deposits towards the south (**Fig. 1.35**).

The more deformed lower sequence is principally composed of volcaniclastics with minor intercalations of limestones. Ranneft and others (1960) put the thickness of the sedimentary fill at about 8,000 m.

THE PHILIPPINE FAULT

The term "Philippine Fault" was first proposed by Willis (1937) to designate a fault zone cutting almost the whole length of the archipelago. Other authors designated various terms to mean the same structure such as Repetti (1935) who proposed the term "Master Fault" or later Willis (1944) who coined the name "Visayan Rift" emphasizing the linear depression that the fault exhibits in Leyte and the significance of extensional zones along the structure. The terms "Philippine Fault" have been used alternatively in the literature.

The Philippine Fault has long been the subject of discussion especially regarding its exact trace, the rate at which it is moving and its geodynamic significance. The fault and its branches traverse the Philippines from Luzon in the north to Mindanao southwards, cutting across Bicol and the Visayas (**Fig. 1.21**). Its presence in Mindanao has been questioned by Hamilton in

1979, but several studies on seismicity (Rowlett and Kelleher, 1976; Acharya and others, 1979; Acharya, 1980; Acharya and Aggarwal, 1980),



Fig. 1.33 Structural sketch map (A) and schematic sections (B) across Samar Island. From Aurelio, 1992

structural mapping (Repetti, 1935; Ranneft and others, 1960; Allen, 1962; Moore and Silver, 1983) and terrane distinction between both sides of the fault (Hawkins and others, 1985), suggest that the structure traverses the whole eastern portion of the island. Its southern termination is the subject of a recent work by Quebral (1994).

Fig. 1.34 Schematic section across the Agusan-Davao Basin showing the Philippine Fault Zone as a terrane boundary according to Hawkins and others, 1985. Read later interpretation by Pubellier and others, 1991



Fig. 1.35 Schematic section across the Cotabato Basin flanked to the west by the Daguma Range and to the east by the Central Mindano volcanic Arc. Modified from Letouzey and others, 1987; according to Pubellier, unpublished data



Fig. 1.36 Morphological expression of the Philippine Fault cutting through eroded volcanic edifices in northern Leyte. Photo by C. Allen, 1962

One of the earliest works presenting a comprehensive description of the Philippine Fault was by Allen (1962) who outlined its regional trace, described its sense of displacement and presented evidence on its activity. With emphasis on the fault's tectonic, kinematic and geodynamic nature, the most recent studies are doctorate dissertations by Maleterre (1989), Pinet (1990), Ringenbach (1992), Aurelio (1992) and Quebral (1994). Billedo (1994) and David (1994) also present studies on similar but probably older structures.

Extent of the fault and morphologic evidence

Identification of the trace of the fault is essentially based from morphologic expression of Quaternary displacements that can be clearly observed on aerial photographs (Allen, 1962), satellite and remotely sensed images (Landsat, SPOT, Radar, etc.) and in the field (Allen, 1962; Kimura and others, 1968; Rutland, 1968; Nakata and others, 1977; Barcelona, 1981; 1986; Maleterre, 1989; Pinet, 1990; Ringenbach, 1992; Aurelio, 1992; Quebral, 1994). Morphologic expressions of the fault include fault scarps, elongated depressions (**Fig. 1.36**), sag ponds and compressive ridges. The fault has been observed to extend for more than 1,200 km from Luzon to Mindanao. The Philippine Fault has the same extent as that of the San Andreas Fault in California (Allen, 1962).

Earlier evidence suggest that displacement along the fault is essentially horizontal (Allen, 1962), but the presence of a vertical component was not ignored by Nakata and others (1977), Barcelona (1981) and Ringenbach (1992). Drainage system anomalies observed in Luzon, Masbate and Leyte (**Fig. 1.37**) demonstrate that the sense of displacement is left-lateral (Allen, 1962; Rutland, 1968; Nakata and others, 1977). Left-lateral movement along the fault is also indicated by large structures it offsets such as mountain ranges (Pinet and Stephan, 1990), sedimentary basins (Mitchell and others, 1986) and lithologic markers (Barcelona, 1981; Cole and others, 1989).

Activity

Pleistocene-Holocene activity along the Philippine Fault is attested by displacement of drainage systems (Allen, 1962) (**Fig. 1.37**) and elongated depressions at the foot of fault scarps (Acharya, 1980). In Leyte, the fault cuts across Pleistocene-Holocene volcanic cones (Bruinsma, 1983). Historically, the most recent activity is the great earthquake of Luzon on July 16, 1990. This Ms 7.8 earthquake was caused by movement of a northern segment of the fault in the vicinity of Cabanatuan. Rupture was observed for over 90 km with left-lateral displacements of as much as 5 m (Ringenbach and others, 1991, 1992; Punongbayan and others, 1990).

About two decades earlier on March 17, 1973, southern Luzon was also struck with a magnitude 7.3 earthquake with epicenter located at Ragay Gulf (Morante and Allen, 1973; Allen, 1975). This earthquake occurred exactly on the trace proposed by Willis (1937) and Allen (1962). Rupture observations onshore showed left-lateral displacements of 2 to 3 m (Morante and Allen, 1973). Further south in southern Leyte, an earthquake of magnitude 5.8 struck on May 6, 1991 on the Leyte branch of the fault (Aurelio, 1992). Due to its relatively weak magnitude, only

Fig. 1.37 Left-laterally displaced drainage patterns in Digdig, Masbate and Leyte. From Allen, 1962

centimetric left-lateral displacements were observable along a 1-km rupture. Rimando (1994) presented the possible hazards that may be associated with movement along the fault while Daligdig (1997) conducted studies on the paleoseismicity and recent activity of its north central Luzon segment.

Seismicity

Although Allen (1962) was not able to establish a clear relationship between seismicity and activity along the Philippine Fault, the Ragay Gulf earthquake of 1973 reopened debates on this particular problem. By recomputing the epicenters of earthquakes prior to 1964, Rowlett and Kelleher (1976) observed several significant seismic events that they associated with activity along the fault. The isoseismic map of the Ragay



Fig. 1.38 Intensity isoseismal map of the Ms 7.3 Ragay Gulf earthquake of 1973, showing the elongation of the source: Philippine Fault. From Garcia and others, 1985

Gulf earthquake (**Fig. 1.38**) shows an elongated contour the long axis of which is parallel to the strike of the fault in the region. This led Garcia and others (1985) to offer confirmation that the earthquake was caused by the fault. Cardwell and others (1980) also observed that focal mechanism solutions of shallow events along the Philippine Fault show essentially left-lateral displacement vectors. Focal mechanism solutions of Philippine Fault related earthquakes that occurred in the past 30 years (reliable instrumental data) and with magnitudes greater than 5 are shown on (**Fig. 1.39**) and discussed in detail by Aurelio (1992).

Extent of displacement, slip rate and age of the fault

The more delicate aspects of the problem involve estimates on the fault's extent of displacement, slip rate and age of formation. A bibliographic summary reveals that calculated values for these parameters considerably differ according to author and studied segment (**Table 1.3**).

Measurements by Mobil Corporation (Philippines) on the Miocene sedimentary facies in Mindanao show left-lateral displacements of around 28 km along the southern trace of the fault (Gervasio, 1971). Barcelona (1981, 1986) later described 5 to 8 km of left-lateral displacement of Plio-Pleistocene sedimentary formations in Leyte.

CHAPTER 2, TECTONICS, THE PHILIPPINES: A COMPLEX PLATE BOUNDARY



Fig. 1.39 Focal mechanism solutions of major earthquakes (>Ms 5.0) related to the Philippine Fault from 1964 to 1991. Replotted from Aurelio, 1992

Field observations in Mindanao, Leyte and Surigao (Barrier and others, 1988) suggest that the tectonic activity in that segment is probably post Miocene. In Luzon, Stephan and others (1986) and Pinet and Stephan (1990) presented cartographic arguments in considering the Luzon Central Cordillera to be left-laterally displaced for around 80 to 100 km with respect to the Southern Sierra Madre Range. This amount of displacement occurred, according to them, mainly towards the end of Miocene and Early Pliocene to Recent. This suggests a displacement rate of around 1.3 cm/yr (90 km in 7 Ma).

In an attempt to reconstruct the Cenozoic history of the Philippine archipelago, Mitchell and others (1986) estimated a 200-km left-lateral displacement since Middle Miocene along the Philippine Fault. Consequently, they consider the Iloilo Basin in Panay as previously
 Table 1.3 Estimate of extent of displacement, slip rate and age of the Philippine Fault according to various authors.

Author	Region	Rate	Displace- ment	Time	Velocity (cm/yr)
Gervacio, 1971	Mindanao	Miocene sediments	28 km	-	-
Acharya, 1980	Philippines	Historical seismicity	-	-	6.85
Karig, 1983	Luzon	Displacement of: - Cordillera/Sierra Madre - Metamorphic belts - Oligo-Miocene	200 km	Middle Miocene to Present	1.5
Barcelona, 1986	Leyte	Plio-Pleistocene sediments	5-8 km	-	-
Mitchell, et al., 1986	Luzon	Displacement of Cagayan and Iloilo basins	200 km	Middle Miocene to Present	1.7
Cole, et al., 1989	Leyte	Displacement of ophiolites in north and south Leyte	110 km	Tertiary	0.55
Pinet and Stephan, 1990	Luzon	Displacement of Cordillera and Sierra Madre	80-100 km	Upper Miocene to Lower Pliocene	1.3
Pinet, 1990	Luzon, Vigan Aggao F.	Displacement of Lower Pliocene sediments	35 km	4.0 Ma to Present	>1.0
Ringenbach, et al., 1992	Luzon, Digdig Fault	Displacement of Pleistocene dikes	17 km	1.3 Ma to Present	>1.3

contiguous with the Cagayan Valley of Luzon. This suggests a slip rate of 1.7 cm/yr (200 km in 12 Ma).

By analyzing the historic seismic events related to the Philippine Fault between 1900 and 1976, Acharya (1980) proposed a slip rate of 6.85 cm/yr. Bischke and others (1990) used aeromagnetic, seismic profile and geologic data to argue that, in fact, a branch of the Philippine Fault has already moved 300 km since Middle Miocene, suggesting an average slip rate of 2.5 cm/yr on that branch alone.

Obviously, estimates of the extent of displacement, slip rate and age of formation of the Philippine Fault depend a lot on criteria used and are very disputable. Aurelio and others (1990a and b) presented arguments that certain segments of the fault seem to have been inherited from older structures while other segments appear to be totally recent structures. Further, Aurelio and others (1991) and Aurelio (1992) conducted extensive fault data analyses on the central segment of the Philippine Fault and estimated an age for the structure of not more than 5 Ma. In conjunction with Aurelio and others' 1991 study, Barrier and others (1991) presented a statistical method in the estimation of the slip rate along the fault by using earthquake slip and regional kinematic vectors and calculated an average slip rate of 2 to 3 cm/yr. Aurelio and others (1994) later presented an expanded discussion on the solution and premises assumed by Barrier and others (1991). And to finally confirm these post-1990 calculations, Duquesnoy and others (1994) performed a geodetic survey (GPS) on the Leyte segment of the Philippine Fault between 1991 and 1993 and confirmed an average left-lateral slip rate of 2.48 +/- 1.0 cm/yr. In 1997, Duquesnoy recomputed more recent data sets and modified the rate to 3.5 cm/yr. The fault in this segment moves by creep. Aurelio and others (1997, 1998, 1999, and 2000) and Rangin and others (1999) further presented results of GPS measurements of an ASEAN-wide network from 1994 to 1998 confirming a 2 to 3 cm/yr slip rate on the Philippine Fault from Luzon to Mindanao.

Prioul and others (2000) conducted a fluid injection experiment on this creeping Leyte segment of the fault. It is observed that even with fluids injected at high wellhead pressures, the fault appears to behave aseismically. This may imply that the creep is independent of the influence of geothermal fluids circulating along the fault plane, contrary to what was earlier believed by Duquesnoy and others (1994) that the aseismic behavior may be due to high hydrothermal flow in the crust at this segment.

Structural regime variations along the Philippine Fault: the three segments

As it traverses the whole length of the archipelago, the Philippine Fault presents at least three varying structural regimes. Consequently, three major segments can be distinguished according to structural character and data availability.

Northern Segment: NW Luzon to Lamon Bay

The northern segment of the Philippine Fault presents characteristics of a transpressional regime where movement is both by strike-slip and thrust faulting. In NW Luzon for example, the vertical thrust component is dominant (Ringenbach and others, 1988; 1990; Maleterre, 1989; Maleterre and others, 1989; Pinet, 1990; Pinet and Stephan, 1990; Ringenbach, 1992). In Luzon, the Philippine Fault is not restricted to a narrow zone as in its central segment in the Visayas. North of Dingalan Bay, the fault branches out into several strike-slip faults generally oriented N-S. From west to east, these branches include the San Manuel-Vigan-Aggao Fault system, Pugo Fault, Tuba Fault, Tebbo-Abra River Fault system, and the Digdig-Kabugao Fault system (**Fig. 1.21**). It is in the Digdig segment where the July 16, 1990 earthquake took place. Between Dingalan Bay and Lingayen Gulf, this fault segment strikes N60°W to N45°W. It reorients to a N-S strike southwards in the Southern Sierra Madre Range.

The northern segment is characterized by a thrust regime that is more structurally similar to the Longitudinal Valley Fault of Taiwan (Barrier, 1985) than to the left-lateral fault in Luzon (Maleterre, 1989). However, the focal mechanism solution of the main shock of the July 16, 1990 earthquake shows a very minimal thrust component (**Fig. 1.39**, solution no. 76).

Central Segment: Bondoc Peninsula to Leyte

South of Luzon, the Philippine Fault disappears into the sea but gets back inland on Bondoc Peninsula. The central segment of the Philippine Fault, between Bondoc Peninsula and Leyte, is characterized by a relatively simple structure. The fault is restricted to a single or a few (2 to 3) well-defined branches. It defines a curvilinear trace convex to the NE. It strikes N40-50°W in Bondoc rotating to N25-30°W in Leyte. All observations along this segment of the fault including rupture during earthquakes, truncated surfaces, fault planes as well as focal mechanism solution of earthquakes attest to an essentially left-lateral movement. An extensive tectonic study of this segment of the fault is presented by Aurelio (1992).

Southern Segment: Mindanao and the Moluccas

The existence and character of the Philippine Fault in Mindanao are up to present very controversial. Field studies coupled with remote sensing data (Pubellier and others, 1991) show that the fault bounds the eastern flank of the Agusan-Davao Basin. In Surigao, the fault strikes N10-20°W. In Davao, it strikes practically N-S. In Surigao, a relay zone between two branches of the fault gives rise to a pull-apart feature expressed by the present-day Lake Mainit. South of the lake, the Lianga Fault branches out southeastwards towards the Philippine Trench. Further south in Davao del Norte, the southeast-trending Mati Fault serves as the southernmost branch of the fault. Recent GPS measurements (Aurelio, 2001) indicate a southward decrease in slip rate along the fault from around 2.4 cm/yr in Surigao to about 1.0 cm/yr in Davao.

Extensive structural investigations by Quebral (1994) show that the Philippine Fault traverses a sedimentary basin (Agusan-Davao) developed over a single pre-Oligocene volcanic arc. This observation is inconsistent with the hypothesis that considers the Philippine Fault as having been inherited from an old suture zone allegedly arising from the collision of two volcanic arcs (Roeder, 1977; Silver and Moore, 1978 a and b; Moore and Silver, 1983; Hawkins and others, 1985; Florendo, 1987). It appears instead that in Mindanao, the fault reactivates old normal faults related to

the formation of the Agusan-Davao Basin and that further to the south; it traverses the basin, the basement and the old volcanic arcs. Structural studies and interpretations of the southern termination of the Philippine Fault are presented by Quebral (1994).

Mechanism

Fitch (1972) first suggested that the Philippine Fault functions in a shear partitioning environment. In this setting, the fault accommodates a component of the oblique convergence between the Philippine Sea Plate and the Philippine archipelago (**Fig. 1.40**).

Pinet and Cobbold (1992) showed this phenomenon by analogue modelling, while GPS experiments between 1991 and 1998 provided quantification of this observation in the context of present-day plate motions. This led Aurelio (2000) to suggest that the formation of the fault marks the onset of a new geodynamic regime in the Philippine region. In the central Philippines, this event corresponds to the creation of a new tectonic boundary separating the Philippine Mobile Belt and the Philippine Sea Plate, following the latter's kinematic reorganization that occurred around 4 Ma. This confirms observations by Seno and Maruyama (1984), Barrier (1985), Huchon (1985), Angelier and Huchon (1986), Lee and others (1990), Kamata (1999), Kamata and Kodama (1999) and Kamata (2000) that during this event, motion of the Philippine Sea Plate shifted its relative movement with respect to Eurasia from a northward to a northwestward motion. Such a setting then favored the formation of a Philippine Fault - Philippine Trench system under a shear partitioning mechanism.

OTHER ACTIVE FAULTS

Other active faults can be identified in addition to the Philippine Fault system and its branches (**Fig. 1.21**). The following discussion includes faults which are either relatively well-understood, or are the subject of recent research. Other faults that may have been mentioned by past authors but which are less understood are not here presented.

Marikina Valley Fault System

Originally named "Marikina Valley Fault System", it was designated later by PHIVOLCS as the Valley Fault system (VFS). The name Marikina Valley Fault System is retained here following standard nomenclature practice. It consists of two NE-trending faults: the Western and Eastern Valley Faults that transect parts of eastern Metro Manila and possibly extend southwards to Tagaytay Ridge. Although long recognized by early workers as a major structure, the fault had been largely assumed as inactive. However, recent studies by PHIVOLCS (e.g. Daligdig and others, 1997; Punongbayan and Rimando, 1996; Rimando and others, 1996) reveal that it is in fact active as evidenced by geomorphic features such as displaced alluvial fans, offset streams, and shutter/pressure ridges. These fault-associated features suggest a right-lateral sense of displacement along the fault. Based on paleoseismological studies, Nelson and others (2000) estimate the occurrence of four earthquake events during the past 1500 years. A young age is also inferred for the eastern segment of the Marikina Valley Fault based on the relatively unconsolidated nature of the



Fig. 1.40 Diagram explaining the concept of shear partitioning as originally proposed by Fitch in 1972

alluvium that was cut by the fault, the thin colluvium material and soil layer that formed after faulting, and the presence of highly sheared yet only slightly weathered wedges of gabbroic bedrock. No recent seismic activity can yet be directly related to this fault but its proximity to the center of Metropolitan Manila (only 5 km) makes it a very significant tectonic feature.

Macolod Corridor

There is current discussion on the existence of a structural feature that would correspond to a NNE-SSW trending corridor originally delineated by earlier workers (e.g. Oles and others, 1991; Defant and others, 1988) on the basis of the petrology and alignment of active and recent volcanoes that include Taal, Banahaw, Makiling, Malepunyo and the maars of Laguna province. The Taal Fracture Zone of Alcaraz (1947) seems to follow the same northeasterly trend. However, there appears to be little structural evidence to prove the existence of such a structural feature, except to associate the NE-trending Tagaytay Ridge as the corridor's northern structural boundary. The structural expression of the southern boundary, where the structure has allegedly acquired its name (Mt. Macolod), is not clear. Recent GPS measurements (Ohkura and others, 2001) suggest that the corridor is a broad left-lateral fracture zone, an observation corroborated by Pubellier and others (2000) after integrating results of seismotectonic studies and radar imagery interpretation.

Lubang-Verde Passage Fault System

This fault system is located offshore between Batangas peninsula and Mindoro Island, following the northwest-southeast alignment of Verde and Lubang islands (thus the name). It is essentially a strike-slip (left-lateral) fault in the vicinity of Verde passage, but appears to transform into a transpressional (thrust/left-lateral) fault as it cuts through the southern section of the Manila Trench accretionary prism. The pure strike-slip movement is evidenced by frequent earthquakes in the Verde passage area, while the transpressional character has been observed through a seabeam survey in the southern termination of the Manila Trench by Rangin and others (1988). These authors consider this structure to play a significant role in the transition from subduction along the Manila Trench to collision in the Mindoro-Palawan-Panay area.

Mindoro/Aglubang Fault

The break in slope between mountainous western Mindoro and the flatlands of eastern Mindoro marks the trace of a north-south trending structure corresponding to the Mindoro Fault. This structure is readily observable from topographic maps, aerial photographs and satellite imagery. Morphological evidence suggests right-lateral motion, with a significant normal component. The most recent manifestation of its activity was a magnitude Ms 7.1 earthquake that ruptured the northern segment (Aglubang Fault) in 1994, causing considerable damage to property and loss of lives on the coastal areas of northeastern Mindoro.

Sibuyan Sea Fault

On the basis of aeromagnetic and seismic data, Bischke and others (1990) claim to have discovered a new branch of the Philippine Fault which they called the Sibuyan Sea Fault, located offshore north of Masbate. By tracing the structure inland, Aurelio (1992) shows, however, that it appears to function independently from the Philippine Fault. Fault data analysis by Aurelio (1992) in the zone between the Sibuyan Sea Fault and the Philippine Fault shows the interplay of strike-slip and normal faulting events, suggesting that the region is controlled by a transtensional tectonic regime. GPS measurements (Duquesnoy and others, Aurelio, 2000; 1994; Bacolcol, 2003) confirm this transtensional behavior.

Using bathymetric (SeaMarc) and paleomagnetic data gathered in the northern section of the Sibuyan Sea, Sarewitz and Lewis (1991) were led to conclude that the Sibuyan Sea Fault is relayed with the Verde Passage Fault, both left-lateral faults, by an aborted spreading center under a transtensional tectonic regime.

Legaspi Lineament

The 1963 edition of the 1:1,000,000 scale Geological Map of the Philippines (Bureau of Mines, 1963) shows a long SE-trending linear feature emanating from Pasacao in the Ragay Gulf area, passing through

Lake Bato then to Legaspi City. Bathymetric maps in the Lagonoy Bay – Rapu-Rapu Islands area indicate a continuation of this structure towards the Philippine Trench. The NW-SE-elongated Lake Bato is a manifestation of a dilational jog along a left-lateral fault system. This sense of movement is consistent with focal mechanism solutions of earthquakes that occasionally occur offshore east of Legaspi, and with the apparent 40-km left-lateral displacement of the Philippine Trench in that latitude (Aurelio, 1992). In the Ragay Gulf area, this structure is clearly evident on seismic profiles and appears to interact with the Philippine Fault close to shore in Buenavista, Quezon (Aurelio, 1992). Considering its morphological prominence and seismic activity, it deserves to be elevated in category from a less significant lineament to a fault.

Tablas Lineament

The Tablas Lineament is a tectonic boundary between the Palawan-Mindoro microcontinental block and the western edge of the Philippine Mobile Belt. It trends northerly as it separates Busuanga peninsula from the Antique Range in Panay Island, and passes offshore northwards east of Tablas Island. The present geodynamic setting of the Philippines obliges the Tablas Lineament to operate as a right-lateral strike-slip fault. Focal mechanism solutions of recent earthquakes in the Panay-Tablas region confirm such sense of movement. This structure appears to connect with the Negros Trench southwards, contributing also partly, in a manner similar to the Lubang-Verde Passage Fault system, in the transition from subduction along the Negros Trench to collision towards Mindoro. As such, it also deserves to be elevated in category from a lineament to a fault.

Mindanao Fault

The Mindanao Fault is a prominent NW-trending linear fracture zone on the western third of Mindanao Island. It has two distinct segments, including that which separates the Daguma Range from the Cotabato Basin corresponding to the Cotabato Fault segment. This segment is highly linear and has features suggestive of normal faulting although it may have been a left lateral strike slip fault during its early history. The Quaternary Mt. Parker volcano is located at the western end of this fault and, on radar images, seems to be cut by the fault. Terraces formed by Quaternary limestone mark the Daguma Range. These, together with the young morphology of incised river valleys, suggest a young age for the fault along which the Daguma Range was uplifted. Although Quaternary in age, it still has to be ascertained whether the fault is active or not (Quebral, 1994).

The Sindangan Fault segment represents the northern continuation of the fault towards northern Zamboanga. Focal mechanism solutions of earthquakes offshore and narrow shear zones transecting recent gravel deposits suggest active left-lateral faulting (Pubellier and others, 1991).

Offshore Cebu-Bohol faults

The occasional occurrence of low to moderate magnitude, shallowseated earthquakes between Cebu and Bohol islands in the Visayas, some capable of causing significant damage to infrastructure, is the subject of current discussions on the possible existence of active faults in the region. Such earthquake generators are most likely offshore, as there have so far been no indications of active faulting within the islands of Cebu and Bohol. More studies are necessary to ascertain these occurrences.

It should be mentioned that active fault studies in the Philippines are spearheaded by PHIVOLCS. This institute regularly updates its list of active faults as new data are gathered and analyzed.

PRESENT-DAY PLATE MOTIONS IN AND AROUND THE PHILIPPINES

Global Positioning System (GPS) data gathered every two years since 1994 over a 42-station network distributed in Southeast Asia under the acronym GEODYSSEA to mean GEODYnamics of South and SouthEast Asia have allowed the analysis of the present-day motion of tectonic blocks in and around the Philippines. Detailed discussion of results of this project for the Philippines have been presented by Aurelio and others (1997, 1998a & b, 1999, 2000), Chamot-Rooke and others (1997), Le Pichon and others (1997), Duquesnoy (1997) and Rangin and others (1999).

Motion vectors in the archipelago and vicinity are in the order of a few to several cm/yr. When microcontinental Palawan is held fixed, the slowest movements can be detected in Zamboanga at less than 2 ± .15 cm/yr westwards (Fig. 1.41). Virac Island moves the fastest at over $7 \pm .17$ cm/yr northwestwards. A triangle, centered in offshore NW Panay and defined by the stations in Virac, Palawan and Panay exhibits the fastest counterclockwise rotation at a rate of about $10 \pm .5^{e-08}$ radians per year (Fig. 1.42). Compressional strain rates are fastest at 150^{e-09} (directed E-W) per year in the central Philippines in NW Leyte (Fig. 1.43). Slower but comparable rates are detected between Surigao, Davao and Zamboanga. The largest extensional strain rate is detected on a NW-SE direction in NW Panay. In general these motion vectors can be explained in the context of the behavior of known active Philippine structures with respect to the interaction of the Philippine Sea and Indo-Australian plates with the southeastern margin of the Eurasian Plate. However, the large extension observed in the Mindoro-Palawan-Panay area appears to contradict existing models of a micro continent - arc collision zone within this section of the archipelago.

Southern Philippines

A strong westerly relative plate motion component is observed on the southernmost station in Davao. This direction is almost perpendicular to the Philippine Fault and Cotabato Trench but oblique to the Cotabato Fault Zone. While this may imply frontal subduction along the trench, the computed motion vector may also mean that there is practically no lateral movement along the Philippine Fault along this segment. This appears to coincide with some indications of a possible seismic gap in the Tagum-Davao area (Quebral, 1994). Further north in Nabunturan town, however, there are clear indications of recent activity along the fault (e.g. overturned Holocene alluvial deposits, Pleistocene anticlines cut by fault) while to the south in Mati and offshore Pujada, earthquakes possibly generated by a

branch of the fault there, have been recorded for the past 100 years. From the Surigao station in the north of Mindanao Island, a significant movement of the Philippine Fault in the order of 2 cm/yr is registered.

To the west, it is interesting to note the occurrence of the Cotabato Fault, a prominent NW-SE trending structure also believed to be a leftlateral strike-slip fault (Pubellier and others, 1991; 1993), located behind the east-dipping Cotabato Trench. Seismicity along this subduction area is fairly high, although it is only known to occur on the northern segments of the Cotabato Fault Zone. Furthermore, it is still unclear whether the Celebes Sea is subducting frontally against the Daguma arc, but if it is, the situation may be operating on a shear partitioning mechanism similar to what is observed in the central segment of the Philippine Fault and the Philippine Trench.

Down south in the Mollucas area, what prevails is a complex collision process involving the consumption of the Mollucas sea crust entailing the imminent accretion of Halmahera arc with Sangihe arc. The process is brought about by a strong E-W stress pattern easily observed on focal mechanism solutions (Aurelio, 1992; Quebral, 1994). This may also have a significant influence on the westerly relative plate motion observed in the Davao station.

Central Philippines

The GPS stations in the central Philippines are located on either side of the Philippine Fault. The Iloilo station is west of the structure while the Virac station is to its east. Motion vectors show a left-lateral displacement along the fault, although a compressive component perpendicular to the strike of the fault is noticeable. This may imply that although the interaction between the eastern and western portions of the Philippine Mobile Belt is essentially characterized by strike-slip faulting, an E-W compressive component is possibly being accommodated along thrust and fold zones. Arguments for this have yet to be verified through a comprehensive tectonic study of the area between Catanduanes Island and Iloilo composed of the islands of Negros, Cebu, Masbate, Leyte and Samar.

In Leyte Island, results of GPS surveys from 1991 to 1994 show a generally strike slip faulting region, with a noticeable extensional component perpendicular to the strike of the Philippine Fault. This obviously differs from what is observed in the GEODYSSEA network. The Leyte network is built around a more local area (longest baseline is about 50 km only) where faults have been characterized to show transtensional characteristics. The difference in tectonic regimes as observed from the two separate networks may mean that at the regional scale, the central Philippine Mobile Belt is undergoing a transpressive deformation (strike slip + compression), while at the local scale, Leyte Island is under transtensional tectonics (strike-slip + extension).s

It is interesting to note that the motion vector in Catanduanes is oriented sub-parallel to the Philippine Sea Plate - Eurasian Plate relative movement. This may suggest that the Philippine Sea Plate - Eurasian Plate relative movement is completely accommodated along the margin. However, slip vectors along the Philippine Trench are generally oriented perpendicular to the trench, implying frontal subduction. This may mean therefore that what is reflected in Catanduanes is not representative of the Philippine Sea Plate - Eurasian Plate relative motion, but may reflect the motion between the eastern section of the Philippine Mobile Belt and the area to its west and southwest. It may merit taking a closer look at the Bicol area, where a poorly-known strike-slip structure (Legaspi Lineament: Aurelio, 1992) orients parallel to the motion vector.



Fig. 1.41 Motion vectors in the Philippines deduced from GPS measurements. From Aurelio and others, 1998



Fig. 1.42 Block rotation rates in the Philippines deduced from GPS measurements. From Aurelio and others, 1998



Fig. 1.43 Strain rates in the Philippines deduced from GPS measurements. From Aurelio and others, 1998



Summary of Significant Tectonic Events In the Philippines

In a very simplified manner, the geologic and tectonic history of the Philippines during the Cenozoic has four very important characteristics, namely;

Origin of Basement Rocks

The nature of basement rocks in the Philippine can be classified into continental, oceanic or arc. Details of these rock suites are discussed in Chapter 2. These basement rocks range in age from as old as Permian (e.g. Mid Permian Minilog Limestone as olistolith in Late Jurassic to Early Cretaceous Guinlo Formation in Palawan), to as young as Late Oligocene (Amnay Ophiolite in Mindoro). They exhibit varying degrees of metamorphism, generally believed to be a function of their position with respect to a tectonic front responsible for the metamorphic event.

Continental Basement

Continentally-derived basement rocks include sedimentary, carbonate and igneous rocks found in Palawan, Mindoro, western Panay and in the Romblon Island Group (Romblon, Sibuyan, and Tablas). These rocks are believed to have originated from mainland Asia before the rifting and eventual opening of the South China Sea between 32 Ma and 17 Ma. At the cessation of the South China Sea spreading, these rocks, by this time collectively constituting the Palawan-Mindoro microcontinent, collided with the western margin of the Philippine Mobile Belt. Post-basement formations include pre-, syn- and post-rift sedimentary basins (mostly observed offshore), igneous intrusions (e.g. Kapoas Granite) and ophiolite obductions (Palawan Ophiolite).

Oceanic Basement

Ophiolite and ophiolitic basement rocks are widely distributed in the archipelago. Ranging in age from Cretaceous (e.g. Palawan Ophiolite) to Late Oligocene (e.g. Amnay Ophiolite), these are believed to have originated from different oceanic spreading centers and have been emplaced in various modes. Aurelio (1996) presented a review of the possible modes of emplacement of Philippine ophiolites in the context of Dewey's 1976 discussion of ophiolitic obduction processes.

• Arc Basement

Like the ophiolites, basement rocks composed of arc rock suites are widespread in the Philippines. These arc basement rocks often exist as volcaniclastic sequences, sometimes with their plutonic and volcanic equivalents, as can be found in the magmatic arcs of the Luzon Cordillera and Sierra Madre Range in Luzon, the Antique Range and Negros Arc (ancient) in the Visayas, and in the East Pacific Cordillera and Daguma Range in Mindanao. Ranging in age from Cretaceous to Present, arc rocks originated from multiple magmatic episodes associated to several subduction events.

Formation of Sedimentary Basins in the Neogene

Formation of sedimentary basins over pre-Neogene basement of diverse characters (continental, ophiolitic, arc) generally started in Late Oligocene. The Upper Oligocene - Lower Miocene limestones generally representing the base of the sedimentary basins formed over the Philippine Mobile Belt are evidence of a shelfal carbonate depositional environment during this period. A general subsidence followed in Middle Miocene times as suggested by the thickness and the wide distribution of turbiditic deposits of this age. From Late Pliocene to Pleistocene, depositional environments become shallower, giving rise to shallow marine clastics (conglomerates, sandstones, shales), passing into carbonates and finally fluviatile deposits. Most of these Neogene deposits are characterized by the abundance of volcanic clasts which reflects the proximity of volcanic edifices to the sedimentary basins, typical in *intra-arc basin* settings.

Magmatism since Cretaceous

Volcanic activity and igneous intrusions have been continually active since Cretaceous times as suggested by the presence of magmatic belts of Cretaceous, Eocene, Oligo-Miocene and Pliocene-Quaternary ages. At present, the Philippine Institute of Volcanology and Seismology lists over 20 active volcanoes in the archipelago.

Miocene Collision

The Palawan-Mindoro microcontinent rifted from mainland Asia and drifted until it collided with the west central portion of the Philippine Mobile Belt during Miocene time. This event gave rise to the emplacement/juxtaposition of pre-Neogene ophiolites over Miocene formations. During the same period, the Upper Oligocene - Lower Miocene portion of the sedimentary formations were deformed and incorporated with sequences of continental, ophiolitic or island arc origin. As a consequence, a Middle Miocene unconformity is well expressed in this part of the archipelago.

It is possible that collisional events prior to Middle Miocene might have also occurred, considering that pre-Miocene fault-fold systems have also been observed in other areas (e.g. Cebu, Daguma Range, Zamboanga, Caramoan Peninsula, etc,). There is a need to further understand the nature of these possible deformational events.

Recent Tectonic Deformation

Deformed formations exhibit complex structural grains due to the superposition of several compressive events, mainly from the Miocene collision and onset and continuation of activity on the major tectonic boundaries (subduction zones and strike-slip faults) starting around 5 Ma. This tectonic regime, influenced by the northwestward movement of the Philippine Sea Plate with the Eurasian margin, promoted oblique convergence causing the Philippine island arc system to deform under a broad shear partitioning regime. This has caused the most recent deformation of sedimentary basins, arc sequences and old basement terranes by activity along major tectonic boundaries.

STRATIGRAPHY AND PETROLOGY

This part presents the stratigraphy and petrology of specific areas in the Philippines according to their affinity to stratigraphic groupings as shown in **Fig. 2.1** and summarized in **Table 2.1**. This presentation deviates from that used in the 1981 edition where geologic formations were presented according to their types (e.g. sedimentary, volcanic or metamorphic), ages and physiographic province affinities. This old format proved to be inconvenient as it obliged the reader to often cross-refer to different chapters while remaining in only one stratigraphic sequence. It also required mentioning the physiographic provinces repeatedly each time rock formations were described according to their rock types as well as geologic ages. This present volume avoids such confusions. Some salient points of the new format can be recognized as follows:

- Islands are presented individually or in groups, making reference whenever necessary to their stratigraphic affinity as shown in **Table 2.1**. For example, Panay Island is presented independently, but reference is made about its affinity to four stratigraphic groupings, namely; 11 (North Palawan Block), 13 (Antique Range), 14 (Iloilo Basin) and 15 (Recent Negros Arc).
- 2. If a grouping is "within" the limits of an island (example: 3 Cagayan Valley Basin within Luzon), then its stratigraphy is presented independently.
- 3. If an island is within a grouping (example: Cebu Island within 17 Visayan Sea Basin), it is presented independently with reference to its stratigraphic grouping.
- 4. A Stratigraphic Grouping corresponds to an area with a distinct stratigraphic character that can be distinguished from those of adjacent areas. For example, Stratigraphic Grouping 1 (Ilocos-Central Valley Basin) is essentially a sedimentary stratigraphic unit, distinct from the primarily volcanic-arc character of Luzon Central Cordillera (Stratigraphic Grouping 2), or from the ophiolitic nature of the Zambales Range (Stratigraphic Grouping 3). Reference can be made to Chapter 1 for the nature of rocks in the archipelago. A brief summary of the new stratigraphic grouping is presented In Table 2.1.
- 5. Discussion of each geologic formation starts with a capsule information that includes, but not limited to, lithology, stratigraphic relations, distribution, age, thickness, previous name/s, author/s and synonymy for quick reference.
- 6. An alphabetical listing of formational names adopted as main entry is appended. A separate listing of stratigraphic names that have been cited, but are not used here as the main entry, is also provided.

7. The Geologic Time Scale used for the stratigraphic columns is adapted from version 2009 of the International Stratigraphic Commission.

Table 2.1	Stratigraphic	Groupinas
	e	0.0000.000

SG No.	Name	Dominant Stratigraphic Character	Major Areas Covered
1	Ilocos-Central Luzon Basin	Sedimentary basin	Ilocos Central Luzon Basin West Central Luzon Basin East
2	Luzon Central Cordillera	Arc	Central Cordillera and Batanes group of islands
3	Cagayan Valley Basin	Sedimentary basin	Cagayan Valley
4	Northern Sierra Madre	Arc / Ophiolitic	Northern Sierra Madre
5	Zambales Range	Ophiolitic / Arc	Zambales Range
6	Southern Sierra Madre	Arc / Ophiolitic	Southern Sierra Madre
7	Southwest Luzon Uplands	Arc	Southwestern Luzon Marinduque Island Northern Mindoro
8	Southeast Luzon Basin	Sedimentary Basin / Arc	Bondoc Peninsula Masbate island group
9	Recent Southeast Luzon Arc	Arc	Southeast Luzon
10	Ancient Southeast Luzon Arc	Arc	Southeast Luzon
11	North Palawan Block	Continental / Metamorphic	Southern Mindoro North Palawan Northwest Panay Romblon island group
12	South Palawan Block	Ophiolitic	South Palawan
13	Antique Range	Ophiolitic / Metamorphic	Westen Panay

14	lloilo Basin	Sedimentary Basin	Central Panay
15	Recent Negros Arc	Arc	Eastern Panay Southwest Negros
16	Ancient Negros Arc	Arc	Central Negros
17	Visayan Sea Basin	Sedimentary Basin	Eastern Negros Cebu Bohol Northwest Leyte
18	Samar Block	Sedimentary Basin / Arc	Samar
19	Leyte Central Highlands	Arc / Ophiolitic	Leyte
20	Leyte Gulf	Ophiolitic	Northeast Leyte Southern Samar Dinagat island group
21	Sulu-Zamboanga Arc	Arc	Sulu Archipelago Zamboanga – Misamis Occidental
22	Central Mindanao Arc	Arc	Central Mindanao
23	Agusan-Davao Basin	Sedimentary Basin	Agusan-Davao Valley
24	Mindanao Pacific Cordillera	Arc / Ophiolitic / Basin	Eastern Mindanao
25	Daguma Range	Arc	Western Cotabato
26	Cotabato Basin	Sedimentary Basin	Cotabato Valley
27	Saranggani Block	Arc	Saranggani Peninsula
28	Pujada Block	Ophiolitic	Pujada Peninsula
29	South China Sea Basin	Oceanic Crust / Basin	South China Sea

GEOLOGY OF THE PHILIPPINES

30	Sulu Sea Basin	Oceanic Crust / Basin	Sulu Sea
31	Celebes Sea Basin	Oceanic Crust / Basin	Celebes Sea
32	Philippine Sea Basin	Oceanic Crust / Basin	Philippine Sea



Fig. 2.1 Stratigraphic groupings





ILOCOS (SG 1)

Suyo Schist

Lithology	Greenschist, serpentinite, chert
Stratigraphic relations	Basement of the sequence in Ilocos; unconformably overlain by the Bangui Formation
Distribution	Suyo, Burgos, Ilocos Norte
Age	Cretaceous (?)
Previous name Renamed by	Suyo Metamorphics (BMG, 1981) MGB (this volume)

The Suyo Schist, exposed largely in Suyo, Burgos, Ilocos Norte, consists of amphibolite, quartz-biotite schist, actinolite-tremolite-talc schist and quartzite, which are mostly in fault contact with serpentinized peridotite. These rocks are probably of Cretaceous age.

The amphibolite schist is light to dark green, fine- to medium-grained and is characterized by planar orientation of green amphibole, chlorite, feldspar and quartz. The rock exhibits usually nematoblastic texture with large bluish green amphibole and prismatic, light-colored epidote.

The quartz-biotite schist, consisting dominantly of quartz with lesser amounts of biotite, epidote, garnet, hematite and piedmontite, occurs intimately with the amphibolite schist.

The actinolite-tremolite-talc schist, a product of dynamothermal metamorphism, is structurally confined along the contact of the intensely sheared serpentinized peridotite.

Ilocos Peridotite

Lithology	Serpentinized peridotite
Stratigraphic relations	Confined in deformation zones;
	unconformably overlain by the Bangui
	Formation
Distribution	Lapog, Ilocos Sur, Baruyen River and
	Bangui, Ilocos Norte
Age:	Cretaceous (?)
Previous name	Baruyen Formation (Smith, 1924)

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	ILOCOS
	HOLOCENE		0.0447	
	PLEISTOCENE	4 Late	0.0117	Uplifted Coral Reefs
Ш	PLIOCENE	1 Early 2 Late 1 Early	2.59 3.60	Laoag Formation
NEOGE		3 Late	7.25	Pasuquin Limestone
	MIOCENE	2 Middle-	13.65	Batac Formation
			15.97	Dagot Limestone Pasaleng Quartz Diorite
		1 Early	20.43	Bojeador Formation
	OLIGOCENE	2 Late 1 Early	23.03 28.4	Magabobbo Limestone
Щ		4 Late	37.2	
PALEOGEN	EOCENE	3 Middle - 2	40.4	
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
EOUS	Upper	Late	00.0	Ilocos Peridotite
CRETAC	Lower	Early	99.6	Suyo Schist
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.2 Stratigraphic column for Ilocos

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Renamed by

MGB (this volume)

This peridotite unit is closely associated with reddish radiolarian chert, previously named Baruyen Formation by Smith (1924) with type locality at the Dungan-Dungan Estate along Baruyen River in Ilocos Norte. Hashimoto and others (1975) believe that the rock at Smith's type locality at Dungan-Dungan Estate along the Baruyen River is not a true chert but a mèlange-like deposit.

This rock unit consists of a train of relatively small bodies of serpentinites, together with schists, that occur along wide deformation zones (10 -100 m wide) trending N-S to N30E (Pinet and Stephan, 1990). One of these zones is traceable for about 140 km from Lapog, Ilocos Sur to Bangui, Ilocos Norte. Pockets of gabbro in the serpentinites have also been noted by Pinet and Stephan (1990).

Bangui Formation

Lithology	Sandstone, conglomerate, mudstone; includes olistostrome
Stratigraphic relations	Unconformable over the Ilocos Peridotite; overlain discordantly by the Magabbobo Limestone
Distribution	Bangui, Baruyen and Lammin area, Ilocos Norte
Age	Late Eocene – Late Oligocene
Thickness	Probably exceeds 2,000m
Named by	Smith (1907)

The name Bangui was first used by Smith (1907) for the sandstone unit, which constitutes the upper member of his Baruyen Series. It is here called Bangui Formation to include not only the sandstone but also the associated conglomerate and shale of Fernandez and Pulanco (1967) southwest of Pasaleng in northeastern Ilocos Norte. These rocks are also seen along the road between Baruyen and Pasaleng. In the Lammin area, a similar sequence is intercalated with marble. However, the upper and lower contacts of this formation have not been described.

According to Pinet (1990), the Bangui Formation consists mainly of volcanic sandstones interbedded with varying amounts of conglomerates and mudstones. In places, the sandstones and mudstones are characterized by alternating red and green beds.

Pinet and Stephan (1990) have noted an olistostrome unit in the Vintar River section containing serpentinite, radiolarian chert, graywacke, basalt and gabbroic clasts. It is 200 m thick and exposed over a distance of 20 km. This unit is regarded as part of the Bangui Formation. This is apparently equivalent to the Baruyen Formation of Smith (1907) with type locality in the Dungan-Dungan Estate along the Baruyen River in Ilocos Norte. It also crops out along Caruan River in Pasuquin. The chert is dirty red, fine-grained, hard and easily breaks into slabs. Irving and Quema (1948) described the chert as intensely folded, strongly fractured and brecciated.

The marble intercalated with the clastic rocks in Lammin area has been dated Late Eocene (BMG, 1982). Pinet (1990) reports that recent dating of planktonic foraminifera in samples from Pasaleng area and elsewhere indicates ages of Late Eocene (P17) to Late Oligocene. The thickness of the Bangui Formation probably exceeds 2000 m.

Magabbobo Limestone

Lithology	Micritic limestone, calcarenite, minor
	argillite
Stratigraphic relations	Unconformable over the Bangui
	Formation; overlain by the Bojeador
	Formation
Distribution	Vintar River near Barangay Megabbobo
	east of Laoag City
Age	Late Oligocene – Early Miocene

Thickness	Undetermined
Previous name	Megabbobo Formation (Pinet, 1990)
Renamed by	MGB (this volume)

The Megabbobo Formation (here renamed Magabbobo Limestone) was defined by Pinet (1990) for the narrow limestone body exposed along Vintar River east of Laoag near barrio Magabbobo. The limestone bodies are disposed along the Vigan-Aggao Fault, which defines the contact between the coastal and median units of Pinet (1990). The formation consists of two members: a lower white, massive micritic limestone with sea urchins and hexacorals and an upper reddish calcarenite with reworked micrites and buff-colored argillites. It rests discordantly over the volcanic sandstone of Bangui Formation. The angular discordance was not observed but only indicated by differences in attitude. Pinet (1990) reports ages ranging from Early Oligocene to early Middle Miocene (P20 - N9). However, its age probably ranges only from Late Oligocene to Early Miocene. Samples dated late Early Miocene to early Middle Miocene age probably belong to the Dagot Limestone.

The thickness and nature of the upper contact of the formation were not described by Pinet (1990).

Bojeador Formation

Conglomerate, graywacke, shale,
limestone and associated volcanic flows
and pyroclastics
Unconformably underlain by Bangui
Formation and Suyo Schist; intruded by
quartz diorite
Vintar, Ilocos Norte and northeast of
Vigan, Ilocos Sur
Early Miocene
500 m
Bojeador Agglomerate and Tuff (Irving and
Quema, 1948)
MGB (this volume)

This formation was originally named Bojeador Agglomerate and Tuff by Irving and Quema (1948) for the rocks at Cape Bojeador, northwestern llocos Norte. The unit rests unconformably over the olistostrome of the Bangui Formation, serpentinites and schists (BMG, 1981). It includes the conglomerate, graywacke, shale, limestone and associated basic flows and pyroclastics of Fernandez and Pulanco (1967) exposed east of Vintar, llocos Norte and northeast of Vigan, llocos Sur. The conglomerate is thick with poorly sorted pebbles and cobbles of angular to subrounded andesite, basalt and limestone set in a sandy and slightly calcareous matrix. The sandstone and shale are well-bedded, cream to buff and locally slightly recrystallized. It is intruded by diorite of probable late Early Miocene age.

The Bojeador Formation was previously estimated to be about 500 m thick and dated Early to Middle Miocene, in which case, it would be partly contemporaneous with the Dagot Limestone (described below). However,

considering the overall stratigraphy of the region, it could be confined to Early Miocene and partly equivalent to the Zigzag Formation of Central Cordillera.

Dagot Limestone

Lithology	Reefal limestone, calcarenite, biosparite, minor calcareous volcanic conglomerate,
Stratigraphic relations	Not reported
	Notreponed
Distribution	Meridionally distributed from the vicinity of
	Laoag City through the summit of Mt.
	Dagot in La Paz, hilltops east of Solsona
	Basin down to the Abra River Valley
Age	late Early Miocene to early Middle
-	Miocene
Thickness	Undetermined
Previous name	Kennon Limestone (Pinet, 1990)
Renamed by	MGB (this volume)

Limestone bodies of Early to Middle Miocene age exposed in several places in the llocos belt are correlated with the Kennon Limestone with type locality along Kennon Road at Camp 3, in the Baguio District in Central Cordillera (Pinet, 1990). These limestone bodies are distributed along a roughly meridional line extending for 200 km from the vicinity of Laoag in the north down to Baguio District. Dagot Limestone occupies the summit of Mt. Dagot in La Paz and one of the hilltops east of Solsona Basin and constitutes a north - south trending backbone of a dome southeast of Bangued. South of Bangued, this formation drops to Abra River valley west of barrio Luba.

The formation as described by Pinet (1990) is a reefal platform with algae, shells, milliolids and benthic foraminifera. Two common facies are light-colored, fine-grained calcarenite and reddish biosparite. Calcareous conglomerates at the base and middle section are volcanic in character. The top of the formation corresponds to limestone breccia grading into a sequence of alternating sandstone-mudstone. The contacts of the limestone with the underlying and overlying formations were not reported. Microfossils indicate a late Early Miocene to early Middle Miocene age.

Pasaleng Quartz Diorite

Lithology	Quartz diorite
Stratigraphic relations	Intrudes Bojeador Formation and older
	units
Distribution	Pasaleng, Pagudpud and areas in
	northeastern Ilocos Norte
Age	late Early Miocene to early Middle
-	Miocene
Named by	MGB (this volume)

Quartz diorite bodies intruding Cretaceous, Paleogene and Early Miocene units were mapped by Fernandez and Pulanco (1967) in
northeastern Ilocos Norte. The intrusive unit is designated here as Pasaleng Quartz Diorite for the exposures in Pasaleng, Pagudpud. The rock is leucocratic, coarse-grained and composed principally of quartz, feldspar and chloritized amphibole. A late Early Miocene to early Middle Miocene age was assigned to this intrusive unit based on its correlation with the Itogon Quartz Diorite Complex in the Central Cordillera.

Batac Formation

Lithology	Thinly bedded sandstone and shale;
	conglomerate
Stratigraphic relations	Not reported
Distribution	Batac, Ilocos Norte and northeast of
	Vigan, Ilocos Sur
Age	late Middle Miocene to Late Miocene
Thickness	Undetermined
Named by	Pinet (1990)

The Batac Formation is a sequence of thinly-bedded sandstones and shales named by Pinet (1990) for the exposures around Batac. Pinet (1990) also defined a Liliputen Formation for the sedimentary sequence exposed along the road between Pinili and Nueva Era, which could be part of the Batac. It consists of conglomerates with clasts of limestone accompanied by sandstones and mudstones with minor tuffs and andesites. The sandstones are slightly volcanic in character. The stratigraphic relations of this formation with respect to other formation probably constitutes the basal portion of the Batac Formation although Pinet (1990) has noted differences in the intensity of deformation between the Liliputen and Batac formations.

Pinet (1990) presumes the age of the Liliputen to be probable late Middle Miocene to early Late Miocene. Nannoplankton age determination gives a dating of Late Miocene (NN11) for the Batac Formation of Pinet (1990). Here, the age of the Batac Formation as a whole is considered late Middle Miocene to Late Miocene. In terms of regional correlation, this is equivalent to the Klondyke Formation of Central Cordillera.

Pasuquin Limestone

Limestone with minor calcareous conglomerate, calcirudite, calcarenite
Discordantly overlies folded Bangui
Formation; unconformable over Bojeador
Formation
Pasuquin River, Ilocos Norte and east-
northeast of Vigan, Ilocos Sur
Late Miocene
200 m
Pasuquin Arenaceous Limestone (Smith,
1907)
MGB (this volume)

The Pasuquin Limestone was called Pasuquin Arenaceous Limestone by Smith (1907). This is exposed along Pasuquin River, northeast of Pasuquin, Ilocos Norte. According to Pinet and Stephan (1990), this limestone forms the summit of a hillock east of Magabbobo where the nearly horizontal limestone overlies the folded Bangui Formation with a prominent angular unconformity. It has also been observed to rest unconformably over the Bojeador Formation east-northeast of Vigan.

It is well-bedded, light cream to light buff, porous and sandy in some places. The basal portion is described by Pinet (1990) as a conglomerate with carbonate matrix and in places bears clasts of serpentinite. The upper facies consists of calcirudites, calcarenites and fossiliferous limestone. It is around 200 m thick. Paleontologic dating indicates a Late Miocene age for the formation. This formation appears to be equivalent to the Mirador Limestone in Central Cordillera and Labayug Limestone in La Union.

Laoag Formation

Lithology	Sandstone with interbeds of siltstone and claystone and occasional reefal limestone and limestone breccia
Stratigraphic relations	Not reported
Distribution	Laoag, Ilocos Norte
Age	late Early Pliocene to Pleistocene
Thickness	Undetermined
Previous name	Laoag Marl Beds (Smith, 1907)
Renamed by	Irving and Quema (1948) as Laoag
	Calcareous Sandstone
Renamed by	MGB (this volume)

Smith (1907) first named the sedimentary rocks exposed along the highway between Bacarra and Laoag, Ilocos Norte as Laoag Marl Beds. Irving and Quema (1948) renamed the rock unit Laoag Calcareous Sandstone. It is here called Laoag Formation. The formation is made up of flat-lying sandstone with interbeds of siltstone and claystone and occasional reefal limestone and limestone breccia towards the top. These are predominantly sandy well-bedded cream to buff calcareous rocks. Some conglomerate beds contain abundant shell and other molluscan, as well as wood and leaf, fossils. Pinet (1990) reports a dating of late Early Pliocene to Pleistocene age for the fossiliferous beds of this formation.

Uplifted Coral Reefs

Lithology	Coral reefs
Stratigraphic relations	Unconformable over the Bojeador
	Formation and Pasuquin Limestone
Distribution	Coasts of Ilocos Norte
Age	Late Pleistocene
Thickness	Up to 30 m
Named by	Smith (1907)

Smith (1907) recognized two levels of raised coral reefs along the shores of llocos Norte: one elevated 30 m high; the other, about three to

four meters above the high tide level. At Cape Bojeador, these reefs lie over the Bojeador Formation and the Pasuquin Limestone. These reefs are consolidated coral fragments and other calcareous debris. Irving and Quema (1948) gave a Late Quaternary age to these reefs.

CENTRAL LUZON BASIN - WEST SIDE (SG 1)

Aksitero Formation

Lithology	Lower Bigbiga Limestone – micritic limestone with tuffaceous turbidite and minor chert
	Upper Burgos Member - Limestone,
	tuffaceous sandstone, siltstone and
	mudstone
Stratigraphic relations	Base of sedimentary sequence in Central
	Luzon; unconformably overlain by the
	Moriones Formation
Distribution	Aksitero River, Bigbiga, Mayantoc, Tarlac
Age	Late Eocene - Late Oligocene
Thickness	Bigbiga limestone - 42 m
	Burgos Member - 78 m
Named by	Amato (1965)

The Aksitero Formation is the oldest sedimentary formation in the west flank of the Central Luzon Basin. It was described by Amato (1965) after exposures along the upper reaches of Aksitero River in the vicinity of Bigbiga in the western foothills of Zambales Range. It represents the sedimentary cover of the Zambales Ophiolite and is made up of pelagic limestone and clastic rocks. The limestone is thin to thick bedded, cream to dirty white and tuffaceous. It is interbedded with thin calcareous and tuffaceous sandy shale. Below the limestone are lenses of rounded to ellipsoidal, generally discontinuous, reddish calcareous chert (Villones, 1980). Smaller chert lenses are interbedded with the limestone and gradually disappear upsection. Amato (1965) gave an age of Late Eocene to Early Oligocene to this formation based on the presence of Hantkenina alakamensis Cushman, Globorotalia cerroazulenses Calc, Globorotalia centralis Cushman and Bermudez and Discoaster barbadiensis Tan Sin Hok in the lower part; and Globorotalia opima nana Balli and Globigerina cipeoensis angustiumbilicata Balli in the upper part. In 1984, Schweller and others (1984) divided the Aksitero into a lower Bigbiga limestone *member* consisting of micritic limestone interbedded with tuffaceous turbidites and an upper Burgos member of interlayered limestone and indurated calcareous and tuffaceous sandstone, siltstone and mudstone. The lower member, which is 42 m thick, was dated Late Eocene to Early Oligocene and the upper 78-m member was dated Middle to Late Oligocene. Thus the age is Late Eocene to Late Oligocene and the aggregate thickness is about 120 m. Garrison and others (1979) state that the hemipelagic limestone and tuffaceous turbidites of the Aksitero were probably deposited at depths of at least 1000 m in a subsiding basin adjacent to an active arc system.

PERIOD	EPOCH	AGE	Ma	WEST	SIDE	EAST SIDE
	HOLOCENE					
	PLEISTOCENE	4 Late 3 Middle	0.0117 0.126 0.78 1.81	Damortis Formation	Bamban Formation	Guadalupe Formation
	PLIOCENE	2 Late	2.59	Cataguintingan Formation		
GENE		1 Early	5.33	Amlang Formation	Tarlac Formation	Tartaro Formation
NEOG		3 Late	7.25	Malinta F	ormation	Lambak Makapilapil
			11.61			Formation Formation
	MIOCENE	2 Middle-	13.65	Moriones I	Formation	Madlum Formation
			15.97			Madum Formation
		1 Early	20.43	~~~~		Angat Formation
			23.03			
	OLIGOCENE	2 Late	28.4	Aksitero I	Formation	
		1 Early	33.9			Bayabas Formation
IN IN		4 Late	37.2			
190	EOCENE	Middle -	40.4			
ALE		2	48.6			
Ľ.		1 Early	55.8			
	PALEOCENE	2 Middle	58.7			
		1 Early	61.7 65.5			
EOUS	Upper	Late				Barenas - Baito Formation
CRETAC	Lower	Early	99.0			
JURASSIC	Upper	3 Late	145.5			
101010	Middle	2 Middle	161.2			
	Lower	1 Early	175.6			

 Table 2.3 Stratigraphic column for Central Luzon Basin

 CENTRAL LUZON BASIN

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Moriones Formation

Lithology	Interbedded sandstone, shale,
	conglomerate with minor limestone;
	identified members are Sansotero
	Limestone and Malo Pungatan Limestone
Stratigraphic relations	Unconformable over the Aksitero
	Formation; overlain conformably by the
	Malinta Formation
Distribution	Aksitero River, Mayantoc, Tarlac
Age	Early Miocene - early Late Miocene
Thickness	over 1,500 m
Named by	Corby and others (1951)

The Moriones Formation was originally named by Corby and others (1951) for the yellowish brown sandstone, sandy shale and conglomerate unconformably overlying the Aksitero Formation, with type section along the Aksitero River. It is made up of an interbedded sequence of sandstone. shale, conglomerate and minor limestone. The sandstone beds range in thickness from a few centimeters to more than a meter. The sandstone is dark grav when fresh and light grav to different shades of brown with oxide stains on weathered surfaces. It is fine to coarse-grained, fairly sorted. slightly tuffaceous, calcareous, well-cemented and consists of angular to subrounded fragments of guartz, feldspar and mafic crystals held together by fine calcareous clavey material. The shale is thinly laminated to medium bedded, dark gray to brown, soft and friable, calcareous, fossiliferous, with occasional carbonaceous layers. The conglomerate at the upper part of the section is poorly bedded to massive, gray to brown, well consolidated with subrounded pebbles, cobbles and small boulders of igneous and metamorphic rocks cemented by a coarse-grained calcareous matrix. The limestone in the upper part is medium bedded, buff to flesh, fine to coarse calcarenite with coral debris and molluscan remains. Foraminiferal assemblages containing Catapsydrax stainforths Balli, Globorotalia fohsi barisanensis Leroy and Globorotalia fohsi fohsi Cushman and Ellisor indicate an age of Early to Middle Miocene. Nannoplankton studies by De Leon and Militante-Matias (1992) reveal an age of Early Miocene (NN4) for the base and early Late Miocene (NN11) for the top of the formation. Corby and others (1951) estimate the thickness to be about 1,500 m, but subsurface data indicate a thicker pile. The section along Aksitero River was estimated to be about 1,000 m thick. The formation was deposited under predominantly bathyal conditions, but shallower depths are indicated for the upper part (Tamesis and others, 1981).

Limestone lenses towards the top of the formation have been noted, and these have been regarded as members of the Moriones Formation (De Leon and Militante-Matias, 1992). The Sansotero Limestone was named by Roque and others (1972) for the irregularly shaped exposures and disconnected patches in Sansotero, Bigbiga in Mayantoc, Tarlac. This was considered a separate younger formation in BMG (1981) but it is included here as a member of the Moriones Formation. The limestone is massive, dirty white to greenish gray, porous with volcanic and sedimentary clasts. Corals, algae, molluscan shells, and benthonic foraminifera of the genera Rotalia, Marginopora and Elphidium are found in the limestone. The limestone at the type locality is 8 m thick. The other limestone member of the Moriones Formation is called Malo Pungatan Limestone (Gwinn and others, 1959). At the area indicated as the type locality, near Caananorgan, the unit consists of calcarenites and porous coralline limestone. Other exposures may be found at Pingul area and further north, to the west of Camiling. The thickness of Malo Pungatan ranges from 3 to 4 m.

Malinta Formation

Lithology Lower Pau Sandstone – sandstone with minor tuffaceous shale, conglomerate and lapilli tuff Upper Aparri Gorge Sandstonesandstone with shale stringers and conglomerate lenses

Stratigraphic relations	Conformable over the Moriones Formation
Distribution	Barrio Malinta, Tarlac and O'Donnell
	River, Tarlac
Age	Late Miocene
Thickness	574 m
Named by	Corby and others (1951)

Overlying the Moriones conformably is the Malinta Formation, which was named by Corby and others (1951) for the sandstone-dominated section exposed in the vicinity of Barrio Malinta, Tarlac. It forms a prominent ridge east of the Moriones outcrop belt from O'Donnell River in the south to about 3.5 km southwest of Sta. Ignacia. Corby and others (1951) recognized two facies, the lower Pau Sandstone and the upper Aparri Gorge Sandstone. The **Pau Sandstone** member consists of sandy shale grading southward to coarse guartz sandstone to tuffaceous pebbly sandstone overlain by a thick sandstone section with minor amounts of coarse sandy tuffaceous shale and conglomerate. The Aparri Gorge member is a well-cemented quartz sandstone with occasional shale stringers and conglomerate lenses. Rogue and others (1972) defined the Malinta as an interbedded sequence of sandstone, shale, conglomerate, and lapilli tuff. The sandstone, which is predominant in the lower and upper parts of the section, is light to gray brown, thin to thick bedded, graded, fine- to medium-grained, fairly well-sorted, well-cemented, tuffaceous and slightly calcareous. The shale is thin to medium bedded, light greenish gray when wet, sandy, tuffaceous and calcareous. The conglomerate at the lower and upper parts of the section is dark gray, massive in places, with rounded to subrounded pebbles, cobbles and occasional boulders of igneous rocks held together by fine- to medium-grained tuffaceous sandstone. The lapilli tuff occurs as dirty white to gray, thin to thick beds. The presence of Globorotalia fohsi labata Bermudez indicates a Late Miocene age for the Malinta Formation. The formation was probably deposited in the inner neritic zone. Studies by BEICIP (1976) indicate tidal conditions for the deposition of the conglomerates, as well as the mudstones and sandstones containing fragments of corals and mollusks. The measured thickness is 574m.

Tarlac Formation

Lithology	Interbedded sandstone, shale,
Stratigraphic relations	Conformable over the Malinta Formation; unconformably overlain by the Bamban
Distribution	Formation vicinity of Tarlac town, Tarlac; O'Donnell
	River; Camiling, Tarlac
Age	Late Miocene - Early Pliocene
Thickness	1,200 m
Named by	Corby and others (1951)

The formation was originally named by Corby and others (1951) for the interbedded shale, sandstone and conglomerate in the vicinity of Tarlac town (now Tarlac City). It is a widespread formation forming a Y-shaped outcrop pattern from O'Donnell River in the south to the town of Camiling in

the north. It rests conformably over the Malinta Formation and is unconformably overlain by the Bamban Formation. The shale is sandy and fossiliferous. The sandstone exhibits spheroidal weathering and has less fossils. The conglomerate is massive to thin bedded with sub-angular to subrounded to flat pebbles, cobbles and boulders of igneous rocks, sandstone and limestone in a coarse, tuffaceous sandstone matrix. The thickness along the Tarlac-Burgos road is 1200 m. Paleontological dating indicates its age to be Late Miocene to Early Pliocene.

Amlang Formation

Lithology	Turbiditic sandstone and shale with minor
	conglomerate
Stratigraphic relations	Transitional to underlying Klondyke
	Formation; conformable over the Labayug
	Limestone; unconformably overlain by the
	Cataguintingan Formation
Distribution	Pangasinan and La Union, including the
	coastal strip from the mouth of Agno River
	to Bacnotan, La Union
Age	Late Miocene – Early Pliocene
Thickness	over 1,620 m along the Rosario-Damortis
	Road
Previous name	Amlang Member of Rosario Formation
	(Corby and others, 1951)
Renamed by	Lorentz (1984)

The Amlang Formation is a thick sequence of clastic rocks consisting mainly of turbiditic sandstones and shales with minor conglomerates. This formation underlies most of the low-lying area in Pangasinan and La Union adjacent to the main Central Cordillera massif, including the coastal strip from the mouth of the Agno River to Bacnotan in La Union. The contact between the Amlang Formation with the underlying Klondyke Formation is gradational, as observed at Km. 216 of the national highway leading to Kennon Road, just off the La Union-Benguet provincial boundary. Its contact with the underlying Labayug Limestone is also gradational.

Until recently, the Amlang Formation together with the Cataguintingan Formation, constituted the **Rosario Formation** of Corby and others (1951). The Rosario Formation was previously subdivided into a lower Amlang Member and an upper Aringay Member. Lorentz (1984) proposes to elevate the constituent members of the Rosario Formation into two distinct formations, namely a lower Amlang Formation and upper Cataguintingan Formation with an unconformity dividing them. Because of the angular unconformity between the lower Amlang Formation and the Cataguintingan Formation, as well as differences in their environment of deposition, the latter name has been adopted for the unit, which was previously known as the upper member of the Rosario Formation.

The lower part of the Amlang Formation consists of thinly bedded gray shales interbedded with buff to brown fine- to medium-grained sandstones. In places, the sandstone beds in the Amlang Formation are more predominant, which Lorentz (1984) designates as the *Cupang Sandstone*

Member. The upper portion of the Amlang Formation has a higher proportion of coarser sediments (sandstones and siltstones with minor pebble conglomerates). Maleterre (1989) also includes a basalt flow as part of the top of the Rosario Formation.

Some sandstone beds in both lower and upper parts of the Amlang Formation exhibit graded bedding and parallel lamination typical of turbidite sequences, as well as sole marks (load casts, tool marks, scour marks) and ripple cross-lamination.

Lorentz (1984) estimates the Amlang Formation to be at least 1,620 m thick as measured along the Rosario-Damortis Road.

Fossils indicate an age of Late Miocene to Pliocene for the Rosario Formation (Tumanda, 1984). Lorentz (1984) gives an age of Late Miocene for the Amlang Formation. Maleterre (1989) gives an age dating of Late Miocene to Early Pliocene for the Amlang Formation, which is the age bracket adopted here. Sedimentological and faunal studies indicate a deep water environment of deposition for the Amlang Formation (Lorentz, 1984; Tumanda, 1984).

Cataguintingan Formation

Lithology	Mainly tuffaceous sandstone, with interbeds of siltstone, shale and conglomerate and minor limestone lenses.
Stratigraphic relations	Unconformable over the Amlang
Distribution	Pangasinan and La Union
Age	Late Pliocene
Thickness	1,100 m at the type locality, and 900 m in
Previous name	Linao Sandstone member (Corby and others, 1951) and Aringay member
Renamed by	(Bandy, 1963) Lorentz (1984)

The Cataguintingan Formation consists mainly of tuffaceous sandstones interbedded with siltstones, shales and conglomerates including minor limestone lenses. It was previously designated by Corby and others (1951) as the upper Linao Sandstone member, and by Bandy (1963) and geologists of the San Jose Oil Company as Aringay Member, of the Rosario Formation. Lorentz (1984) raised this unit to formation rank and renamed it Cataguintingan Formation, after Brgy. Cataguintingan where the exposures are more continuous and the stratigraphic relation with the Amlang Formation is more defined. It rests unconformably over the Amlang Formation. The Cataguintingan has yielded abundant molluscan shell fragments as well as echinoid spines, ostracods and red algae. The upper portion of this formation has proportionately less conglomerate beds than the lower portions. The upper beds are also more tuffaceous and sometimes exhibit high proportions of magnetite. Lorentz (1984) gives a thickness of 1,100 m as measured at the type locality and attains a maximum of 2,600 m farther north, but is only 900 m to the south. It was dated Pliocene by Lorentz (1984) but Maleterre (1989) gives an age dating of Late Pliocene for this formation, which is adopted here.

Damortis Formation

sandstone, calcarenite, siltstone,
limestone and marl
Unconformable over the Cataguintingan
Formation
Damortis beach, Pangasinan
Pleistocene
50-200 m
Corby and others (1951)

Along Damortis beach near the PNR railway station is a small exposure of the Damortis Formation consisting of westward dipping sandstones, calcarenites, siltstones and marl. It rests unconformably over the Cataguintingan Formation near the type locality. This gently dipping sequence of clastic rocks commonly contains molluscan fossils. In places the sandstones are dark-colored due to the presence of heavy minerals. To the north, resting on the Amlang Formation at Bacnotan is the 20-m thick **Bacnotan Limestone**, regarded by Maleterre (1989) as a facies of the Damortis Formation. Tamesis and others (1981) estimate the thickness of the formation to range from 50m to 200m on the basis of seismic data. Javelosa (1994) reports a ¹⁴C dating of 28,250 ± 345 years BP at the top of a sandstone horizon in raised tidal flats along the Damortis coast. The formation is considered Pleistocene in age.

Bamban Formation

Tuffaceous sandstone and lapilli tuff with basal conglomerate
Unconformable over the Tarlac Formation
Bamban, Tarlac
Pleistocene
Undetermined
Corby and others (1951)

The name Bamban Formation was used by Corby and others (1951) to designate the tuffaceous clastic and tuff section in Bamban, Tarlac. The best exposure was the almost vertical bluff immediately south-southwest of the highway (now covered by lahar) where it is made up of tuffaceous sandstone and well-bedded lapilli tuff. The basal conglomerate is massive, fairly well-consolidated, and consists of poorly sorted sub-angular to subrounded pebbles, cobbles and small boulders of diorite, andesite and basalt with minor amounts of scoria cemented by tuffaceous sand and volcanic ash. It is locally cross-bedded and grades laterally and vertically to sandstone. The sandstone is bedded, fairly sorted, soft, porous, tuffaceous and consists mainly of angular to subrounded grains of feldspar, quartz and ferromagnesian minerals in a fine silt and volcanic ash cement. Interbedded with the sandstone are thin beds of hard, well-cemented and brittle tuffaceous shale. The tuff is medium to thick bedded, hard, brittle and consists of well-cemented, fine volcanic ash, dust and lapilli. Mafic minerals and small fragments of scoriaceous materials are dispersed in the tuff. It is Pleistocene in age and the environment of deposition might have been sub-aqueous.

CENTRAL LUZON BASIN - EAST (SG 1)

Barenas-Baito Formation

Lithology	Spilitic and basic to intermediate volcanic flows and breccias with intercalated metasedimentary rocks
Stratigraphic relations	Overlain by the Bayabas Formation
Distribution	Norzagaray, Bulacan; Laur-Dingalan,
	Nueva Ecija to Angono and Tanay, Rizal
Age	Late Cretaceous
Named by	De la Rosa and others (1978)

The oldest rocks on the east side of the Central Valley basin belong to the Barenas-Baito Formation. This was named by De la Rosa and others (1978) for the rocks cropping out along Barenas and Baito creeks about 25 km east-northeast of Norzagaray, Bulacan. These rocks are also exposed in the areas around the Laur-Dingalan Fault Zone in Nueva Ecija in the north down to Angono and Tanay, Rizal in the south (Revilla and Malaca, 1987). The formation is made up of spilitic and basic to intermediate volcanic flows and breccias with intercalated metasedimentary rocks. The latter are thin to medium bedded, varicolored indurated sandstones, siltstones, argillites, chert and local lenses of conglomerate. As used by Revilla and Malaca (1987), this unit includes the pillow basalt of the socalled Angat Ophiolite, the volcaniclastic member of the Maybangain Formation in southern Sierra Madre and the Coronel and Dingalan formations of Rutland (1967) in the Laur-Dingalan fault zone. On the other hand, this sequence is considered by (Ringenbach (1992) to be equivalent only to the volcanic carapace and sedimentary cover of the Angat Ophiolite, and is therefore below the Maybangain Formation and equivalent to the Kinabuan Formation. Paleontological dating of radiolarian mudstone samples from the Tayabasan River indicates a Late Turonian or Coniacian age (early Late Cretaceous) for the formation (Blome, 1985). The interpretation of Ringenbach (1992) is adopted here.

Bayabas Formation

Lithology	Andesite flows, pyroclastic rocks, siltstone, sandstones, conglomerates with limestone lenses
Stratigraphic relations	Overlies the Barenas-Baito Formation
Distribution	Western and central part of southern
	Sierra Madre
Ag	Late Eocene - Early Oligocene
Previous name	Bayabas Metavolcanics (De la Rosa and
	others, 1978)
Renamed by	Pelayo (1981)

The Bavabas Formation overlies the Barenas-Baito Formation at Sapa Maon, a tributary of Bayabas River, northeast of Norzagaray, Bulacan. This was designated by De la Rosa and others (1978) as Bayabas Metavolcanics but was renamed Bavabas Formation by Pelavo (1981) to include the metasedimentary rocks. The metavolcanics are andesite flows, and pyroclastics, including andesitic tuff-breccia, while the sedimentary rocks are well-bedded siltstone, shalv sandstone and conglomerate. Small lenses of dark gray marbleized limestone are intercalated with the clastic rocks. Exposures of this formation in the western and central part of the southern Sierra Madre Range follow a north-south trend. The lower part contains Late Eocene to Early Oligocene small foraminiferal species called Cassigerinella eocena Corday (BMG, 1981). Revilla and Malaca (1987) report that clastic samples collected by Blome (1985) as well as Pelayo (1981) in Norzagaray, Bulacan, were also found to contain Late Eocene to Early Oligocene fossils. The limestone that bears Early Miocene fossils reported in BMG (1981) could represent a younger formation (Angat Formation?) and not part of the Bayabas Formation. The Bayabas Formation is therefore considered Late Eocene to Early Oligocene in age and not Late Eocene to Early Miocene. It is partly equivalent to the Maybangain Formation of Haeck (1987).

Angat Formation

Lithology	Lower calcareous shale and sandstone member; Upper limestone member
Stratigraphic relations	Unconformable over the Bayabas Formation; overlies diorite
Distribution	Angat River; western flank of southern Sierra Madre range; Norzagaray; Camachile area in eastern Bulacan
Age	Early Miocene
Thickness	1,950 m
Previous name	Angat Limestone (member of Quezon Formation)
Named by	Corby and others (1951)
Renamed by	Gonzales and others (1971)

Resting unconformably over the Bayabas Formation is the Angat Formation. It also unconformably overlies the diorite in the Camachile area in eastern Bulacan. The formation was originally used by Corby and others (1951) to designate the lower member of their Quezon Formation. It was raised into formation rank by Gonzales and others (1971). Its type locality is along Angat River about 6 km east of Norzagaray. It crops out along the western flank of Sierra Madre, forming an almost continuous north-south belt that splits into two at the Camachile area in eastern Bulacan. The smaller western edge ends at Balite Creek about 4 km northeast of Norzagaray and the eastern strip stretches for about 1.5 km south of Angat River. The formation consists of a lower clastic member representing a minor part of the formation and an upper limestone member.

The clastic member is made up of thin beds of calcareous shale and clayey sandstone with occasional sandy limestone lenses. The sandstone

is usually graded and well-cemented while the limestone lenses are dense, brittle and partly siliceous. Mollusks, coral stems and laminae of carbonaceous materials are dispersed within the section. These, together with the abundance of *Heliocosphaera* species, suggest shallow marine deposition.

The limestone member consists of a lower bedded reef-flank deposit and an upper biohermal mass. This member is characterized by local thickening and thinning over a fairly continuous belt. The lower part is made up of calcareous rock detrita and fine slime with interbeds of fine siliceous layers. The biohermal portion is cavernous, white to buff, occasionally gray to pink, partly crystalline, and essentially consists of skeletal remains of reef-building organisms (corals and algae) with abundant molluscan fragments and bryozoan stems. The thickness of the formation varies from one locality to another, but the maximum exposed thickness is 1,950 m. Along Madlum River, the biohermal portion is approximately 100 m thick.

The clastic facies contains *Globigerinoides sicanus De Stefani* as well as nannofossils including *Heterosphaera mediterranea* and *Sphenolithus cf. heteromorphous*, which indicate an age of NN4-NN5, probably NN4, equivalent to Early Miocene (Villanueva and others, 1995). Recent studies by Villanueva and others (1995) indicate an Early Miocene age for the limestone based on the presence of *Cycloclypeus (K.) transiens*. Abundant large foraminifera, corals, algae and molluscan remains in the limestone and carbonaceous materials in the clastic facies indicate deposition in a shallow neritic environment.

Madlum Formation

Lithology	lower Clastic Member – sandstone; silty shale; middle Alagao Volcanics –
	andesite flow, pyroclastic breccia,
	tuffs, graywacke, argillite;
	upper Buenacop Limestone
Stratigraphic relations	Conformable over the Angat Formation
Distribution	Area between Angat and Peñaranda
	rivers; San Ildefonso, Bulacan; type
	locality is along Madlum River, Brgy.
	Madlum, San Miguel, Bulacan
Age	Middle Miocene
Thickness:	> 1,000 m
Named by	Williams (1960)
-	

The term Madlum Formation was first used by geologists of the San Jose Oil Company (Williams, 1960 in Gonzales and others, 1971) to designate the sequence of shale, siltstone, wacke and conglomerate exposed along Madlum River close to Brgy. Madlum, San Miguel, Bulacan. They also included in this formation the upper metavolcanic member of the **Sibul Formation** and upper tuffaceous member of the **Quezon Formation** of Corby and others (1951) exposed in the Angat River area. Melendres and Verzosa (1960) subdivided the Madlum into the Angat River Limestone, Alagao Volcanics and Buenacop Limestone members. The

middle and upper members were retained by Gonzales and others (1971) but changed the Angat River Limestone to Clastic Member. The Madlum formation conformably rests on top of the Angat Formation.

Clastic Member

The *Clastic Member* is extensively distributed in an almost continuously exposed belt between Angat and Peñaranda rivers. It is a thick sequence of thin to thick bedded sandstone and silty shale with minor basal conglomerate and occasional limy sandstone interbeds. The sandstone is fine- to medium-grained, fairly well-sorted, well-cemented and calcareous, with sub-angular to subrounded fragments of mafic rock detrita, quartz and feldspar cemented by fine clayey material. The shale, which occurs in thinner beds compared to the sandstone, is calcareous. The basal conglomerate is massive with well rounded cobbles and pebbles of mafic igneous rocks, chert and limestone dispersed in a coarse calcareous matrix.

Two foraminiferal zones have been recognized in the Clastic member by Villanueva and others (1995): *Globorotalia fohsi peripheroronda* Zone (N6-N10) and *Globorotalia fohsi fohsi* Zone (N10-N11), which were also earlier reported by Gonzales and others (1971).

• Alagao Volcanic

Melendres and Verzosa (1960) used the term Alagao Volcanics to designate the sequence of pyroclastic breccia, tuffs, argillites, indurated graywacke and andesite flows exposed in Alagao, San Ildefonso, Bulacan. Its type locality, as designated by Gonzales and others (1971), is the section along the San Ildefonso-Akle road. The metavolcanic member of the Sibul Formation of Corby and others (1951) and the andesite-basalt sequence in the Rodriguez-Teresa area. Rizal are included in this member. Generally, the rock unit is purplish gray in fresh surfaces but weathers into brick-red to purple shades. The pyroclastic breccia, the prevalent rock type, is massive and made up of angular to subrounded cobble to boulder sizes of andesite, basalt, chert and other volcanic rocks set in a tuffaceous matrix. The tuffaceous beds weather into bentonitic clay. The volcanic flows are massive, fine-grained and vesicular. The vesicles are filled with calcite, chalcedony or chlorite, Along Bayabas River, the estimated thickness is about 175 m, although it could be thicker along Angat River further south.

• Buenacop Limestone

The *Buenacop Limestone* was originally used by Melendres and Verzosa (1960) to designate the limestone sequence exposed at Barangay Buenacop, San Ildefonso, Bulacan with type section along Ganlang River. It also occurs as narrow discontinuous strips formed by a series of almost north-south aligned low ridges and several small patches between Sta. Maria and Sumacbao rivers. The limestone in the lower part is thin to medium bedded, crystalline, slightly tuffaceous, porous with numerous fragments of volcanic rocks, chert nodules, and detrital crystals of mafic minerals. This characteristic distinguishes it from the other limestones in the

area. The upper part is massive, cavernous, with dispersed occasional andesite fragments, volcanic debris and fossils of reef-building organisms such as corals, algae, mollusks and foraminifera. Fossils indicate an age of Middle Miocene for this limestone member, which was probably deposited in a shelf area. The estimated thickness at the type locality is 150 m.

Samples of the Buenacop Limestone yielded a number of foraminifera, including *Miogypsina polymorpha, Cycloclypeus (Metacycloclypeus) transiens, Lepidocyclina (N.) sumatrensis* and *L. (N.) ferreroi.* Thus an age of Middle Miocene is assigned to the Madlum Formation, although deposition could have started in early Middle Miocene. Deposition might have taken place in a progressively deepening environment probably from shelf-edge to upper bathyal depths. It is over 1,000 m thick in the type locality.

Lambak Formation

Tuffaceous shale, sandstone,
conglomerate
Unconformable over the Madlum
Formation
Lambak depression, Sta. Maria, Bulacan;
Norzagaray, Bulacan
Late Miocene
> 1,000 m
Lambak Shales and Sandstones (Alvir,
1929)
MGB (this volume)

Resting unconformably over the Madlum Formation is the Lambak Formation. This was previously designated as Lambak Shale and Sandstones by Alvir (1929) to designate the tuffaceous shale and sandstone sequence in the Lambak depression, which is roughly 7 km long and 2 km wide, extending from Angat River southwards to Santa Maria, Bulacan. As the physical features and lithology resemble that of weathered andesite and basalt, previous workers considered this unit as part of the Alagao Volcanics. Gonzales and others (1971), however, found small foraminiferal species in the formation. The Lambak Formation is best exposed along Minuvan Creek, a northeast-flowing tributary of Santa Maria River that cuts across Barrio Minuyan (Bigti), Norzagaray, Bulacan. The formation is made up of a sequence of massive to poorly bedded, hard, tuffaceous, sandy shale and massive, well-indurated, poorly sorted, medium to coarse arkosic sandstone, which is locally conglomeratic. The coarser components are mainly sub-anglar to subrounded crystals of quartz and feldspars in a clayey, tuffaceous and calcareous matrix. The conglomeratic part includes cobbles and pebbles of volcanic rocks and diorite cemented by coarse tuffaceous material. At the northern end of the outcrop belt, the Lambak probably exceeds 1000 m in thickness. Planktonic foraminiferal fossils Orbulina universa d'Orbigny and indeterminate species of Globigerinoides were found in some samples. The Lambak is dated Late Miocene and deposited under open sea condition.

Makapilapil Formation

Lithology	Tuffaceous sandstone, mudstone
Stratigraphic relations	Unconformable over the Madlum
	Formation
Distribution	Makapilapil Ridge, Papaya, Nueva Ecija
Age	Late Miocene
Thickness	500 – 800 m
Named by	Melendres and Verzosa (1960)

Correlative to the Lambak Formation and also unconformably overlying the Madlum Formation in eastern Nueva Ecija is the Makapilapil Formation. This was first used by Melendres and Verzosa (1960) for the sequence of tuffaceous sandstone and mudstone localized at Makapilapil ridge southeast of Papava. Nueva Ecija with type locality along Kawayan River. a northeast- flowing stream along the west margin of the outcrop area. The sandstone comprising the bulk of the formation is thin to thick bedded, dark gray to brown, medium- to coarse-grained, tuffaceous and locally conglomeratic, hard and with abundant mafic crystals giving a peppery appearance to the rock. The shale interbeds are thinner than the sandstone but are also grav to brown in color. The individual beds are 1 - 6 cm thick and grade laterally and vertically over short distances into sandstone. The basal conglomerate is made up of sub-anglar to subrounded boulders, cobbles and pebbles of volcanic rocks, sandstone and limestone in a coarse, sandy tuffaceous matrix. The interbedded limestone is massive, porous, coarse, sandy or conglomeratic with numerous fragments of basalt, andesite and mafic detrita. What distinguishes this formation from the other clastic units is its dark gray color and tuffaceous character. It is estimated to be about 500 to 800 m thick. but could reach 1,000 m. It is Late Miocene in age.

Tartaro Formation

Lithology	Mudstone, sandstone
Stratigraphic relations	Not reported
Distribution	Barrio Tartaro, San Miguel; Biak-na-Bato;
	Alagao, all in Bulacan
Age	Late Miocene to Early Pliocene
Named by	Melendres and Verzosa (1960)

Along Madlum River in the vicinity of Barrio Tartaro about 2 km west of Barrio Sibul, San Miguel, Bulacan, a sequence of clayey mudstone crops out, designated as Tartaro Formation by Melendres and Verzosa (1960). It is also exposed along the Baliculing and Salapungan rivers in the vicinity of Biak-na-Bato and Alagao, respectively. The Tartaro is a sequence of mudstones and sandstones, which is massive or obscurely bedded, distinctively greenish-gray, soft, poorly consolidated and contains abundant molluscan shells. The mudstone comprises the greater bulk of the section. The sandstone is poorly consolidated, loosely cemented, friable, mediumto coarse-grained and locally conglomeratic. Villanueva and others (1995) assign a probable Late Miocene (Tortonian) to Early Pliocene (Zanclean) age to this formation on the basis of nannofossils (zones NN10-NN15). The formation was probably deposited in a shallow, lagoonal near shore environment.

Guadalupe Formation

Lithology	Alat Conglomerate member – conglomerate, sandstone, mudstone, Diliman Tuff member – tuff, pyroclastic breccia, tuffaceous sandstone
Stratigraphic relations	Unconformable over the Tartaro Formation
Distribution	Quezon City; Pasig, Makati, southern
	Nueva Ecija
Age	Pleistocene
Thickness	1,500 – 2,200 m
Named by	Smith (1913)

This formation was named by Smith (1913) for the tuff sequence that crops out along the Pasig River in Guadalupe, Makati, Metro Manila, which was earlier described by Von Drasche (1878). In the Angat-Novaliches region, Alvir (1929) described the same sequence but referred to it as Guadalupe Tuff Formation. Corby and others (1951) called it Guadalupe Tuffs and Teves and Gonzales (1950) named it Guadalupe Formation with two members: a lower Alat Conglomerate and an upper Diliman Tuff member. The formation unconformably overlies the Tartaro and on the basis of the presence of *Stegodon* fossils and other vertebrate remains, leaf imprints and artifacts, it is assigned a Pleistocene age.

Alat Conglomerate

The **Alat Conglomerate** crops out along Sapang Alat, about 3 km north of the Novaliches Reservoir and forms an extensive outcrop belt underlying the hills and lowlands in eastern Bulacan and southeastern Nueva Ecija. The Alat is a sequence of conglomerates, sandstones and mudstones. The conglomerate, which is the most predominant rock type, is massive, poorly sorted with well-rounded pebbles and small boulders of underlying rocks cemented by coarse-grained, calcareous and sandy matrix. The interbedded sandstone is massive to poorly bedded, tuffaceous, fine- to medium-grained, loosely cemented, friable and exhibits cross bedding. The mudstone is medium to thin bedded, soft, sticky, silty and tuffaceous. Maximum estimated thickness of this member is 200 m.

• Diliman Tuff

The **Diliman Tuff** is well exposed in Diliman, Quezon City and between Santa Maria and Balu rivers in Bulacan. It also covers large portions of Pasig City, Makati City, southern Rizal province and adjoining areas. The whole sequence is flat-lying, medium to thin bedded and consists of finegrained vitric tuffs and welded pyroclastic breccias with minor fine- to medium-grained tuffaceous sandstone. Dark mafic minerals and bits of pumiceous and scoriaceous materials are dispersed in the glassy tuff matrix. The thickness of the Diliman Tuff is 1,300-2,000 m. Fossil plant leaves of the genus *Euphorbliaceae*, deer and elephant teeth, and bits of wood recovered in Guadalupe and Novaliches suggest a Pleistocene age.

CENTRAL CORDILLERA (SG 2)

Pugo Formation

Lithology	Basalt, volcanic breccia, fragmental flow, pyroclastic rocks, sandstone, mudstone, minor chert
Stratigraphic relations	Unconformably overlain by its equivalent in the Baguio District by the Zigzag
	Formation, and in the Bontoc area by the Maliten Formation
Distribution	Mankayan, Benguet; Baguio District;
	Itogon, Benguet
Age	Cretaceous – Eocene
Thickness	over 1,000 m and may reach 1,600 m.
Previous name	Pugo Series (Schafer, 1954)
Renamed by	Peña (1970)
Synonymy	Lepanto Metavolcanics (Lepanto
	Consolidated Company)

The Pugo Formation was previously designated by Schafer (1954) as Pugo Series probably in reference to the exposures within the Pugo claims of Benguet Consolidated, Inc. in the Baguio District. This is a sequence of basaltic and andesitic flows and breccias with minor interbeds of sandstones, argillites and chert, as well as pyroclastic rocks. Pillow lava structures in the volcanic rocks have been noted in some places. This formation underlies a large part of the eastern part of the Baguio District, which is intruded by later igneous rocks, notably the Central Cordillera Diorite Complex as well as by a variety of dikes, including lamprophyres.

In places, the rocks exhibit considerable effects of low-grade metamorphism (greenschist facies) and even mapped separately as **Dalupirip Schist**. This metamorphic effect is localized along narrow shear zones (up to 1.5 km wide) near contacts with quartz diorite bodies as in Ambalanga River and portions of Agno River, especially near barrio Dalupirip in Itogon, Benguet from where it derives its name.

Crispin and Fuchimoto (1980) report a K-Ar age of 82.6 Ma, equivalent to Late Cretaceous, for a sample of the schist. The Pugo Formation is considered to be of Cretaceous-Eocene age.

The total thickness of the Pugo Formation probably exceeds 1,000 m and may even reach 1,600 m (Balce and others, 1980).

The equivalent of the Pugo Formation in the Cervantes-Bontoc area is Lepanto Metavolcanics, so named for the basement rocks in the area by the geologists of Lepanto Consolidated Mining Company. This unit

PERIOD	EPOCH	AGE	Ма	CENTRAL CORDILLERA & BATANES
NEOGENE	HOLOCENE PLEISTOCENE PLIOCENE MIOCENE	4 Late 3 Middle - 2 Late 1 Early 2 Late 1 Early 3 Late 2 Middle-	0.0117 0.126 0.78 1.81 2.59 3.60 5.33 7.25 11.61 13.65 15.97 20.43	Mankayan Dacitic Complex Mirador Limestone Klondyke Formation Kennon Limestone Zinzag Formation
EOGENE	OLIGOCENE	2 Late 1 Early 4 Late 3 Middle -	23.03 28.4 33.9 37.2 40.4	Central Cordillera Diorite Complex Sagada Formation Malitep Formation
s PALI	PALEOCENE	1 Early 3 Late 2 Middle 1 Early	48.6 55.8 58.7 61.7 65.5	Pugo Formation/Lepanto Metavolcanics
CRETACEOU	Upper	Late Early	99.6	
JURASSIC	Upper Middle Lower	3 Late 2 Middle 1 Early	145.5 161.2 175.6 199.6	

Table 2.4 Stratigraphic column for Central Cordillera and Batanes

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

occupies a narrow N-S trending belt on both sides of the Abra River Fault. The volcanic rocks include massive flows and pillow basalts, which are highly fractured and epidotized. They are commonly weakly metamorphosed into greenschists, although they rarely exhibit distinct foliation. Intercalated with these volcanic flow rocks are volcanic breccias and green and red tuffaceous sandstones, siltstones and mudstones with some chert. In places, the volcanic flows are intruded by numerous diabasic dikes (Ringenbach, 1992). Reports of small outcrops of gabbro and gabbro float, in addition to the occurrence of dikes evoking a sheeted dike complex, have led Ringenbach (1992) to consider this unit as part of an ophiolitic basement. This unit may also be correlated with the volcanic flows constituting Maleterre's (1989) Pingkian Ophiolite farther east. Radiometric dates of samples of volcanic rock from Mankayan, Benguet range from 39 Ma to 42 Ma (Sajona, 1999, unpublished report). A limestone clast in the upper member of the Malitep Formation, which unconformably overlies the Lepanto metavolcanics, was dated Late Eocene. The Lepanto is presumably of Cretaceous-Eocene age.

Malitep Formation

Lithology	Lower member - Volcanic flows, breccia, and tuff,
	Upper member - Volcanic conglomerate,
Stratigraphic relations	Unconformably overlies the Lepanto
	Formation in Bontoc area, and
	conformably overlain by the Sagada
	Formation
Distribution	Bontoc area, Mountain Province; Licuan,
	Abra; Solsona area, Ilocos Norte;
	Kabugao area, Kalinga-Apayao
Age	Late Eocene
Thickness	Lower member – 750 m; Upper member –
	1,700 m
Named by	Maleterre (1989)
Synonymy	Formations I and II of Licuan Group
	(MMAJ-JICA, 1980)

The Malitep Formation is a sequence of volcaniclastic strata exposed around Bontoc town, corresponding to the formations (I and II) of **Licuan Group** of MMAJ-JICA (1980) and BMG (1981). This formation rests unconformably over the Lepanto Metavolcanics and is conformably overlain by the Sagada Formation. As described by Maleterre (1989), it is divided into a lower member made up mainly of dacitic flows, tuffs and breccias having a thickness of about 750 m, and an upper member of volcanic conglomerate, sandstones and tuffs, with a total thickness of around 1,700 m along the Malitep and Sabangan rivers. The breccias of the lower member contain clasts of dacite, spilite, schist and limestone.

The *Licuan I formation* exposed along Layacan River west of Besao is composed chiefly of basalt, basaltic andesite and pyroclastic rocks intercalated with 2-m thick limestone. Formation II is made up of andesite lava and andesitic pyroclastic rocks with intercalated limestone lenses, reaching up to 50 m thick along Malibcong River in Abra. It was mapped by MMAJ-JICA (1980) in Licuan area in Abra, Solsona area in Ilocos Norte and Kabugao area in Kalinga-Apayao. The *Licuan II formation*, considered equivalent to the Malitep Formation, also contains limestone lenses up to 50 m thick in the Abra area (MMAJ-JICA, 1980).

A limestone clast from a conglomerate of the Malitep Formation was dated Late Eocene (Maleterre, 1989). This is consistent with the Late Eocene dating by MMAJ-JICA (1980) of a limestone lense in a formation of Licuan Group in Bontoc area. MMAJ-JICA (1980) also reports that a limestone clast in tuff breccia in Abra area was dated Eocene. The age of the formation as a whole is therefore pegged at Late Eocene.

Lithology	Lower member – limestone, biomicrite, biosparite
	Upper member – red and green
	mudstones with minor conglomerate;
Stratigraphic relations	Conformably underlain by the Malitep
	Formation in Bontoc area, and overlain by
	the Balili Formation in the Lepanto mine
	area in Mankayan, Benguet
Distribution	Cervantes-Bontoc Road; Sagada,
	Mountain Province
Age	Late Eocene – Early Oligocene
Thickness	>200 m and may reach 400 m.
Previous name	Sagada Limestone (Maleterre, 1989)
Renamed by	MGB (this volume)
Synonymy	Tineg Formation (MMAJ-JICA, 1977),
	Apaoan Volcaniclastics (Garcia, 1991),
	Columbus Formation (Maleterre, 1989)

Sagada Formation

The Sagada Formation was originally described by Maleterre (1989) as Sagada Limestone for the pre-Miocene limestone in the Cervantes-Bontoc area. He divided it into three members, namely: a lower member with a thickness of 100 - 200 m, consisting of thinly bedded limestone, biomicrites and biosparites; a 100-m thick middle member of well-bedded red and green mudstones with minor conglomerate; and a 5-m thick upper member made up of volcanic biomicrite. However, Ringenbach (1992) considers the upper member as part of the overlying Balili Formation, so that the Sagada Formation is left with only two members: a lower limestone member and an upper clastic member. The best sections are exposed west of Bontoc, on the Cervantes-Bontoc road, between Sabangan and Bauko. This formation shows a gradational and concordant contact with the Malitep Formation along Sabangan River.

A large part of the Sagada Formation apparently corresponds to the **Tineg Formation** of MMAJ-JICA (1977, 1980) and BMG (1981). This was described as a sequence of pyroclastic rocks with intercalated dacitic flows, sandstones, mudstones and limestone mapped in Abra area (where it was originally recognized), Kalinga-Apayao and Bontoc area. It was estimated to be 300 - 400 m thick in Abra area, but presumably attains a thickness of 1,500 m in Bontoc area. The 200-m thick limestone body in Sagada, which MMAJ-JICA (1980) included as part of its Tineg Formation, is probably the same as the limestone of the Sagada Formation described by Maleterre (1989). The **Apaoan Volcaniclastics** of Garcia (1991) could also be equivalent to the upper member of the Sagada Formation.

Maleterre (1989) reports a dating of Late Eocene to Early Oligocene age for the Sagada Limestone. MMAJ-JICA (1980) dates the limestone at Sagada as Late Oligocene. Garcia (1991) reports an Early Oligocene dating by Maac for radiolaria from red beds of the Apaoan Volcaniclastics obtained from Level 670, Tubo area. Here, the age of the Sagada Formation is regarded as probable Late Eocene to Early Oligocene.

The lower limestone member of the Sagada Formation is correlated with the **Columbus Formation** farther southeast. The type section of the Columbus Formation is along an unnamed tributary of Agno River (Maleterre, 1989) and outcrops are limited on hilltops east of Agno River. The formation consists of thinly laminated biomicrite, which shows volcanic clasts in places. It is about 200 m thick and is dated Oligocene, probably Early Oligocene.

Central Cordillera Diorite Complex

Lithology	Hornblende quartz diorite, tonalite, granodiorite, quartz monzodiorite, pyroxene-bearing diorite, hornblende diorite, monzodiorite, minor gabbro
Ctrationaphia valationa	latrudea Lepente, Duga, and Malitan
Stratigraphic relations	intrudes Lepanto, Pugo, and Malitep
	Formations
Distribution	Mankayan, Benguet; Bontoc area; Baguio
	District
Age	Late Oligocene
Previous name	Agno Batholith (Fernandez and Pulanco
i i o nouo namo	1967)
Renamed by	Yumul and others (1992)
,	

The batholithic intrusions of intermediate composition (diorite, guartz diorite, granodiorite) in incised valleys and mountains constituting the spine of Central Cordillera, was designated as Agno Batholith by Fernandez and Pulanco (1967). Previously, these intrusions were named after specific localities in Baguio District by Schafer (1954) such as Antamok Diorite, Virac Granodiorite, Kelly Diorite and Itogon Quartz Diorite. Because of the dissimilarities in periods of intrusion, Wolfe (1981) proposes to name the Oligocene intrusive bodies (mostly in northern Cordillera) as Cordillera **Batholith** and the younger diorites (mostly occupying the west flank of the Cordillera in the south) as Agno Pluton. However, because of the lack of criteria for distinguishing one from the other in the field (except where they intrude Miocene rocks), these dioritic intrusives were lumped together by Yumul and others (1992) into a single unit, which they named Central Cordillera Diorite Complex. It consists mainly of intermediate rocks such as hornblende quartz diorite, tonalite, granodiorite, quartz monzodiorite, pyroxene-bearing diorite, hornblende diorite, monzodiorite, with minor alkaline gabbro and quartz gabbro. The bulk of the diorite complex consists of hornblende quartz diorite. They are mostly intrusive into the Pugo Formation. Few clasts of dioritic rocks were noted in Zigzag Formation.

Here, the Central Cordillera Diorite Complex is considered an earlier pulse of plutonic intrusion in the region as distinguished from a later phase represented by the Itogon Quartz Diorite (see below). Wolfe (1981) reports an average dating of 27 Ma (Late Oligocene) representing the earlier phase and 12-15 Ma for the later phase. Maleterre (1989) reports values of 29 Ma and 30.6 Ma for samples near Bontoc that correspond to Late Oligocene plutonism postulated by Wolfe (1981). Encarnacion and others (1993) report a zircon U-Pb dating of 26.8 \pm 0.4 Ma for a quartz diorite sample taken east of Baguio City, about 2 km west of the Agno River.

Plutonism could have extended to Early Miocene as indicated by K-Ar dating of 16-20 Ma (Maleterre, 1989).

Zigzag Formation

Lithology	Conglomerate, sandstone, shale, with minor limestone and interbeds of volcanic flows and tuff
Stratigraphic relations	Unconformably overlies the Pugo Formation along Bued River in Camp 4,
	Tuba, Benguet and unconformably
Distribution	Baguio District; Cervantes-Bontoc area
Age	Late Oligocene – Early Miocene
Thickness	1,700 m and may even reach 3,000 m
Previous name	Zigzag Series (Leith, 1938)
Renamed by	Peña (1970)
Synonymy	Bokod Formation (Maleterre, 1989), Balili Formation (Lepanto Consolidated Mining Co.)

This is a sequence of conglomerates, sandstones and shales, in places with limestone lenses and interbeds of volcanic flows and tuffs, unconformably overlying the Pugo Formation. The type locality of this formation, previously designated as Zigzag Series by Leith (1938), is situated along Bued River past Camp 6 where the Kennon Road starts to zigzag upwards towards Baguio City. The exposure of the section along the flanks of the Bued Canvon is characterized by an alternation of maroon and green beds of clastic rocks. Dark gray limestone interbeds at the type locality contain numerous molluscan fossils. Downstream at Camp 6, the sedimentary sequence is intruded by quartz diorite porphyry, producing mineralized skarn and marble. Conglomerates at the type locality as well as at Camp 3 and Acop's Place contain clasts of volcanic rocks identified with those of the Pugo Formation and much fewer clasts of medium grained diorite and guartz diorite. Towards the top of the sedimentary sequence at Camp 3, clasts of amygdaloidal basalt in the conglomerate are notable. The clastic rocks along this section exhibit current ripples, parallel and cross laminations and normal and reverse graded bedding.

Maleterre (1989) also describes exposures corresponding to the Zigzag Formation in the western part of the Bontoc-Cervantes area, which are folded into a north plunging anticline. These consist of volcanic conglomerates, sandstones, red chert with limestone lenses, tuffs and volcanic flows (pillow basalts and keratophyres).

The Camp 3 to Camp 4 section of the Zigzag Formation has an estimated thickness of 1,700 m (Peña and Reyes, 1970). Tamesis and others (1982) estimate the Bued River section to be as thick as 1,800 m, although they assume that it is thicker in other places. Maleterre (1989) estimates a minimum thickness of 3,000 m for the Zigzag Formation in the Bontoc-Cervantes area.

On the basis of dating of samples of the Zigzag Formation in the Baguio area and the Cervantes-Bontoc area, the formation is assigned a Late Oligocene-Early Miocene age.

The **Bokod Formation**, exposed along the Baguio-Cagayan Basin Road, is correlated with the Zigzag Formation. It lies above the Columbus Formation. It outcrops between Bokod Fault to the west and Pingkian to the east. As described by Maleterre (1989), the formation consists of red and green beds of tuffs, volcanic sandstones and andesitic conglomerates whose total thickness could exceed 1,000 m.

Also correlated with the Zigzag Formation is the **Balili Formation**, which is best exposed along Sabangan River near Bauko. It was named by geologists of Lepanto Consolidated Mining Company for the thick sequence of sandstones, volcanic conglomerates, basalt flows, andesitic pyroclastics and breccia forming the Balili Cliffs on the western flank of Mt. Data. It was redefined by Baker (cited in Ringenbach, 1992) to include the volcaniclastic and clastic facies from Bauko to Cervantes up north and to Buguias down south. The contact between the Balili Formation and the Sagada Limestone has not been described but the attitudes of their bedding indicate a concordant relation. East of Mankayan, along Payeo River, the Balili is disconformable over the volcanic substratum.

Various ages have been assigned to the Balili Formation. Gonzales (cited in Garcia, 1991) reports a Late Oligocene dating of foraminifera from the limestone capping the Balili sediments. Sillitoe and Angeles (1985) give a Late Oligocene - Middle Miocene age range for the basal conglomerate. The Balili Formation was dated by Maleterre (1989) as Late Oligocene-Early Miocene on the basis of the dating of intraformational limestone clasts in the conglomerate at the upper section of the formation. Garcia and Bongolan (1990) assign a Middle Miocene age for the formation. Here, the age range Late Oligocene-Early Miocene is adopted for the Balili Formation. Middle Miocene - Late Miocene sedimentary rocks in the area is considered here as part of the Klondyke Formation.

Kennon Limestone

Lithology	Massive biohermal limestone with associated calcarenite and calcirudite and minor mudstone
Stratigraphic relations	Unconformably overlies the Zigzag
	Tuba, Benguet area, and unconformably
	overlain by the Klondyke Formation in the
	Baguio District
Distribution	Baguio District; Itogon and Mankayan,
	Benguet
Age	late Early Miocene – early Middle Miocene
Thickness	240 m at the type locality
Named by	Corby and others (1951)
Synonymy	Butac Limestone (Cervantes-Bontoc area)

The Kennon Limestone unconformably overlies the Zigzag Formation and unconformably rests below the Klondyke Formation at its type locality at Camp 3 along Kennon Road at Km 225-226. The formation also outcrops on Mt. Sto. Tomas and in Trinidad, Benguet. In the type locality, the formation consists principally of massive cream to buff to dark gray biohermal limestone with associated calcarenites and calcirudites. The basal portion consists of wackes, including a conglomeratic calcarenite near the base, which contains clasts of volcanic rocks and small amounts of diorite pebbles and cobbles. Thin lenses of sandstones and siltstones have been observed in the middle section.

Towards the top, the limestone grades into a bioherm-mudstone complex with a thickness of 52 m, which was separately named by Durkee and Pederson (1961) as **Twin Peaks Formation**. The reef mudstone at the base of the Twin Peaks grades upward into a mudstone-graywacke sequence. The Twin Peaks, however, could be considered a member of the Kennon Limestone.

The Kennon Limestone has a total thickness of 240 m at the type locality, including the Twin Peaks member. Balce and others (1980) give a thickness of 240 m for the limestone north of Trinidad.

Paleontological analyses of limestone samples taken from several localities indicate an age of early Middle Miocene (Tan, 1994). Maleterre (1989) reports age determinations of late Early Miocene to early Middle Miocene for the Kennon Limestone.

The **Butac Limestone** in the Cervantes-Bontoc area is considered equivalent to the Kennon Limestone. This limestone is about 100 m thick and was dated Early to Middle Miocene, probably Middle Miocene (Tf1-Tf2).

Itogon Quartz Diorite

Lithology	Hornblende quartz diorite, tonalite, minor
	gabbro
Stratigraphic relations	Intrudes Pugo, Zigzag and Lepanto
	formations
Distribution	Mankayan, Benguet; Bontoc area; Baguio
	District
Age	Middle Miocene
Named by	Schafer (1954)
Synonymy	Kelly Diorite (Schafer, 1954); Bagon
	Intrusive (Sillitoe and Angeles, 1985)

The Itogon Quartz Diorite was one of the diorite bodies named by Schafer (1954) for the plutonic bodies around the Baguio District. The other intrusives named by Schafer (1954) are: Antamok Diorite, Virac Granodiorite and Kelly Diorite, of which Kelly seems equivalent to the Itogon Quartz Diorite. These also comprise the Agno Batholith of Fernandez and Pulanco (1967). The bulk of the quartz diorite bodies consists of hornblende quartz diorite although diorites with smaller amounts of quartz or none at all are known to occur. At Philex Mine at Padcal, Tuba, Benguet, the quartz diorite is fringed by gabbro. The numerous quartz diorite clasts found in the Klondyke Formation are derived from this intrusive body.

As indicated by radiometric dating, there are two main pulses of plutonic intrusions in the region, the earlier phase being the Oligocene Central Cordillera Diorite Complex and the later phase represented by the Middle Miocene (12-15 Ma) Itogon Quartz Diorite (Wolfe, 1981; Maleterre, 1989). Fission track dating of zircons from a sample of quartz diorite near Philex Mine gave 15 Ma, which agrees with the K/Ar dating of 14.8 Ma for the same sample (Lovering, 1983). Sillitoe and Angeles (1985) cite a K/Ar dating of biotite (12 \pm 0.4 Ma) and hornblende (13 \pm 0.8 Ma) from tonalite intruding conglomerates at Mankayan, Benguet, confirming a Middle Miocene emplacement of some of the intrusives. This includes the **Bagon Intrusive** in Lepanto area.

Klondyke Formation

Lithology	Lower member - Polymictic conglomerates Upper member – Sandstone, mudstone, shale with minor conglomerate, limestone, calcarenite and calcirudite
Stratigraphic relations	Unconformably overlies the Kennon
	Limestone in the Baguio District and
	grades at the top into the Amlang
	Formation; overlain concordantly by the
	Mirador Limestone
Distribution	Baguio District; Itogon, Benguet
Age	late Middle Miocene to early Late Miocene
Thickness	2,820 m at the type locality; up to 3,500 for
	the Marcos Highway section
Previous name	Klondyke Series (Leith, 1938)
Renamed by	Balce and others (1980)
Svnonvmv	Suvoc Conglomerate (Gonzales, 1956)
-,,	

The Klondyke Formation, previously designated as Klondyke Series by Leith (1938), is a thick sequence of clastic sedimentary rocks consisting mainly of polymictic conglomerates with interbedded sandstones, siltstones, shales and occasional limestone lenses and in places intercalated with flow breccias and pyroclastic rocks. Clasts of the conglomerate consist of volcanic rocks and quartz diorite as well as sedimentary rocks, including limestone fragments. Some of these clasts attain boulder-size dimensions.

The Klondyke Formation rests unconformably over the Kennon Limestone at Bued River and Kennon Road (Km. 225) near the Klondyke Hot Springs, from where the formation obtained its name. The Kennon Road section traverses the formation downdip up to Km. 216, at the La Union-Benguet provincial boundary, where it grades into the Amlang Formation. It is also well exposed along Marcos Highway and Asin Road and has been mapped at such high elevations as Mt. Santo Tomas in Baguio City. The Klondyke Formation is overlain concordantly by the Mirador Limestone along Marcos Highway near Tuba River, at Irisan along Naguilian Road and along Asin Road.

On the basis of their study of the Marcos Highway section of the Klondyke Formation, De Leon and others (1990) subdivide the formation into a lower member consisting mainly of massive to thickly bedded conglomerate with tuffaceous or calcareous matrix and an upper member consisting of mudstone-shale with sandstones and conglomerates as well as occasional thin beds of calcarenites and calcirudites and lenses of limestone.

On the other hand, Balce and others (1980) subdivide the unit into two intertonguing coeval units, distinguished by the predominance of conglomerate in one (Klondyke Conglomerate) and of pyroclastics in the other (Pico Pyroclastics). The pyroclastics outcrop around Mt. Santo Tomas, in Pico area at Trinidad and other areas around Baguio City.

Estimates of the thickness of the formation vary from a low of 1,798 m (Balce and others, 1980) to a high of 3,500 m for the Marcos Highway section (De Leon and others, 1990).

On the basis of nannofossils obtained from samples along Marcos Highway, De Leon and others (1990) date the formation as Middle Miocene to early Late Miocene.

Polymictic conglomerates in the vicinity of Suyoc are probably correlative with the Klondyke Formation. These conglomerates with interbeds of alternating gray to black siltstones and sandstones were earlier defined as **Suyoc Conglomerate** overlying the volcaniclastics of the Balili Formation (Gonzales, 1956; Maleterre, 1989). The conglomerate contains well-rounded pebbles and cobbles of chert, epidotized volcanic rocks and intraformational limestones. However, Baker (1983) and Ringenbach (1992) regard the relationship between the conglomerate and volcaniclastics as intertonguing, and therefore the conglomerate is considered part of the Balili Formation. Nevertheless, the Suyoc Conglomerate could still be a distinct unit as indicated by its Middle Miocene dating,

Mirador Limestone

Lithology	Porous to massive coralline limestone
Stratigraphic relations	Conformably overlies the Klondyke
	Formation
Distribution	Baguio District
Age	Late Miocene
Thickness	> 120 m
Named by	Leith (1938)
Synonymy	Copias Limestone (Encina and Del
	Rosario, 1978) Labayug Limestone
	(Francisco, 1974)

Mirador Limestone is a cream-colored, porous, coralline limestone named by Leith (1938) for the outcrop at Mirador Hill in Baguio City. It was presumed by Leith (1938) to be of Pliocene age probably because it occupies the hilltops around Baguio City. It has an estimated thickness of over 120 m at Mount Mirador and Dominican Hill (Leith, 1938). This limestone also occupies a ridge to the south of Philex mine and extends up to Ansagan, Tuba, Benguet.

In terms of stratigraphic relations, Mirador Limestone overlies the Klondyke Formation and apparently underlies the Baguio Formation. The conglomerate underlying the limestone along Marcos Highway near the Tuba River Bridge is believed to be part of the Klondyke Formation, although Maleterre (1989) maintains that it is part of the Zigzag Formation.

Balce (1978) reports a dating of Middle to Late Miocene (Tf_2 - Tf_3) fossils in a limestone sample taken from Marcos Highway, near the junction with Santo Tomas Road. The limestone body here is contiguous with the limestone at Mirador Hill. A limestone sample from the ridge west of Upper Bued Creek was also dated probable Miocene-Pliocene by the Paleontological Section of the Bureau of Mines (file report, 1977). A tentative Late Miocene age is given to the Mirador Limestone on the basis of stratigraphic relations and scanty paleontologic dating.

The **Copias Limestone** of Encina and Del Rosario (1978) at Barrio Gambang, Atok is probably equivalent to the Mirador Limestone. This massive, cream to pink limestone body is 150 m thick and reported to be confined within the pyroclastic beds of Klondyke Formation, about 200 m above its base. The limestone, containing Middle Miocene to Late Miocene foraminifera, was reported by Paleontological Section of the Bureau of Mines and Geosciences (file report, 1977) as probably reworked.

The Mirador Limestone is also probably correlative to the **Labayug Limestone** (Francisco, 1974 cited in Lorentz, 1984) whose type locality is at the Northern Cement quarry in barrio Labayug, Sison, Pangasinan. The nature of the contact with the underlying Klondyke Formation is not clear, since it is hidden, while its contact with the overlying Amlang Formation at Sapid Creek is gradational. It has a thickness of 290 m at the type locality but thins out towards the north. It is dated Late Miocene.

Baguio Formation

Lithology	Tuff, andesite, basalt, volcanic breccia,
	conglomerate
Stratigraphic relations	Overlies Mirador Limestone
Distribution	Baguio District
Age	Late Miocene – Early Pliocene
Thickness	> 100 m
Named by	Smith and Eddingfield (1911)
Synonymy	Pico Pyroclastics (Dumapit, 1966), Irisan
	Formation (Maleterre, 1989)

The Baguio Formation was originally defined by Smith and Eddingfield (1911) and modified by Dickerson (in Smith, 1924) but has been virtually

subsequently abandoned. This is equivalent to the Pico Pyroclastics of Dumapit (1966), which was regarded by Balce and others (1980) as a coeval member of the Klondyke Formation. De los Santos (1982) proposes the resurrection of the term for the pyroclastic rocks around Baguio, which apparently rest above the Mirador Limestone. Aside from exposures around Baguio City and Pico, Trinidad, the formation is also exposed on the northeast flank of Mt. Santo Tomas, where it appears to rest on top of the Mirador Limestone as observed along the road going up to Mt. Santo Tomas.

The rocks constituting this formation include tuff (sometimes enclosing blocks of andesite and volcanic breccia), volcanic conglomerate, andesite and volcanic breccia as well as poorly indurated polymictic conglomerate. Mahdi (1992) observes that in Camp 8, the tuff is overlain by basaltic flow breccias and pyroclastic flow deposit with an overall thickness of 25-40 m. At Trinidad, the formation consists of andesitic tuff breccia and poorly indurated conglomerates. The poorly indurated conglomerate is equivalent to the **Irisan Formation** of Maleterre (1989) that outcrops between Naguilian Road and Trinidad Valley and estimated to be about 100 m thick.

Maleterre (1989) reports a 3.57 Ma K/Ar dating (equivalent to Early Pliocene) of a basalt clast from a conglomerate between Zigzag Road and the Loakan airport. This basalt is correlated by Maleterre (1989) with the basalt layer at the top of Rosario Formation. Datings of volcanic clasts from Malaya Formation in Bontoc give values of 6.2 - 3.7 Ma, corresponding to a volcanic phase during Late Miocene to Early Pliocene time. The Baguio Formation could be taken as the equivalent of such volcanic phase, in which case its age of formation would fall between Late Miocene and Early Pliocene time.

Black Mountain Quartz Diorite

Lithology	Quartz diorite porphyry
Stratigraphic relations	Intrudes Pugo Formation and Zigzag
	Formation in the Baguio area
Distribution	Black Mountain, Camp 6, Kennon Road
Age	Late Miocene - Pliocene
Named by	Balce and others (1980)
Renamed by	MGB (2004)

The unit was previously named Black Mountain Porphyry Complex by Balce and others (1980) for the porphyritic quartz diorite stocks and small bodies intruding Pugo Formation and Zigzag Formation in the Baguio area. The type locality is at the former copper mine of Black Mountain Inc. at Camp 6 through which the Kennon Road passes. The quartz diorite consists mainly of plagioclase, hornblende and quartz some occurring as phenocrysts ranging from 0.5 mm to 12 mm set in a fine-grained groundmass of the same minerals. These quartz diorite bodies are associated with porphyry-type copper deposits in Black Mountain mine in Camp 6 below Bued River, Philex Mine, Sto. Nino Mine as well as in Lepanto Mine (Far Southeast Deposit) and other places. A Late Miocene to Early Pliocene age (3.8 - 5.9 Ma) for the quartz diorite porphyry in Baguio area is indicated by K/Ar and fission track dating. (Wolfe, 1981; Teledyne Isotopes, 1988). The Guinaoang quartz diorite stock and other quartz diorite bodies in Lepanto mine area are associated with dacites. K/Ar dating indicates a range of 2.5 Ma to 3.5 Ma (equivalent to Pliocene) for the Lepanto quartz diorites, which is later than those for the Baguio area (Arribas and others, 1994; Sillitoe and Angeles, 1985).

Balacbac Andesite

Lithology	Andesites, lamprophyres, appinites
Stratigraphic relations	Intrudes Pugo and Zigzag formations
Distribution	Baguio District
Age	Late Miocene - Pliocene
Previous name	Emerald Creek Complex (Schafer, 1954)
Renamed by	Balce and others (1980)

Late Tertiary andesites occurring as dikes and small intrusive bodies in the Baguio District was previously named collectively as Emerald Creek Complex by Schafer (1954). The Balacbac Andesite was designated by Balce and others (1980) for the hornblende andesite at Balacbac, at the Western Minolco Mine area. This is probably contemporaneous with the deposition of the pyroclastics and associated volcanics of the Baguio Formation. They are generally unmappable, although they may be so numerous in some areas, such that they are mapped as dike complexes. Thus, the Emerald Creek Complex of Schafer (1954) and Camp 4 Complex (Malicdem, 1971) indicate areas in which these late Neogene intrusive bodies occur as dike swarms. These rocks include lamprophyres and appinites and other porphyritic rocks, which exhibit prominent pyroxene and hornblende phenocrysts as well as ordinary andesite porphyry with varying sizes and amounts of plagioclase phenocrysts.

Dating of two samples of andesite by K/Ar was reported by Maleterre (1989) to be 5.1 Ma and 3.5 Ma. Radiometric dating of volcanic clasts from the Malaya Formation ranges from 6.2 Ma to 3.7 Ma, while that of a volcanic clast from Baguio Formation gave 3.57 Ma. These suggest volcanic activity during Late Miocene – Early Pliocene time, probably contemporaneous with the deposition of Baguio Formation.

A later phase of andesite emplacement is suggested by Plio-Pleistocene dates for some samples. Dating of samples of andesite porphyry by radiometric (K/Ar) and fission track methods reported by Lovering (1983) indicates an age of 1.9 Ma and 1.8 Ma, respectively, equivalent to latest Pliocene.

Mankayan Dacitic Complex

Lithology	Dacite, breccias, pyroclastic rocks
Stratigraphic relations	Intrudes older rocks
Distribution	Lepanto mine, Mankayan, Benguet;
	Baguio District
Age	Late Pliocene – Pleistocene
Previous name	Imbaguila / Bato Dacite Porphyry
Named by	Lepanto Consolidated Mining Company
Renamed by	MGB (this volume)

Synonymy Balatoc Dacite Plug; Sto. Niño breccia pipe

Dacitic rock units are represented by dacite porphyries in the Lepanto mine, Mankayan, Benguet and the Balatoc Dacite Plug in the Baguio District. Dacite domes, diatreme breccias and pyroclastics in the Lepanto area preceded and post-dated epithermal mineralization. These are known locally as **Imbaguila Dacite Porphyry**, and **Bato Dacite Porphyry** and their pyroclastic equivalents. The Imbaguila predates mineralization while the Bato postdates the mineralization.

The plug at the Balatoc Mine is roughly a vertical pipe measuring 980 m by 730 m in plan and tapers downward to a maximum known depth of 2,000 m (Mitchell and Leach, 1991). The pipe contains blocks of various rock types that include quartz diorite, andesite, metasediments, dacite and granodiorite. The matrix is made up of dacitic and andesitic material as well as an admixture of quartz, plagioclase and clayey material. Gold-bearing veins traverse the breccia. Later andesite dikes also cut across the breccia.

A similar type of breccia pipe is present in the Sto. Niño Mine. According to Balce (1978), it is 1,200 m by 500 m in plan and the bulk of the pipe is dacitic in composition.

Wolfe (1981) gives a K/Ar date of 1.7 Ma for a sample of dacite. Maleterre (1989) reports K/Ar dating of 1.5 Ma and 1.9 Ma for samples of dacite. MMAJ-JICA (1983) gives a dating of 0.8 Ma for the Balatoc Plug. These datings are equivalent to Pleistocene. In Lepanto, K/Ar dating of biotite from the earlier dacite gave a value of 2.9 ± 0.4 Ma (Sillitoe and Angeles, 1985). On the other hand, K/Ar datings reported by Arribas and others (1994) for the later dacites (0.96 \pm 0.29 Ma; 1.18 \pm 0.08 Ma) are close to the dating for the Balatoc Plug (0.8 Ma).

Malaya Formation

Lithology	Sandstone, conglomerate, with minor
	dacitic tuff, ignimbrite
Stratigraphic relations	Not reported
Distribution	Cervantes Basin, Benguet
Age	Pleistocene
Thickness	1,200 m
Named by	Maleterre (1989)

The Malaya Formation was defined by Maleterre (1989) and Ringenbach (1992) for the thick clastic and volcaniclastic sequence that constitutes the infill of the Cervantes Basin with type locality along Malaya River, west of Cervantes. The bulk of the basin fill consists mainly of lightcolored, poorly indurated sandstones and conglomerates associated with minor dacitic tuff and ignimbrites. Most of the clasts are andesites, and clasts represented by the substratum (metavolcanics, diorites) are rare. An upper member confined around the Malaya River area is made up of 200 m of poorly indurated red sandstone, claystone and polymictic conglomerates. The clasts in the conglomerates include andesites, metavolcanics and diorites. Slope breccias along the Abra River fault south of Malaya intertongue with the clastic and volcaniclastic rocks. The total thickness for this formation was estimated by Maleterre (1989) at 1,200 m.

This formation could be coeval with the Mankayan Dacitic Complex in Mankayan, Benguet, especially the upper member (Bato dacitic pyroclastics), since the Malaya Formation is intercalated with dacitic tuff and ignimbrites.

A Late Miocene to Pliocene age was earlier assigned to the Malaya Formation (Maleterre, 1989). Later studies, however, indicate that the age is younger than was supposed, since field data point to a post-mineralization deposition. Previously, mineralization was thought to have occurred at around 2.9 Ma (Sillitoe and Angeles, 1985). More recent data indicate that mineralization took place between 1.45 and 1.2 Ma (Arribas and others, 1994). Laser probe dating (40 Ar/ 39 Ar) of hornblende from an ignimbrite bed in the Malaya Formation gives a best age estimate of 0.9 ± 0.2 Ma. Therefore, a Pleistocene age is adopted for the Malaya Formation.

Pleistocene – Recent Volcanic Centers

Lithology	Dacite, andesite, pyroclastic rocks, lahar,
Stratigraphic relations	Overlies or intrudes older rocks
Distribution	Kalinga; Apayao; Benguet; Bontoc
Age	Late Pleistocene - Recent
Correlation	Lapangan Tuff (Baker, 1983), Volcanic
	centers in Kalinga, Apayao, Benguet,
	Babuyan Islands, Mt. Cagua in Cagayan

Late Pleistocene to Recent volcanism related to the subduction of the South China Sea plate along the Manila Trench is represented along the length of the Central Cordillera by numerous volcanic centers. These include the cluster of volcanoes in Kalinga-Apayao, Bontoc and Benguet such as Ambalatungan, Binuluan, Bumakan and Podakan volcanoes, Mt. Pusdo, Mt. Tabeyo and Mt. Data.

A K/Ar dating of 0.5 Ma was obtained from a sample taken from Mt. Pusdo volcanic plug near Lepanto (Ringenbach and others, 1990). Almost the same result (≤ 0.5 Ma) was obtained from pristine hornblende in an andesite clast of laharic breccia from the western slopes of Mt. Data (Sillitoe and Angeles, 1985). A younger value was given for the **Lapangan Tuff**, a thin veneer of ash fall in Lapangan, near the mine area of Lepanto Consolidated Mining Co. Humic soil beneath the tuff sampled in Buguias gave a ¹⁴C dating of 18,820 ± 670 years BP (BED-JICA, 1981). A more recent volcanic activity is indicated by ¹⁴C dating of charred wood in dacitic pyroclastics on the road near the summit of Mt. Tabeyo, the second highest summit in the Central Cordillera (2,819 m masl), which gave a value of 7,790 ± 55 BP (Ringenbach, 1992). These datings indicate that volcanic activity has persisted in the Central Cordillera from Late Pleistocene to Recent times.

BATANES GROUP OF ISLANDS – BABUYAN SUB-PROVINCE (SG 2)

The Babuyan Subprovince is composed mainly of the submarine Lubao-Babuyan Ridge between Luzon and Taiwan. The ridge forms islands, the northernmost of which is Lubao in Taiwan and the southernmost, the Babuyan Islands Group. The ridge is about 185 km wide just north of Luzon and tapers northward. It is cut by several channels and troughs.

The Babuyan Islands Group is composed of five islands with Calayan being the largest. The Batanes Islands Group, in contrast, constitutes the northernmost part of the Philippine archipelago. It is composed of 10 islands with Itbayat, having 95 sq. km land area, being the largest.

Most of the islands are underlain by basalt and andesite flows surrounded by reef limestone fringing the shoreline. Limestone terraces are noticeable features suggesting intermittent emergence.

This subprovince is termed as the Babuyan Segment by Defant and others (1990) and as the Bashi Segment by Yang and others (1996). It is described by Yang and others (1996) as having a double arc structure consisting of a western volcanic chain (WVC) and a younger eastern volcanic chain (EVC) based on their geographic distribution, eruption ages. geomorphology, and the geochemical signatures of the magmas. These volcanic chains are about 50 km apart just north of Luzon (18°N) and merge into a single volcanic chain near Batan Island (20°N). The EVC consists of Batan (Mt. Iraya), Babuyan, Didicas, Camiguin, Mt. Cagua, Y'Ami, North, Mabudis, Siayan, Diogo, Balintang, Hsiaolanyu, and Lutao. The first five islands mentioned are still active. On the other hand, the WVC is composed of Batan (Mt. Matarem), Itbayat, Sabtang, Lanyu, Ibohos, Dequey, Panuitan, Calavan and Dalupiri. No active volcanism has been reported in this chain. Whole rock K-Ar age determination done on several fresh samples proved that the volcanic activity in WVC ceased at 4 - 2 Ma whereas the activity in EVC is almost exclusively Pleistocene. The WVC was initially the active volcanic front of the arc. Volcanic activity stopped for an interval of 4 - 2 Ma then resumed further east forming the EVC.

Volcanic rocks from the Babuyan Island Group that yield ages of around 1 Ma or less consist mostly of basaltic andesites with minor basalts and andesites (McDermott and others, 1993).

Batan Island

The oldest rocks are Late Miocene (9 - 7 Ma) andesitic flows that are exposed at the central isthmus of the island. These flows are hornblendeand orthopyroxene-bearing andesites and are usually weathered. They outcrop sporadically beneath the reefal limestones and the young ash deposits originating from Mt. Iraya, located at the northern part of the island.

The Pliocene Matarem composite volcano, ranging in age from 5.8 to 1.7 Ma, defines the southern part of Batan. The central part of this volcano

GEOLOGY OF THE PHILIPPINES

is made up of a number of andesitic necks and plugs, andesitic flows, and younger basaltic flows with minor associated pyroclastics, while its periphery is predominantly composed of reworked layer deposits (lahar deposits and tuffaceous beds) with some interbedded ash and pumice layers. Mt. Matarem lavas are highly porphyritic and range from basalts to hornblende-orthopyroxene acid andesites.

The Quaternary Mt. Iraya lavas show a wide compositional range from basalts to andesites. Basalts contain rounded or broken xenocrysts possibly originating from the mechanical disintegration of peridotitic xenoliths. Ultramafic xenoliths (deformed harzburgites, dunites, and lherzolites) within hornblende-bearing andesites are commonly mantled by centimetric hornblende rims. Mantellic peridotites and pyroxenites occur as rounded inclusions, about 5 - 20 cm wide, within Mt. Iraya basaltic and andesitic flows and *nuee ardente* deposits. Batan lavas older than 2 Ma are calc-alkaline; while the youngest belong to high-K calc-alkaline series.

A pyroclastic deposit that overlies the reefal limestone and some *nuee ardente* deposits at the western foot of Mt. Iraya and in Basco has been dated 1,480 yr B.P. (Richard and others, 1986). This pyroclastic unit includes a sequence of ash fall and pumice fall deposits about 30 m thick with minor intercalated ash flow layers.

Sabtang Island

Preliminary sampling done by Defant and others (1990) indicates calcalkaline basalts and basaltic andesites ranging in age from 3.8 to 2.9 Ma, and possibly equivalent to the Mt. Matarem products on Batan.

Babuyan de Claro Island

The five volcanic centers of the island, namely Cayonan, Naydi, Dionisio, Mt. Pangasun, and Mt. Babuyan, consist mainly of a succession of calc-alkaline andesitic and basaltic andesitic lava flows. The Babuyan Claro stratovolcano, which stands 837 masl, has reportedly erupted in 1831 and 1917 (PHIVOLCS, 1997).

Camiguin Island

The northern part of the island is made up of a Mio-Pliocene (3-7 Ma) calc-alkaline andesite shield volcano with effusive vents. Volcanic centers, namely, Mt. Camiguin, Mt. Malabsing, Pamoctan, and Didicas Volcano, located at the south of the island are younger. Mt. Camiguin (Camiguin de Babuyanes) is a stratovolcano with a height of 712 masl, which had reportedly erupted in 1857 (PHIVOLCS, 1997). Alternating andesitic lava and pyroclastic flows are observed in Mt. Camiguin.

Calayan Island

Calayan is located approximately 30 km west of the main volcanic axis of the Luzon arc (Batan – Babuyan – Camiguin - Mt. Cagua). It is significantly older than the other islands (approximately 7 - 4 Ma) except for Batan's oldest units. The four effusive volcanic centers of the island, Mt.

Nongabaywaman, Mt. Macara, Mt. Calayan, and Mt. Piddan, are overlain by Plio-Quaternary reef limestones near the shore. The Calayan lavas range in composition from the oldest unit (ca. 6-7 Ma) of basaltic andesite flows to 5-6 Ma andesitic lava flows to the youngest volcanic formation of (ca. 4 Ma) rhyolitic lava flow (in Defant and others, 1989).

Mt. Cagua Volcano

This active volcano is considered part of the Babuyan segment, though located in the northernmost part of Luzon, because it falls within the N-S trend of the Northern Luzon extinct volcanic centers. The Pleistocene Mt. Cagua volcanic flows, composed mainly of andesite, impinge upon Miocene sedimentary rocks southeast of Gonzaga, Cagayan. Historical records reveal solfataric activity at Mt. Cagua in 1860 and 1907 (PHIVOLCS, 1997).

CAGAYAN VALLEY (SG 3)

Abuan Formation

Lithology	Basalt, andesite, pyroclastic rocks,
	sandstone, shale
Stratigraphic relations	Constitutes the basement of Cagayan
	Valley basin
Distribution	Western part of northern Sierra Madre;
	southwest of Divilacan River; Maconacon
	River
Age	Eocene
Previous name	Abuan River Formation (MMAJ-JICA,
	1989)
Renamed by	MGB (this volume)
Synonymy	Dumatata Formation (Huth, 1962),
	Caraballo Group (MMAJ-JICA, 1977)
Correlation	Mt. Cresta Formation (MMAJ-JICA, 1989)

The Abuan Formation, which was named as Abuan River Formation by MMAJ-JICA (1989), is the oldest formation in the western part of the Northern Sierra Madre and presumably comprises part of the basement of the Cagayan Valley sedimentary sequence. It is a heterogeneous mixture of basaltic to andesitic flows, pyroclastics and sedimentary rocks widely distributed in the southwest part of Divilacan River and northern and western part of Maconacon River. The age of deposition of the Abuan formation is inferred to be before Early Oligocene, probably Eocene. The thickness of this formation was not indicated by MMAJ-JICA (1989).

The Abuan is probably partly equivalent to the *Caraballo Group*, which was named by MMAJ-JICA (1977) for the volcanic and sedimentary rocks comprising the basement of northern Sierra Madre. This was later renamed by Ringenbach (1992) as Caraballo Formation. Its age was previously presumed by MMAJ-JICA (1977) to be Cretaceous-Eocene, but it was later found to be Middle – Late Eocene (Ringenbach, 1992).

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	CAGAYAN VALLEY BASIN
NEOGENE	HOLOCENE		0.0117	
	PLEISTOCENE	4 Late		Awiden Mesa Formation
		2 1 Early	1.81	r r r r r
	PLIOCENE	2 Late 1 Early	3.60 5.33 7.25	Cabagan Formation
	MIOCENE	3 Late		
		2 Middle-	11.61 13.65	Callao Formation
		1 Early	15.97 20.43	Lubuagan Formation
PALEOGENE	OLIGOCENE	2 Late 1 Early	28.4	Ibulao Limestone Sicalao Limestone Dibuluan Formation
	EOCENE	4 Late	33.9 37.2 40.4 48.6	Abuan Formation
		Middle - 2		
		1 Early	55.8	
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7	
CRETACEOUS	Upper	Late	65.5	
	Lower	Early	99.6	
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	161.2	
	Lower	1 Early	199.6	

Table 2.5 Stratigraphic column for Cagayan Valley Basin

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

The Abuan Formation may be correlated with the **Mt. Cresta Formation**, which is exposed typically on the slopes of Mt. Cresta and lies scattered on the ridges of the Northern Sierra Madre Range, as mapped by MMAJ-JICA (1989). It is a dacitic complex of lava flows, intrusive rocks, pyroclastic rocks and sedimentary deposits, conformably overlain by the well-bedded Oligocene Masipi Green Tuff of Northern Sierra Madre.

The **Dumatata Formation** of Huth (1962), which was considered as the basement of the Cagayan Valley sedimentary sequence in BMG (1981), may be regarded as partly equivalent to the Abuan Formation. The Dumatata Formation is composed of an alternation of basic lava flows, partly metamorphosed pyroclastic breccia and tuffaceous sandstone and siltstone. It is about 550 m thick.

Dibuluan Formation

Lithology	Volcanic flows, breccias, pyroclastic rocks, sandstone, conglomerate, siltstone, mudstone
Stratigraphic relations	Unconformable over the Abuan Formation; unconformably overlain by the Ibulao Limestone
Distribution	Western flank of northern Sierra Madre
Age	Early Oligocene
Previous name	Dibuluan River Formation (MMAJ-JICA, 1989)
Renamed by	MGB (this volume)
Synonymy	Dumatata Formation (Huth, 1962)
Correlation	Masipi Green Tuff (MMAJ-JICA, 1989),
	Mamparang Formation (MMAJ-JICA,
	1977), Lower Zigzag Formation
	(Caagusan, 1978)

This formation, named by MMAJ-JICA (1989) as Dibuluan River Formation, is found along the western flanks of the Northern Sierra Madre Range. It embodies the principal position of the westward-dipping monoclinal structure of the Cagayan Basin. It unconformably overlies the Abuan Formation and is unconformably overlain by the Ibulao Limestone along Dibuluan River and elsewhere in the southeastern end of the Cagayan Valley Basin (Aurelio and Billedo, 1987). The Dibuluan Formation consists mainly of basic volcanic flows, volcanic breccias and pyroclastic rocks, with interbeds of clastic rocks. The clastic rocks in the lower portions generally consist of well-indurated brownish gray to greenish gray feldspathic wacke with minor intercalated intraformational conglomerate, while the upper portions are marked by thin to medium beds of green siltstone and light green to red, well-indurated mudstone.

Radiometric K-Ar dating of a sample of basic lava flow of the Dibuluan Formation gave an age of 29 Ma, equivalent to late Early Oligocene (Billedo, 1994).

This formation is partly equivalent to the **Dumatata Formation** of Huth (1962) in the southwestern part of the Cagayan Valley Basin (see description above). The Dibuluan could also be correlated with the Oligocene **Masipi Green Tuff** of MMAJ-JICA (1989) in Northern Sierra Madre. The Masipi Green Tuff represents a sequence of parallel-bedded greenish tuff, tuffaceous sandstone and some pyroclastic rocks found at the type locality, Masipi River, in Cabagan, Isabela. The nannofossils contained in tuffaceous sandstone indicate a Middle to Late Oligocene age (MMAJ-JICA, 1987). Likewise, it could be correlated with the **Mamparang Formation** of MMAJ-JICA (1977) in the eastern fringe of the Northern Sierra Madre Range. The Dibuluan Formation may also be considered as partly equivalent to the **Lower Zigzag Formation** of BED (1986a) and Caagusan (1978), which is estimated to be around 1,800 m thick.
Ibulao Limestone

Limestone, calcarenite, calcirudite Unconformable over the Dibuluan
Formation; unconformably overlain by the
Lubuagan Formation
Kiangan Valley, Ifugao; Maddela and
Bayombong Nueva Vizcaya; Jones and
Cabagan, Isabela
Late Oligocene
150 – 600 m (BMG, 1981); 200-450 m
(Billedo, 1994)
Corby and others (1951)
Sicalao Limestone

The Ibulao Limestone, named by Corby and others (1951), is a biohermal to biostromal well-bedded limestone with varying thicknesses of intercalated calcirudites and calcarenites. It rests unconformably over the Dibuluan Formation and is overlain unconformably by the Lubuagan Formation. The type locality of this limestone is at Ibulao Gate, Kiangan Valley, Ifugao. The limestone is well exposed in Sto. Domingo at the end of Kiangan Valley and in Nueva Vizcaya and Isabela, where it trends northeast from the southern portions of Maddela up to the rivers of Aburao and Tugawi, south of Jones, Isabela. It also outcrops farther north in Cabagan, Isabela. The Ibulao is primarily biohermal to biostromal in the southeastern and northeastern parts of the valley. It has a reported thickness of 150 to 600 m (BMG, 1981), although Billedo (1994) limits the thickness range to only 200-450 m for the limestone in the eastern side of the valley. Recent paleontological determinations confirm an age of Late Oligocene (Billedo, 1994). A shale sample collected at the base of the overlying Lubuagan Formation at Dibuluan River yielded nannofossils of biochronological zone NP25 or late Late Oligocene, suggesting the upper limit of the Ibulao Limestone (Billedo, 1994).

Sicalao Limestone

Lithology	Limestone, calcarenite, calcirudite
Stratigraphic relations	Unconformable over volcanic rocks;
	transitional to Lubuagan Formation
Distribution	Western flank of Cagayan Valley;
	traceable from Luna, Apayao to Salegseg,
	Kalinga; Rizal, Cagayan
Age	Late Oligocene (?)
Thickness	546 m
Named by	Durkee and Pederson (1961)
Synonymy	Ibulao Limestone

The Sicalao Limestone was defined by Durkee and Pederson (1961) in reference to the limestone unit on the western flank of the Cagayan Valley, which is considered to be equivalent to the Ibulao Limestone. According to Durkee and Pederson (1961) the Sicalao can be traced nearly continuously from Luna, Apayao near the north coast, southward to Salegseg, Kalinga. It rests on volcanic rocks and is transitional to the overlying Lubuagan

Formation, designated by Durkee and Pederson (1961) as the Mabaca River Group. The limestone consists mainly of thick beds of calcarenite and calcirudite, becoming argillaceous and thinly bedded at the topmost 20 m. It has an estimated thickness of 546 m as measured along the Anaguan Creek section at Rizal, Cagayan (Durkee and Pederson, 1961). It is dated Early Miocene (T-e₄₋₅) by Durkee and Pederson (1961) on the basis of orbitoid fauna in the limestone but its stratigraphic position suggests a probable Late Oligocene age. It is considered by BED (1986a) and Caagusan (1978) to be coeval with the Lubuagan Formation, which is assigned an age range of Early Miocene to Middle Miocene.

Lubuagan Formation

Lithology	Sandstone, mudstone, shale, claystone, conglomerate
Stratigraphic relations	Unconformable over the Ibulao Limestone
Distribution	Conner, Kalinga - Apayao; Magat River, Isabela
Age	Late Oligocene - Early Miocene
Thickness	2,700 m
Previous name	Lubuagan Coal Measures (Corby and others, 1951)
Renamed by	Gonzales and others (1978)
Synonymy	Mabaca River Group (Durkee and
	Pederson, 1961)
Correlation	Upper Zigzag Formation (Caagusan, 1978)

The Lubuagan Formation, originally described by Corby and others (1951) as Lubuagan Coal Measures, is exposed along the west side of Cagayan Valley from Conner, Kalinga-Apayao to Magat River, Isabela. It is primarily a thick sequence of clastic sediments with minor pyroclastic intercalations. The formation rests unconformably over the Ibulao Limestone east of Jones, Isabela up to the southern extremities of the Cagayan Valley Basin.

A tripartite subdivision was recognized and was mapped under the Mabaca River Group by Durkee and Pederson (1961) based on varying sandstone-shale ratio. These were given formational rank but were reduced to member status by Gonzales and others (1978). These members are the Asiga, Balbalan and the Buluan.

The lower Asiga Member was named after barrio Asiga along the Mabaca River west of Pinukpok, Apayao. It consists mainly of interbedded shale and graywacke. The member has a thickness of about 1500 m.

The Balbalan Sandstone Member was named after Balbalan, a barrio along Mabaca River between Saltan and Pasil rivers in Kalinga- Apayao. It is composed dominantly of fine- to coarse-grained sandstone and conglomerate. It measures 1165 m thick along the Mabaca River east of Asiga.

The upper Buluan Member is characterized by the predominance of dark gray silty claystone with occasional thin graywacke beds. It was named after the exposures along Buluan Creek near Buluan, Kalinga-Apayao. As measured along the Tuao-Conner Road, the thickness is 1,036 m.

On the other hand, Maac (1988) subdivides the Lubuagan Formation into a *Sicalao Limestone* member and a *Cañao Turbidite* member.

Recent paleontological dating of samples of the Lubuagan Formation indicates an age range of late Late Oligocene (nannofossil zone NP25) to Early Miocene (nannofossil zones NN2- NN3) as reported by Billedo (1994). The Lubuagan Formation of BED-WB (1986) and Caagusan (1978) is assigned an age range of Early Miocene to Middle Miocene.

The **Upper Zigzag Formation** of BED (1986a) and Caagusan (1978) spanning the age range of Late Oligocene to Early Miocene may be considered equivalent to the Lubuagan Formation. However, BED (1986a) and Caagusan (1978) regard this sequence of clastic rocks as coeval with the Ibulao Limestone.

Callao Formation

Lithology	Limestone, conglomerate, sandstone, shale
Stratigraphic relations	Unconformable over the Lubuagan
Distribution	Callao at Peñablanca, Gattaran, Paret
	Embayment, Cagayan
Age	Middle Miocene
Thickness	540 - 1,000 m
Named by	Corby and others (1951) as Callao
-	Limestone
Renamed by	MGB (this volume)
Correlation	Aglipay Formation (MMAJ-JICA, 1975)

The formation was previously named Callao Limestone by Corby and others (1951) for the limestone section exposed at Barrio Callao, Peñablanca, Cagayan. It is basically a reef complex, which grades into a clastic facies in the deeper part of Cagavan Valley. A sequence of conglomerate, sandstone and shale in Dutan River on the eastern part of the valley, was found to be unconformable over the tilted beds of the Lubuagan Formation. The limestone body describes a crescent shape extending to the northern foothills of Sicalao Ridge, east-northeast of Gattaran, Cagayan. The lower limestone unit is well-developed in the southern part of the valley and along the eastern flank, while the clastic facies outcrops over the rest of the valley. The limestone facies is flesh to gray and coralline with few large foraminifera. The clastic facies is composed of light gray, fine- to medium-grained sandy limestone with interbeds of shale and conglomerate at the base. A sample of shale from Dutan River yielded nannofossils of NN7 zone (late Middle Miocene). Likewise, recent dating of the limestone indicates a Middle Miocene age. The reef limestone was deposited in a near-shore environment, the clastic facies in deeper water. It is about 540 m thick at the type locality (Durkee and Pederson, 1961) but is 1000 m thick at the Paret Embayment.

The Callao Formation is equivalent to the **Aglipay Formation** of MMAJ-JICA (1975), which outcrops at the southern end of the Cagayan Valley Basin. The limestone member of this formation is exposed near the town of Aglipay, in the lower reaches of Addalam River. This formation was likewise dated Middle Miocene based on the dating of benthic foraminifera found in the limestone.

The Callao is considered by BED (1986a) and Caagusan (1978) as a Late Miocene formation coeval with the Cabagan Formation. The equivalent of the Middle Miocene formations for BED (1986a) and Caagusan (1978) are the **Sicalao Limestone** and **Lubuagan Formation**.

Cabagan Formation

Lithology	Calcareous shale and sandstone;
	limestone; siltstone; conglomerate
Stratigraphic relations	Unconformable over the Callao Formation
	and older rocks
Distribution	Cabagan, Isabela; Kalinga- Apayao
Age	Late Miocene – Early Pliocene
Thickness	750-1,000 m
Named by	Geophoto Exploration Ltd (1966)

The formational name was introduced by Geophoto Exploration Ltd (in BM Petroleum Division, 1966) referring to the sedimentary section along Cabagan River in Cabagan, eastern Isabela and similar deposits throughout the Cagayan Valley. It is distributed at the margins and at the core of the Pangul Anticline in the center of the valley. From south to north the Cagayan Valley Basin, the Cabagan Formation covers of unconformably the Lubuagan Formation, the Ibulao Limestone, Callao Limestone and older dioritic units. Caagusan (1978), however, describes the relation between the Callao Limestone and Cabagan Formation as intertonguing. Three lithologic entities are represented in the formation. The lower consists chiefly of gray silty to sandy calcareous shale with interbeds of calcareous sandstone and limestone; the middle, essentially dark gray shale with thin beds of nodular limestone; the upper, dominantly siltstone and fine-grained sandstone. Maac (1988) describes а conglomeratic facies of this formation exposed along the Tabuk-Batong Buhay route in Kalinga-Apayao. The formation is 750 m thick at its type locality but could reach an overall thickness of 1,000 m (Billedo, 1994). Calcareous sandstone sampled in the lower portion of the formation yielded large foraminifera indicating a Late Miocene age, while nannofossils from a shale sample from the upper portion were dated Late Miocene to late Early Pliocene (NN7 and NN11) as reported by Aurelio and Billedo (1987).

Ilagan Formation

Lithology Sandstone, conglomerate, shale *Stratigraphic relations* Conformable over the Cabagan Formation

Distribution	Ilagan, Isabela; Sicalao-Casiggayan High
Age	Late Pliocene – Early Pleistocene
Thickness	2,200 m
Previous name	Ilagan Sandstone (Corby and others,
	1951)
Renamed by	MGB (this volume)

The name Ilagan Sandstone was used by Corby and others (1951) for the exposure along Ilagan River, south of Ilagan, Isabela. Subsequent workers called it Ilagan Formation. It is widespread over the valley south of the Sicalao-Casiggayan High. It conformably overlies the Cabagan Formation. The Ilagan Formation is divided into a lower marine shale and sandstone alternation and an upper coarser marine sandstone and continental sandstone and conglomerate sequence. The bottom is characterized by abundant mollusks. The formation is 2200 m thick in the type area. BED (1986a) assigns an age of Late Pliocene to Early Pleistocene for the Ilagan. Marine fauna indicate warm, shallow to brackish water deposition.

Awiden Mesa Formation

Lithology	Dacitic tuff, tuffaceous sandstone
Stratigraphic relations	Not reported
Distribution	Awiden Mesa, Lubuagan, Kalinga-Apayao;
	Pasil and Chico river valleys between
	Balatoc and Tabuk, Kalinga-Apayao
Age	Late Pleistocene
Thickness	300 m
Named by	Durkee and Pederson (1961)
Correlation	Tabuk Formation (Caagusan, 1978)

The formation was named by Durkee and Pederson (1961) after Awiden Mesa, 6 km northwest of Lubuagan, Kalinga-Apayao. Remnants of the rock unit occur in Pasil and Chico river valleys between Balatoc and Tabuk, Kalinga-Apayao. The formation is composed of dacitic welded tuffs and tuffaceous clastic rocks. The tuffaceous sediments are of various shades of tan and gray and show variable clast sizes and rounding. The maximum thickness in the type locality is at least 300 m. The formation contains mammalian fossils, including elephant and rhinoceros remains, which point to an early Late Pleistocene age (Durkee and Pederson, 1961). The formation is probably equivalent to the **Tabuk Formation** of Caagusan (1978) and BED (1986a), which consists of 300 m of tuffs that are transitional to terrestrial conglomerates, sandstones and lahars.

NORTHERN SIERRA MADRE - CARABALLO (SG 4)

Isabela Ophiolite

Lithology

Peridotite, massive and layered gabbro, sheeted dike complex, pillow basalt, pelagic sedimentary rocks

Stratigraphic relations	Constitutes the basement of northern
	Sierra Madre; unconformably overlain by
	the Dibuakag Volcanic Complex
Distribution	Coastal strip from Dinapique Point to
	Bicobian, Isabela; Baler, Quezon; San
	Ildefonso Peninsula
Age	Early Cretaceous
Previous name	Isabela Ultramafic Complex (Aurelio and
	Billedo, 1987)
Renamed by	MGB (this volume)

The Isabela Ophiolite consists of an ultramafic complex, gabbros and associated pillow basalt and pelagic sedimentary rocks as well as their metamorphic equivalents. This ophiolite unit represents a complete sequence of a normal ophiolitic suite that includes peridotites, massive and layered gabbros, dike complex, pillow basalts and its sedimentary carapace.

The ultramafic rocks are extensively exposed along the coast from Dinapique Point northwards to Divilacan Bay, which was designated by Aurelio and Billedo (1987) as **Isabela Ultramafic Complex**. These consist mostly of peridotite with subordinate dunite and pyroxenite, which are almost completely serpentinized and intruded in some places by diabasic dikes. Significant chromite mineralization is associated with the ultramafics.

Both massive and layered gabbros were observed in the upper reaches of Dimapnat, Pinacanauan and Anggo rivers, between the latitudes of Dinapique and Port Bicobian, Isabela.

Pillow basalt, represented by **Bicobian Basalt**, was found to be in thrust contact with the overlying pelagic **Dikinamaran Chert** in Bicobian, Isabela. The Dikinamaran Chert was previously named Dikinamaran River Pelagics by Billedo (1994).

These pelagic sedimentary rocks consist mainly of highly indurated alternating brownish and light reddish chert and interpreted as the sedimentary carapace of the ultramafic complex. Radiolarian fossils in the chert indicate an age of Early Cretaceous (MMAJ-JICA, 1987). The ultramafic complex is therefore thought to be no younger than Early Cretaceous.

Metamorphosed equivalents of the Isabela Ophiolite are found eastsoutheast of Baler and in San Ildefonso Peninsula, named by Billedo (1994) as Dibut Bay Metaophiolite. These include highly tectonized ultramafic rocks composed wholly of deformed pyroxenites and highly foliated gabbro with associated amphibolite layers. A sample of the amphibolite gave a radiometric ⁴⁰Ar-³⁹Ar dating of 92 Ma, equivalent to early Late Cretaceous, which is considered as indicative of the age of metamorphism of the ophiolite (Billedo, 1994).

The **Pingkian Ophiolite** of Maleterre (1989) at the southeast portion of the Cordillera and covering portions of the Caraballo could be dismembered portions of the Isabela Ophiolite.

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	NORTHERN SIERRA MADRE - CARABALLO
	HOLOCENE		0.0117	
	PLEISTOCENE	4 Late 3 Middle 2 1 Early	0.126 0.78 1.81	
NEOGENE	PLIOCENE	2 Late 1 Early	2.59 3.60 5.33	Pantabangan Formation
		3 Late	7.25 11.61	Palanan Formation
	MIOCENE	2 Middle-	13.65 15.97	Aglipay Limestone
		1 Early	20.43	Palali Formation Kanaipang Limestone Cordon Svenile
	OLIGOCENE	2 Late 1 Early	23.03	Dupax Diorite Mamparang Formation Complex
GENE	FOCENE	4 Late 3	37.2 40.4	Caraballo Formation
PALEC	LOOLILL	2 1 Early	48.6	Dinalungan Diorite Complex
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	Lubingan Formation
CEOUS	Upper	Late	65.5 99.6	Dibuakag Volcanic Complex
CRETA	Lower	Early	145.5	Isabela Ophiolite
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.6 Stratigraphic column for Northern Sierra Madre-Caraballo

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Dibuakag Volcanic Complex

Lithology	Pillow basalt, pelagic limestone
Stratigraphic relations	Unconformable over the Isabela Ophiolite
Distribution	Palanan, Isabela
Age	Late Cretaceous
Thickness	800 m
Named by	Billedo (1994)

The Dibuakag Volcanic Complex consists mainly of pillow basalts interstratified with steeply dipping pelagic limestones, which Billedo (1994) considers as distinct from the Bicobian Basalt and Dikinamaran Chert. The formation is distributed along the coast of Palanan from Dipaguiden to Dibuakag (also known as Kananalatiang Point). It is possibly unconformable over the Isabela Ophiolite as well as with the overlying Kanaipang Limestone and Palanan Formation. Radiometric K-Ar dating of a sample of the basalt indicates an age of 87 Ma, equivalent to Late Cretaceous. Paleontologic dating of foraminifera and radiolarians from samples of limestone and calcareous clay, respectively, also indicates a Late Cretaceous age for the formation. The formation is estimated to be about 800 m thick (Billedo, 1994).

Outcrops of greenschists along Dalugan Bay at the eastern coast of San Ildefonso Peninsula could be weakly metamorphosed equivalents of the Dibuakag Volcanic Complex. These are elongated or stretched pillow basalts, schistose volcanic breccia and andesitic flow with marble lenses and associated phyllites and greenschists. South of Baler, greenschists and highly silicified lithic tuffs were also encountered. These rocks were named by Billedo (1994) as **Dalugan Schist**. It may be correlated with the **Quidadanom Schist** of Polillo Island.

Lubingan Formation

Lithology	Weakly metamorphosed sandstone, siltstone, mudstone, marble and volcanic
Stratigraphia relationa	llows Brobably overling Dibuskag Velegnia
Stratigraphic relations	Probably overlies Dibuakag voicanic
	Complex and situated beneath the
	Caraballo Formation
Distribution	Bongabon to Labbi, Nueva Ecija
Age	Paleocene (?) – Early Eocene
Thickness	Not determined
Named by	Rutland (1968)

The Lubingan Formation was named by Rutland (1968) for the thick sequence of metamorphosed sedimentary and volcanic rocks at the northeastern portion of the southern end of the Northern Sierra Madre. Along the road from Bongabon to Labbi, Nueva Ecija, the formation is composed of phyllitic clastic rocks, volcanic flows and pinkish to greenish marbles. Alternating black and red calcareous sandstone and siltstone beds and occasional volcanic conglomerates and breccias are likewise present.

Ultramafic rocks are often found in the vicinity of the Lubingan Formation, but since the contact between the two units was not clear, it was either described as an intrusive or a thrust fault. Ringenbach (1992) interpreted it as a tectonic contact defined by a northeast trending high-angle shear zone separating the Lubingan Formation from the ultramafics found east and southeast of Baler area. Likewise, the contact between the Lubingan Formation and younger Caraballo Formation near Labbi, Nueva Ecija is delineated by the north-northwest sub-vertical Labbi Fault (Ringenbach, 1992).

The formation was assigned a Cretaceous-Paleogene age by BMG (1981). Hashimoto (1978) reports Eocene Nummulites in marbles intercalated with greenschist in Calaanan and Labbi River, which presumably belong to this formation.

Dinalungan Diorite Complex

Lithology	Diorite, quartz diorite, minor gabbro
Stratigraphic relations	Intrudes older formations
Distribution	Dinalungan, Casiguran, Pantabangan in
	Aurora province
Age	Middle Eocene
Previous name	Coastal Batholith
Named by	MMAJ-JICA (1977); BMG (1981)
Renamed by	MGB (this volume)

Huge bodies of diorite, tonalite and gabbro collectively called **Coastal Batholith** by MMAJ-JICA (1977) intruding the Caraballo Formation is here renamed as Dinalungan Diorite Complex. Exposures may be encountered from west of Dinalungan, Aurora to Pantabangan, Nueva Ecija underlying a large part of the Caraballo Mountains and the Northern Sierra Madre. The northern part is mainly dioritic, whereas the southern part is predominantly tonalite. The diorites consist of dark greenish gray, medium- to coarse-grained quartz diorite and dark-colored fine- to medium-grained diorite. Radiometric K-Ar datings obtained by MMAJ-JICA (1977) range from 49 Ma to 19 Ma. Wolfe (1981), however, classifies the ages obtained and regrouped those intrusive rocks dated 49-43 Ma as representing the Coastal Batholith.

Caraballo Formation

Lithology	Basaltic and andesitic flows and breccia and associated pyroclastic rocks, volcanic sandstone, conglomerate, mudstone and chert
Stratigraphic relations	Unconformably overlain by Mamparang Formation
Distribution	Manglad River, Qurino; Dibuluan and Tugawi rivers, Isabela; Dinapique and Divilacan Bay, Isabela; around San Ildefonso Peninsula; north of Dingalan; Digdig, Nueva Ecija
Age	Middle Eocene – Late Eocene
Thickness	6,000 – 10,000 m
Previous name	Formations I, II, III of the Caraballo Group (MMAJ-JICA (1977)
Renamed by	Ringenbach (1992)
Correlation	Mingan Formation and Coronel Formation (Rutland, 1967)

The most extensively exposed rocks in the Northern Sierra Madre are those belonging to the Caraballo Formation, previously designated by MMAJ-JICA (1977) as Caraballo Group and subdivided into Formations I, II and III. Ringenbach (1992) renamed the Caraballo Group as the Caraballo Formation. This formation is composed of a proximal and distal volcanosedimentary facies.

The proximal facies consists mainly of basaltic to andesitic flows and breccias with associated basaltic to andesitic sandstones and

conglomerates and pyroclastic rocks. Highly indurated layers of mudstone and chert also occur occasionally within the sedimentary and pyroclastic rocks. Good exposures at low elevations are found along the banks of Manglad River, Quirino and the upper reaches of Dibuluan and Tugawi rivers in Isabela. The basaltic and andesitic rocks generally occur as volcanic breccia flows, characteristically green to black, occasionally vesicular and amygdaloidal and have reddish to brown shades when weathered. Along Abuan River, basaltic to andesitic fragments of the volcanic breccia attain diameters of around 10 cm.

The distal facies of the Caraballo Formation is well exposed along the eastern side of the Northern Sierra Madre Range, in Divilacan Bay, west and south of Dinapique, south and east of San Ildefonso Peninsula and north of Dingalan. This facies consists of well bedded red and green mudstones, siltstones, sandstones, and pyroclastic rocks, with occasional fragmental flows and conglomerates. On the western side of the northern Sierra Madre, from San Jose to Digdig, Nueva Ecija, red and green siltstones and mudstones are overlain by gray to black tuffs and conglomerates, which coarsen upwards and become intercalated with pillow basalts.

The Caraballo Formation has a well-constrained age of Middle to Late Eocene (Ringenbach, 1992) on the basis of K/Ar dating of a basalt sample $(39 \pm 1.97Ma)$ and paleontological datings of pelagic clastic rocks associated with pillow basalt (Middle Eocene) and limestone (Late Eocene) lying above and esitic conglomerate (Ringenbach, 1992).

The total thickness of this formation is estimated to be between 6,000 to 10,000 m. It is probably equivalent to the Abuan Formation, which comprises the basement of the Cagayan Valley sedimentary sequence.

In the Laur-Dingalan Fault Zone, the **Mingan Formation** and **Coronel Formation** of Rutland (1967) probably partly correspond to the Caraballo Formation. The Mingan Formation consists of pyroclastic rocks, which appear to be welded, varying from coarse unsorted volcanic breccias to tuffs. They are well exposed in the Bongabon-Gabaldon area, Nueva Ecija. The age of the formation is estimated by BMG (1981) to be Late Eocene. The Coronel Formation consists of volcanic flows with interbeds of cherty mudstones and fine graywacke. It is exposed over a large part of the Laur-Dingalan Fault Zone, particularly in the southwestern part, where the typical section along the Dingalan Forest Products Co. road may be found. Pillow lavas are commonly well preserved in this section. It is considered to have been emplaced during Late Eocene to Early Oligocene (BMG, 1981).

Dupax Diorite Complex

Lithology	Diorite and quartz diorite
Stratigraphic relations	Intrudes Caraballo and other older
	formations
Distribution	Burgos to Aritao, Nueva Vizcaya; Isabela
Age	Early Oligocene – early Early Miocene
Previous name	Dupax Batholith
Named by	MMAJ-JICA (1977); BMG (1981)
Renamed by	MGB (this volume)

The Dupax Diorite Complex, previously known as Dupax Batholith (BMG, 1981) represents a second episode of magmatic intrusion following the emplacement of the Dinalungan Diorite Complex. These plutonic intrusives in the Caraballo Mountains consist mainly of diorites with varying quartz content, which are finer-grained compared to the Dinalungan Diorite. It was named after the exposures from Burgos to Aritao, Nueva Vizcaya, northwest of Dupax. Quartz diorites, including tonalite and granodiorite, having similar ages as the diorites at Dupax, which are exposed in the axial part of northern Sierra Madre, were designated by Billedo (1994) as the Northern Sierra Madre Batholith. Here, the diorites of Caraballo (otherwise known as Dupax Batholith) and the quartz diorites of the Northern Sierra Madre Batholith are named collectively as the Dupax Diorite Complex. These diorites intrude the Caraballo Formation and other older formations. New radiometric datings (⁴⁰K/⁴⁰Ar and ⁴⁰Ar/³⁹Ar) give values of 30 Ma to 21.9 Ma, equivalent to Early Oligocene to early Early Miocene (Billedo, 1994) conforming to the 33 Ma to 22 Ma age bracket given by MMAJ-JICA (1977).

Mamparang Formation

Lithology	Basalt and andesite flows, tuff breccia, tuff and minor dacitic rocks, mudstone and
	limestone
Stratigraphic relations	Unconformable over the Caraballo
	Formation; overlain by Sta. Fe Formation
Distribution	Mamparang Mountains; Kasibu, Nueva
	Vizcaya
Age	late Early Oligocene
Thickness	4,000 m
Named by	MMAJ-JICA (1977)
Synonymy	Dumatata Formation (Huth, 1962),
	Dingalan Formation (Rutland, 1967)

The Mamparang Formation of MMAJ-JICA (1977) is mainly distributed in the Mamparang Mountains and in the upper reaches of Cagayan River and most of the Kasibu area in the eastern fringe of the Northern Sierra Madre Range. The Mamparang consists of greenish gray to dark green andesite lava, andesitic tuff breccia, alkali andesite lava, basalt lava and basaltic tuff with subordinate dacitic volcanic rocks, mudstone, tuff and limestone. In Kasibu area, narrow limestone lenses with large foraminifera are intercalated with alkali andesite lava. The agglomerates found in Aburao Creek are reddish on weathered surfaces and contain well-bedded angular green and red siltstone and mudstone probably reworked from the underlying Caraballo Formation (Billedo, 1994). The clasts are typical of the red and green distal volcanic facies of the Caraballo Formation.

In the upper reaches of Cagayan River, MMAJ-JICA (1977) reports that this formation conformably overlies the Caraballo Formation. However, Billedo (1994) has observed an outcrop of volcanic conglomerate identified with Mamparang Formation to lie unconformably on the pelagic volcaniclastic rocks of the Caraballo Formation at the mouth of the Dikapanikian River, north of Dingalan, Nueva Ecija. In the southern reaches of Addalam River, west-northwest of Maddela, an andesite outcrop belonging to the Mamparang Formation and apparently above the Caraballo Formation was dated 28.82 ± 1.99 Ma by radiometric K-Ar method (Billedo, 1994), equivalent to late Early Oligocene. MMAJ-JICA (1977) estimates a thickness of about 4,000 m for this formation. It is probably equivalent to the **Dumatata Formation** designated by Huth (1962) for the exposures of partly metamorphosed agglomerate, tuffaceous breccia, tuffaceous sandstone and siltstone in the southwestern part of Cagayan Valley. Probably also corresponding to the Mamparang Formation is the **Dingalan Formation** of Rutland (1968). This is typically exposed along the Dingalan Forest Products Co. road in the Laur-Dingalan Fault Zone. It is made up of coarse epiclastic breccias, fine graywacke and cherty mudstones. Its age is placed at Late Oligocene by BMG (1981).

Cordon Syenite Complex

Lithology	Syenite, monzonite, tinguaite, shonkinite
Stratigraphic relations	Intrudes Palali Formation
Distribution	Cordon, Isabela; Palali
Age	late Late Oligocene
Named by	Punongbayan (1974)
Synonymy	Palali Batholith (MMAJ-JICA, 1977)

The Cordon Syenite Complex consists of syenites and associated alkali rocks, including tinguaite and shonkinite, exposed mainly in the southwestern portion of the Cagayan Valley Basin (near the provincial boundary between Isabela and Nueva Vizcaya). Some of the syenites and monzonites of the **Palali Batholith** of MMAJ-JICA (1977) probably belong to this unit. Radiometric Rb-Sr dating of K-feldspar and biotite separates from pegmatite intruding shonkinite stock indicates as age of 25 Ma (Knittel, 1983).

Sta. Fe Formation

lower member - limestone
upper member - clastic rocks
Unconformable over Dupax Diorite and
Caraballo Formation
Natbang – Sta. Fe – Dalton Pass, Nueva
Vizcaya; Baler, Quezon
Late Oligocene – Early Miocene
800 m
MMAJ-JICA (1975)
Disubini Formation (Billedo, 1994)

The oldest sedimentary sequence covering the Northern Sierra Madre was named Santa Fe Formation by MMAJ-JICA (1977). This outcrops mainly in the eastern part of Natbang and along the road from Santa Fe to Dalton Pass in Nueva Vizcaya. MMAJ-JICA (1975) recognizes a lower limestone member and an upper clastic member. The limestone is white to pinkish gray and is about 100 m thick (Ringenbach, 1992). Three local exposures of the limestone member have been observed to lie unconformably over the plutonic rocks of the Dupax Diorite Complex and the basaltic clastic rocks of the Caraballo Formation (Billedo, 1994). Large foraminifera in limestone samples from Dalton Pass indicate an age of Late Oligocene to Early Miocene. The total thickness of this formation is estimated at 800 m (JICA- MMAJ, 1975).

The **Disubini Formation** defined by Billedo (1994) with type locality along Disubini River at the southern portion of San Ildefonso Peninsula is apparently equivalent to the Sta. Fe Formation. It also outcrops in the interior and along the eastern shoreline between Palanan and Dinapique, Isabela. The Disubini Formation is composed of a lower limestone member and an upper turbidite member. The limestone member, which is about 20-25 m thick, unconformably overlies the ultramafic rocks of the Isabela Ophiolite. The upper turbidite member consists of shale-sandstone interbeds with minor thin layers of limestone. The upper member is often in fault contact with the lower limestone member although the turbidite sequence was observed to rest conformably over the limestone in Sto. Niño.

Paleontologic dating of foraminifera from several limestone samples indicates an age of Late Oligocene to Early Miocene. Limestone beds from the upper turbidite sequence also yielded Late Oligocene to Early Miocene foraminifera. However, numerous samples of shale from the upper turbidite member indicate a nannofossil zone of NP-25, equivalent to late Late Oligocene. Overall, the age of the formation may be taken as Late Oligocene to Early Miocene.

Kanaipang Limestone

Lithology	Coralline limestone with associated
	calcilutite and calcarenite
Stratigraphic relations	Unconformable over Isabela Ophiolite
Distribution	Dinapique and Palanan, Isabela
Age	Early Miocene
Named by	Aurelio and Billedo (1987)

The Kanaipang Limestone was designated by Aurelio and Billedo (1987) for the small, nearly flat-lying, isolated patches of limestone near the shoreline between Dinapique and Palanan. These limestone bodies were observed to rest unconformably over peridotites of the Isabela Ophiolite. The basal conglomerate of the formation also contains numerous subrounded to rounded clasts of peridotite, gabbro and reddish to greenish volcanic rocks in a calcareous matrix. Southwest of Palanan, the basal part of the formation resting on the peridotites consists of interbeds of calcilutite, calcarenite and massive coralline limestone. This formation was assigned a Pliocene-Pleistocene age by MMAJ-JICA (1987). However, recent paleontologic dating of numerous samples gives a range of Early to Middle Miocene, although the more reliable determinations indicate an Early Miocene age (Billedo, 1994).

Palali Formation

Lithology

Andesitic and dacitic flows and tuff breccias, basaltic lava, mudstone, sandstone and welded tuff

Stratigraphic relations	Unconformable over the Caraballo and
	Mamparang formations, Dupax Diorite
	Complex
Distribution	Sta. Fe- Dalton Pass- Aritao, Nueva
	Vizcaya
Age	late Early Miocene
Thickness	300 m
Named by	MMAJ-JICA (1977)
Synonymy	Natbang Formation

This formation was named by MMAJ-JICA (1977) for the rocks exposed in the vicinity of Palali Mountains. It outcrops around Santa Fe, Dalton Pass and Aritao, Nueva Vizcaya and some areas in the southern part of the Caraballo mountain range. The rocks are mainly composed of greenish dacitic tuff breccia, dacite lava, andesite lava, andesitic tuff breccia, basaltic lava, mudstone, sandstones and welded tuff. Some andesitic plugs intruding the Dibuluan Formation and Lubuagan Formation (of the Cagayan Valley Basin) could be intrusive facies of the Palali Formation. In the tuff breccia of Palali Mountain, pebbles of syenite and syenite porphyry as well as the quartz diorite of Dupax Diorite Complex are included in the tuff breccia near Santa Fe. The Palali Formation unconformably overlies the Caraballo Formation, Mamparang Formation and Dupax Diorite Complex in Palali Mountain and around Santa Fe. Radiometric K-Ar dating of dacitic welded tuff indicates an age of 17.6 ± 1.0 Ma, equivalent to late Early Miocene (MMAJ-JICA, 1977). Recent dating of a basaltic dike and a basaltic cobble identified with the Palali Formation confirms the previous dating of 17 Ma (Ringenbach, 1992). The formation has a thickness of around 300 m (BMG, 1981).

The **Natbang Formation** of MMAJ-JICA (1977) exposed at Natbang, west of Bayombong, Nueva Vizcaya is probably equivalent to the Palali Formation. It is mainly made up of conglomerates with alternating beds of sandstones and mudstones and intercalated thin layers of basaltic lavas. It was dated Early to Middle Miocene.

Aglipay Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Caraballo
	Formation
Distribution	Aglipay, Quirino
Age	Middle Miocene
Thickness	200 m at the type locality
Previous name	Aglipay Formation (MMAJ-JICA, 1977)
Renamed by	Billedo (1994)
Synonymy	Macde Limestone (Hashimoto and others,
	1978)

The Aglipay Limestone was previously designated Aglipay Formation (MMAJ-JICA, 1977, BMG, 1981) for the light pink limestone exposed near Aglipay, Quirino in the lower reaches of Addalam River. This unit is found only in Aglipay and two other small areas north of Aglipay. Except for the observed unconformable contact with the Caraballo Formation, its relation

to other units has not been observed. On the basis of age determination of large foraminifera, its age is placed at Middle Miocene. Billedo (1994) reports an average thickness of around 200 m at the type locality. It probably corresponds to the Middle Miocene **Macde Limestone** of Hashimoto and others (1978) exposed near Macde, some 20 km southwest of Bayombong, Nueva Vizcaya.

Palanan Formation

Lithology	Calcareous sandstones and mudstone
Stratigraphic relations	Unconformable over the Kanaipang
	Limestone
Distribution	Palanan, Isabela
Age	late Middle Miocene – early Late Miocene
Named by	Aurelio and Billedo (1987)

The Palanan Formation as defined by Aurelio and Billedo (1987) was thought to underlie the Kanaipang Limestone. However, recent studies by Billedo (1994) indicate that this formation actually rests unconformably over the older Kanaipang Limestone. The formation is made up of thickly bedded sequence of calcareous sandstone and indurated mudstone. Numerous limestone clasts in the coarse-grained sandstone beds of this formation are probably derived from the underlying Kanaipang Limestone. Paleontologic dating by MMAJ-JICA (1987) gives an age of Late Miocene for this formation. More recent dating indicates a nannofossil zone of NN8, equivalent to Middle - Late Miocene boundary. The formation could therefore be regarded as having an age bracket of late Middle Miocene to early Late Miocene.

Pantabangan Formation

Lithology	Sandstone, mudstone, conglomerate
Stratigraphic relations	Unconformable over the Palali and Sta. Fe
	Formations
Distribution	Pantabangan Basin, Nueva Ecija
Age	Pliocene
Named by	Ringenbach (1992)
Synonymy	Matuno Formation (MMAJ-JICA, 1977)
Correlation	Ilagan Formation (Cagayan Valley),
	Tartaro Formation (southern Sierra Madre)

The Pantabangan Formation is a sequence of sandstone, mudstone and polymictic conglomerates forming gently rolling hills in the vicinity of Pantabangan Basin. An unconformity separates this formation from the underlying Palali and Santa Fe formations. An increase in the amount of conglomerates towards the south and east suggests a provenance from this direction. The formation itself has not been dated, but it is believed to be partly equivalent to the Plio-Pleistocene *llagan Formation* of the Cagayan Valley Basin. Ringenbach (1992) has obtained a dating of 1.3 Ma (Pleistocene) for a biotite extracted from an andesite intruding the Pantabangan Formation. Furthermore, Ringenbach (1992) correlates this formation to the *Tartaro Formation* on the western flank of the Southern Sierra Madre dated as Plio-Pleistocene from benthonic foraminifera. It is estimated to attain a thickness of 1,000 m (Ringenbach, 1992). The *Matuno Formation* is probably equivalent to the Pantabangan Formation. This was named by MMAJ-JICA (1977) for the sequence of alternating yellowish brown to gray sandstone and mudstone covering a wide area around Maddela and Tauayan, Quirino province in the uppermost to middle reaches of Cagayan River. No fossils have been recovered from samples of this formation, but it is considered Pliocene in age.

ZAMBALES RANGE (SG 5)

Zambales Ophiolite Complex

Lithology	Peridotite, gabbro, diabasic dike complex, diorite, pillow basalt, pelagic limestone, sandstone, mudstone
Stratigraphic relations	Constitutes the basement of Zambales;
Distribution	Occupies the greater part of Zambales
	province; Mayantoc, Tarlac; Barlo and
	Sual, Pangasinan
Age	Eocene
Previous name	Zambales Ultramafic Complex (Stoll, 1962)
Renamed by	MGB (this volume), BMG (1981) as Zambales Ophiolite

The Zambales Ophiolite Complex, an east-dipping complete sequence of oceanic crust and mantle material, is located at the western portion of Central Luzon spanning 160 km N-S and 40 km at its widest (E-W) portion. Three structural massifs separated by WNW trending faults are recognized: Masinloc, Cabangan and San Antonio. Petrological and geochemical studies reveal that this ophiolite suite can be divided into two major units, the Coto and Acoje blocks (Hawkins and Evans, 1983; Yumul, 1989, 1990), each made up of a complete ophiolite sequence: residual (upper mantle) - transition zone - cumulate (base of crust) - volcanic (oceanic crust) rocks. The Acoje Block occupies the northern half of the Masinloc Massif, and also the San Antonio Massif at the southern portion of the Zambales Range. The Coto Block encompasses the Cabangan Massif and the southern half of the Masinloc Massif. An Eocene age has been assigned to this ophiolite, based on overlying Eocene pelagic limestones of the Aksitero Formation (Villones, 1980; Scweller and others, 1983). This is supported by whole rock K-Ar ages of 46.6 ± 5.1 Ma and 44.3 ± 3.5 Ma for a dike at Coto mine and a sill in Sual, Pangasinan, respectively (Fuller and others, 1991). Tectonic (Karig, 1982) and paleomagnetic (Fuller and others, 1983) studies suggest that the Zambales ophiolite is an allochthonous terrane. Stratigraphic evidences (Scweller and others, 1983), in turn, point to its emergence during the Oligocene to Early Miocene.

Coto Block

This consists, from bottom to top, of metamorphic harzburgite, dunite, troctolite, allivalite, olivine gabbro and a high level plutonic-volcanic suite of

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	ZAMBALES RANGE
	HOLOCENE		0.0117	
	PLEISTOCENE	4 Late 3 Middle - 2 Late	0.0117 0.126 0.78 1.81	Bolinao Limestone Bataan Volcanic Arc Complex
ENE	PLIOCENE	2 Late 1 Early	3.60	
NEOGI		3 Late	7.25	Sta. Cruz Formation
			11.61	Cabaluan Formation
	MIOCENE	2 Middle-	13.65	
		1 Early	15.97 20.43	
		2 Late	23.03	
	OLIGOCENE	1 Early	28.4 33.9	Aksitero Formation
ENE	EOCENE	4 Late	37.2	
ALEOG		Middle - 2	40.4 48.6	Balog-Balog Diorite
A		1 Early	55.8	
	PALEOCENE	2 Middle 1 Early	58.7 61.7	Zambales Ophiolite
CEOUS	Upper	Late	00.6	
CRETAC	Lower	Early	99.0	
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	161.2	
	Lower	1 Early	199.6	

Table 2.7 Stratigraphic column for Zambales Range

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

diorite, diabase and basalt. Massive to banded harzburgites are mostly serpentinized and consist basically of olivine, orthopyroxene, spinel and minor clinopyroxene. The harzburgites are separated from the cumulate rock suite by a transitional zone of intensely fractured black serpentinized dunite, which contain chromite lenses in places. The contact between the transition zone dunite and cumulate gabbro is characterized by interlayering-interfingering of dunite, harzburgite and gabbro. The mafic cumulates are represented by anorthosite, troctolite, and olivine gabbro. These exhibit rhythmic layering and structures such as scour and fill, graded bedding and flame structures reminiscent of turbidites. Intrusive relationships among the higher level units - basalt, diabase and gabbro suggest that these rocks were more or less contemporaneous. Dike boundaries are usually defined by chilling on both sides. The basalt and which show evidence of low-grade greenschist facies diabase. metamorphism, have aphyric to porphyritic and intersertal to intergranular

textures. Clinopyroxene is predominant over plagioclase and olivine. Disseminations of magnetite, ulvospinel and pyrite are common. The diorites/tonalites are holocrystalline to poikilitic, and are composed of plagioclase, brown amphibole, quartz and minor clinopyroxene and magnetite. Epidote and chlorite are the dominant alteration minerals.

Acoje Block

The bottom to top sequence of the Acoje Block consists of metamorphic harzburgite with associated lherzolite and dunite, well developed ultramafic and mafic cumulates and a high level plutonicvolcanic suite of gabbro-diorite-dolerite and basalt. The massive and intensely fractured residual harzburgites are associated with pockets of Iherzolite, and are much fresher compared to their counterparts of the Coto Block. Like in the Coto Block, the residual-cumulate transition is marked by a dunite layer. This dunite in Acoje, called 'black' dunite in the mine, has a very dark appearance probably due to abundant iron oxide dust inclusions. In addition, these dunites host chromite and nickel mineralization. Several gabbro dikes intrude the dunite. The ultramafic cumulates consist of rhythmically layered clinopyroxenites, dunites, wehrlites and harzburgites. Olivine, spinel and pyroxene are the main minerals, although completely altered plagioclases are very sparsely present. Talc, serpentine and iron oxide stains are very common. The mafic cumulates - gabbro, eucrite, gabbronorite and anorthosite - exhibit normal and reverse graded bedding and other features such as chanelling, scour and fill, slumping and flame structures. The rocks are mostly medium- to coarse-grained, consisting chiefly of plagioclase, pyroxene and olivine. Unlike in the Coto Block, orthopyroxene is an important cumulus phase in the Acoje Block. The diorite-diabase sill/dike complex associated with basalts is best exposed in the Barlo-Sual area. The basalt-dolerite units are usually aphanitic and areenish grav and slightly chloritized and argillized. The diorites are fine- to medium-grained and grayish-white in color. The basaltic flows and pillow basalts in Barlo are host to Cyprus-type massive sulfide deposit.

The origin of the Zambales Ophiolite Complex is still open to debate. Yumul and others (1990b, c) advocate a South China Sea Basin origin for the ophiolite, whereas earlier workers (Hawkins and Evans, 1983; Fuller and others, 1983 and Schweller and others, 1983) do not favor such hypothesis. Nicolas and Violette (1982), based on petrofabric studies, concluded that the Acoje Block is characterized by vertical plastic flow patterns indicating a mid-ocean spreading ridge environment. The Coto Block, on the other hand, has subhorizontal plastic flow patterns, which are supposed to indicate its remoteness from the spreading ridge. Finding no volcanic or continental materials in the overlying hemipelagic Aksitero Formation, Schweller and others (1983) were convinced that the ophiolite was formed in an open ocean environment far from any continent or island arc.

The petrology and geochemistry of the Coto and Acoje blocks are distinct from each other. While the former has geochemical characteristics transitional between normal MORB and island arc rocks, the latter is principally island arc in character. To account for such peculiarity, Hawkins (1980) and Hawkins and Evans (1983) propose a paired volcanic arc-backarc model, in which one component was tectonically juxtaposed against the other. Geary and others (1989), in turn, suggest that the Zambales Ophiolite preserves a normal ocean crust (forearc)-island arc complex that was formed by two distinct crustal generation events. Mitchell and others (1986) offer a model in which island arc volcanics truncated and formed on top of a MORB crust. Finally, Yumul (1987) believes that the Zambales ophiolite originated as a Paleogene subduction-related marginal basin, a precursor to the South China Sea basin, rifted from the Asia mainland. He forwarded two models, one in which the Coto Block first formed as a marginal basin followed by the installation of an island arc (Acoje Block), or alternatively, one in which the island arc was split to form the Coto Block back-arc basin.

Balog-Balog Diorite

Lithology	Diorite, quartz diorite, pegmatite,
	plagiogranite
Stratigraphic relations	Intrudes gabbro and diabase dike complex
Distribution	Balog-balog, Tarlac; Mayantoc, Tarlac
Age	Eocene
Named by	Villones and others (1979)

In the western flank of Zambales Range is a diorite complex originally called Balog-Balog Diorite by Villones and others (1979) for the diorite exposures at Balog-Balog, Tarlac. It is also well exposed at Mayantoc, Tarlac. The complex is a dike system intruding the gabbro and diabase dike swarms of the ophiolite suite. It appears to be late differentiates of the gabbro of the ophiolite and is an intrinsic part of the ophiolite complex. The Balog-Balog consists of diorite, quartz diorite, pegmatite, plagiogranite and possibly tonalite and monzonite. The diorite is fine- to coarse-grained and pegmatitic. The main diorite is light to dark gray, equigranular and contains abundant hornblende crystals. The quartz diorite is light-colored and pinkish with crystals of free quartz and potash feldspars. The coarse crystalline pegmatite contains large euhedral crystals of hornblende in a felsic matrix.

Aksitero Formation

Lithology	Lower Bigbiga Limestone – micritic limestone with tuffaceous turbidite and minor chert Upper Burgos Member – Limestone, tuffaceous sandstone, siltstone and
Stratigraphic relations	mudstone Represents the sedimentary cover of the Zambales Ophiolite Complex; unconformably overlain by the Moriones
	Formation
Distribution	Aksitero River, Bigbiga, Mayantoc, Tarlac
Age	Late Eocene – Late Oligocene
Thickness	Bigbiga limestone - 42 m, Burgos Member - 78 m
Named by	Amato (1965)

The Aksitero Formation represents the sedimentary cover of the Zambales Ophiolite. It is the oldest sedimentary formation in the west flank of the Central Luzon Basin. It was named by Amato (1965) for the exposures of pelagic limestone and clastic rocks along the upper reaches of Aksitero River in the vicinity of Bigbiga in the western foothills of Zambales Range. The limestone is thin- to thick-bedded, cream to dirty white and tuffaceous. It is interbedded with thin calcareous and tuffaceous sandy shale. Below the limestone are lenses of rounded to ellipsoidal. generally discontinuous, reddish calcareous chert (Villones, 1980). Smaller chert lenses are interbedded with the limestone and gradually disappear upsection. Amato (1965) gave an age of Late Eocene to Early Oligocene to this formation based on the presence of Hantkenina alakamensis Globorotalia cerroazulenses Calc. Globorotalia centralis Cushman. Cushman and Bermudez and Discoaster barbadiensis Tan Sin Hok in the lower part; and Globorotalia opima nana Balli and Globigerina ciperoensis angustiumbilicata Balli in the upper part. In 1984, Schweller and others (1984) divided the Aksitero into a lower Bigbiga limestone member consisting of micritic limestone interbedded with tuffaceous turbidites and an upper Burgos member of interlayered limestone and indurated calcareous and tuffaceous sandstone, siltstone and mudstone. The lower member, which is 42 m thick, was dated Late Eocene to Early Oligocene and the upper 78-m member was dated Middle to Late Oligocene. Thus the age is Late Eocene to Late Oligocene and the aggregate thickness is about 120 m. Garrison and others (1979) stated that the hemipelagic limestone and tuffaceous turbidites of the Aksitero were probably deposited at depths of at least 1000 m in a subsiding basin adjacent to an active arc system.

Lithology	Lower member – conglomerate, sandstone, siltstone Upper member – limestone, calcarenite,
	marl
Stratigraphic relations	Unconformable over ophiolite;
	conformably overlain by the Sta. Cruz
	Formation
Distribution	Cabaluan, Zambales
Age	Middle Miocene – Late Miocene
Thickness	250 m
Previous name	Zambales Limestone and Conglomerate
	(Corby and others, 1951)
Renamed by	MGB (this volume)

Cabaluan Formation

This formation was previously named Zambales Limestone and Conglomerate by Corby and others (1951) for the rocks exposed as an inverted S-shaped belt 5 km east of Naluo Point, Sta. Cruz, Zambales. It can be subdivided into a lower clastic member and an upper limestone member. Karig and others (1986) proposed to make the Cabaluan River section as a reference section, since the formation is well exposed and developed there. The formation is here renamed Cabaluan Formation, as Zambales is a non-specific locality in terms of geographic appellation. On the other hand, the Ophiolite Complex can append the name of the province since it is exposed in the greater part of Zambales. Along Cabaluan River, the lower clastic member consists of a 130-m thick sequence of conglomerate, sandstone and siltstone. Its base lies unconformably over serpentinized harzburgite. Clasts in the basal conglomerate are made up almost entirely of pebbles and cobbles of serpentinized harzburgite. Sand components of the finer clastics also consist mainly of serpentinites. In places, the clastic sequence is carbonaceous and contains fossils, including plant remains, gastropods and coral fragments. Coquina and lignite lenses are interspersed within the sequence. The conglomerates in the upper portion have smaller pebblesized clasts and sandstones become more dominant towards the top. The lower clastic member is massive to moderately bedded, in places showing cross-bedding. A littoral setting is indicated for the deposition of the lower clastic member (Karig and others, 1986).

The upper limestone member consists mainly of reefal limestone. The lower portion of the limestone member is a 20-30 m thick sequence of buffcolored, poorly bedded bioclastic limestone, which grades into medium bedded bioturbated calcareous sandstone and then into silty marl. This clastic sequence is overlain by 100 m of the main reefal limestone. This is predominantly massive and forms prominent ridge crests. The limestone grades upward into coral boulder limestone with abundant shell and coral debris to interbedded bioclastic limestone and sandy marl to mudstone.

The thickness of the formation varies widely, but the Cabaluan River section is approximately 250 m thick (Karig and others, 1986). The foraminiferal assemblage of the upper limestone member includes *Orbulina universa* indicating an age no older than Middle Miocene (Zone N9). Karig and others (1986) also report that calcarenites at the top of the limestone member yielded a foraminiferal assemblage of late Late Miocene age (Zone N17/N18).

Sta. Cruz Formation

Lithology	Lower member - mudstone and marl; Middle member – calcarenite Upper member - sandstone, siltstone, mudstone
Stratigraphic relations	Conformable over the Cabaluan Formation
Distribution	Sta. Cruz, Zambales; Bolinao, Pangasinan southward to Iba, Zambales
Age	late Late Miocene
Thickness	750 m
Previous name Renamed by	Sta. Cruz Marl (Von Drasche, 1878) Stoll (1962)

Von Drasche (1878) first named the sedimentary rocks exposed at Sta. Cruz, Zambales as Sta Cruz Marl, which was later renamed Sta. Cruz Formation by Stoll (1962). The formation can be traced along a wide belt from Bolinao, Pangasinan that thins out to the south at Iba, Zambales.

Along the Cabaluan River section, the contact with the underlying limestone member of the Cabaluan Formation is transitional. The predominantly clastic unit above the limestone of the Cabaluan Formation is considered by Karig and others (1986) as representing the Sta. Cruz Formation, which they divide into three members: lower mudstone and marl, middle calcarenite and upper turbiditic clastic sequence. Planktic and benthic foraminifera from the three members suggest a progressive deepening in the environment of deposition up to mid-bathyal depths for the middle calcarenite and upper sequence of sandstone - pebble conglomerate - tuffaceous mudstone. Karig and others (1986) report that planktic foraminifera from all three members indicate a late Late Miocene age (zone N17/N18). A thickness of at least 750 m is estimated for the whole formation, broken down as follows: 175-200 m for the lower mudstone and marl member; 50 m for the middle calcarenite; and at least 500 m for the upper clastic sequence.

Bolinao Limestone

Lithology	Limestone
Stratigraphic relations	not reported
Distribution	Bolinao, Mabini, Agno, Hundred Islands,
	Pangasinan
Age	Pliocene - Pleistocene
Thickness	250 m
Named by	MGB (this volume)

Coralline reefal limestone at Mabini, Bolinao, Agno and the Hundred Islands in Pangasinan were previously included with the Sta. Cruz Formation. However, Karig and others (1986) argue that these limestones were formed in a distinctly different environment and therefore represent another formation. They also cite a proprietary report of the Philippine Bureau of Energy Development that describes horizontal Early Pliocene limestone capping Middle to Late Miocene sedimentary sequence in Burgos. Recent samples of limestones in the Hundred Islands and in Bolinao also yielded Pliocene-Pleistocene fossils. At Mabini, Pangasinan, BEICIP (1976) reports that the limestone, with an estimated thickness of 250 m, yielded fossils, which were dated Early Pliocene (N19). In the absence of more detailed studies of these limestones, they are tentatively designated as Bolinao Limestone.

Bataan Volcanic Arc Complex

Lithology	Basalt, andesites, dacite, pyroclastic flow,
Stratigraphia relations	IUII Overling intrudes Zembeles Ophialite and
Stratigraphic relations	Torlas Formation
Distribution	Bataan peninsula; Zambales; Arayat,
	Pampanga; Amorong and Balungao,
	Pangasinan; Cuyapo, Nueva Ecija
Age	Late Miocene - Recent
Named by	MGB (this volume)

The Bataan Volcanic Arc Complex comprises the Central Luzon segment of the Luzon volcanic arc. This segment is separated from the Northern Luzon segment by the northwest trending Umingan-Lingayen branch of the Philippine Fault that separates the Central Luzon Basin from the Caraballo Range and Central Cordillera. To the south, this segment is separated from the southern Luzon segment by the "Macolod Corridor" of Defant and others (1988), a northeast-trending swath of volcanic centers transverse to the general direction of the arc. Within the Central Luzon segment, two distinct belts of volcanic centers are recognized. The western belt includes Pinatubo, Negron, Cuadrado, Bitnung, Balakibok, Santa Ritas, Natib, Samat, Mariveles, and Limay, among others. These have been extruded through the Zambales ophiolite terrane. The eastern belt. consisting of Balungao, Amorong, Cuyapo and Aravat, lie along the axis of the Central Luzon Basin upon which a thick pile of Tertiary sedimentary rocks have been laid. It is not known whether the Central Luzon Basin is floored by the Zambales ophiolite. Offshore, farther to the west, is the Manila Trench, which defines the structure along which the South China Plate is being subducted beneath the Luzon arc of the Philippine Sea Plate. A general younging of the volcanic centers from west to east is noted by De Boer and others (1980), with the western belt dating back to more than 4 Ma (Mariveles Complex) and even up to 8 Ma (Mt. Pinatubo) and the eastern belt giving a range of 1.59 Ma (Mt. Cuyapo) to 0.53 Ma (Mt. Arayat). Bau and Knittel (1993) assign a range of 7 Ma to Present for the western belt and 1.7 Ma to 0.1 Ma for the eastern belt. This suggests that volcanism was initiated in the west and progressed eastward with the subducting slab, which could have induced partial melting of the mantle during its descent. Defant and others (1988) estimate that the eastern and western belts are approximately 100-120 km and 180-200 km, respectively, above the Wadati-Benioff zone, whereas Bau and Knittel (1993) reckon that the eastern belt is 180 km above the subducting slab. The main characteristics of the eastern and western belts are tabulated below

Attributes	West	East
Depth to subducting slab	~ 100 km	~ 200 km
Number of volcanic centers	> 10	4
Alkalinity	Low to medium K	Medium to high K
Tholeiitic (T) vs calc- alkaline (CA)	Tholeiitic to calc- alkaline	Mostly calc-alkaline
Petrology	Basaltic to dacitic;	Basaltic to dacitic
	includes adakites	includes adakites

 Table 2.32 Comparison of attributes of Eastern and Western Volcanic Belts, Bataan Volcanic Belt

Western Volcanic Belt

The volcanic rocks belonging to the western Central Luzon volcanic arc are mostly andesites with minor dacites and basalts. Basaltic rocks that include those from Natib, Mariveles and Limay bear varying amounts of olivine and pyroxenes (Defant, and others, 1991). Amphibole is also present in minor amounts in the rocks examined by Defant and others (1991).

In general, the rocks of the western Central Luzon belt may be characterized as tholeiitic to calc-alkaline, low-K to medium-K basalts, basaltic andesites and andesites with minor dacites. Samples from Limay plot in the basalt field; those from Samat fall in the basaltic andesite field. Samples from Mariveles are within the basaltic andesite and andesite fields and those from Pinatubo and Mt. Boovillao in Subic are confined in the dacite perimeter. Samples from Natib span the whole range from basalt to dacite.

Balakibok Volcanic Complex (Late Miocene)

Mt. Balakibok and similar remnant strato-volcanoes, such as Mt. Cuadrado and older volcanic deposits around Mts. Mariveles and Pinatubo, represent volcanic complexes that have been dated Late Miocene. The complex consists of andesitic to dacitic volcanic domes, plugs, pyroclastic flows and proximal fall deposits and their epiclastic derivatives (Ramos and others, 2000). The basal sections of Balakibok are intruded by granodiorite and diorite porphyries.

• Mariveles Volcanic Complex (Pliocene – Recent)

The Mariveles Volcanic Complex consists of lava flows, pyroclastic flows, ashfall deposits and their epiclastic derivatives. Ramos and others (2000) recognize several sub-units such as Mt. Limay and Mt. Samat satellite cones, pyroclastic fans, and pyroclastic flows. The composition of the rocks that comprise this complex ranges from basalt to basaltic andesite to andesite. Rock samples from the Mariveles complex give radiometric age dates ranging from 4.1 Ma – 0.19 Ma (Wolfe, 1981).

Mt. Natib is probably equivalent to Mariveles. The composition of the rocks underlying Mt. Natib, however, ranges from basalt to dacite. Radiometric K-Ar dating of Natib rocks yielded ages that range from 3.9 Ma to 0.54 Ma (Wolfe, 1981).

• Pinatubo Volcanic Complex (Recent)

Mt. Pinatubo, the northernmost volcano of the western volcanic belt, belongs to an andesitic stratovolcano that produced voluminous ignimbrites (Wolfe and Self, 1983) before its eruption in 1991. Radiometric ¹⁴C dating of the pre-eruption volcanic ejecta yielded ages of 6,000 BC, 350 BC and 1342 AD (de Boer and others, 1980; Newhall and others, 1996). The 14-15 June 1991 eruption of Mt. Pinatubo ranks among the world's largest in this century, producing an estimated volume of 7-11 km³ of dacitic tephra (Bautista and others, 1991), or about 4 km³ of dense-rock-equivalent (DRE). It had a towering height of 1,745 masl before the 1991 eruption, but has been lowered to 1,445 masl after the 1991 eruption (PHIVOLCS, 1997).

The paroxysmal eruption of 15 June was preceded by a 12 June eruption that produced an andesitic dome with basalt inclusions. The

eruptions in the succeeding days extruded two types of dacitic pumice: white phenocryst-rich vesicular, and gray, phenocryst-poor pumice with small vesicles. The andesites are highly porphyritic with phenocrysts of plagioclase, hornblende, clinopyroxene, olivine and Fe-Ti oxides. Quartz xenocrysts and anhydrite are occasionally present. The fine-grained matrix consists of clinopyroxene, plagioclase, Fe-Ti microphenocrysts and brown to light gray glass. These andesites are interpreted as having been generated by the mixing of dacitic and basaltic magma.

Eastern Volcanic Belt

The volcanic mounts comprising the Western Volcanic Belt have squeezed into Late Tertiary sedimentary rocks during Pleistocene time. The sedimentary rocks through which these volcanic rocks have emerged consist of tuffaceous sandstones with minor conglomerates, which are apparently part of the Late Miocene-Pliocene Tarlac Formation. Some of their principal petrologic characteristics are summarized in the table below.

Locality	Rock Type	Alkalinity	Calc-alkaline vs. tholeiite
Arayat	Trachyandesite to Basaltic trachyandesite to Basalt	High-K to medium-K	Tholeiitic to Calc- alkaline
Amorong	Basaltic andesite to basalt	High-K to medium-K	Tholeiitic to Calc- alkaline
Balungao	Dacite - Trachyandesite	Medium-K	Calc-alkaline
Сиуаро	Trachyandesite – Andesite- Dacite	Medium-K	Calc-alkaline

 Table 2.33 Petrologic characteristics of volcanoes of Eastern Volcanic Belts, Bataan Volcanic Belt

• Mt. Arayat (Pleistocene)

Mt. Arayat consists mainly of basalt and a domal protrusion of later andesite (Bau and Knittel, 1993). The andesite reportedly contains inclusions of mafic to ultramafic xenoliths and/or cumulates (Bau and Knittel, 1993). In general, the Arayat rocks may be characterized as tholeiitic to calc-alkaline, high-K to medium-K basalts and basaltic trachyandesites with minor trachyandesites (Peña, 1998). Most of the basaltic samples from Arayat may be regarded as tholeiitic, while the trachyandesites are calc-alkaline. Radiometric K-Ar dating indicates that the latest activity of Arayat could have occurred at 0.53 Ma (Defant and others, 1993).

• Mt. Amorong (Pleistocene)

Mt. Amorong has twin peaks, which are disposed in an east-west direction. The eastern peak consists of light to medium gray, finegrained basaltic rock grading to diabase. Phenocrysts consist of pyroxene and olivine. The western peak, which has a crater, is underlain by dark gray andesite with phenocrysts of pyroxene and hornblende. Chemical analyses indicate that the volcanic rocks in the lower slopes around the western peak have closer affinity with the basaltic rocks of the eastern peak. It would appear then that the rocks from the western peak represent a later extrusive phase of the volcano. In terms of chemical composition, the rocks of Amorong are tholeiitic to calc-alakaline, medium-K to high-K basalt and basaltic andesite (Peña, 1998). An age of 1.14 Ma was obtained through radiometric K-Ar dating (Wolfe and Self, 1983).

• Mt. Balungao (Pleistocene)

Mt. Balungao is a volcanic plug characterized by a domal center consisting of andesite-dacite porphyry with prominent phenocrysts of plagioclase, which may be mistaken for quartz on cursory examination. Samples from Mt. Balungao are characteristically porphyritic, with prominent glomerophyric andesine and hornblende needles and prisms. Exposures of finer-grained andesite with less prominent phenocrysts could represent the marginal facies of the dome. Thick to medium bedded laharic conglomerate rests on the shoulder of this dome. The pyroclastic deposit evidently records a volcanic event in which the ash tuff was laid down first and then debris in the form of lahar was deposited later On the basis of chemical composition, the rocks of Balungao may be characterized as medium-K, calc-alkaline dacites and trachyandesites (Peña, 1998).

• Mt. Cuyapo (Pleistocene)

Mt. Cuyapo, with three peaks, is a volcanic plug of andesitic to dacitic composition. Fresh samples are light gray, but slightly weathered samples are buff to pinkish shades with prominent hornblende needles. Samples from Mt. Cuyapo are characteristically porphyritic, mainly oxyhornblende andesites with dacitic facies. In terms of chemical composition, the Cuyapo rocks are calc-alkaline, medium-K trachyandesite, andesites and dacites (Peña, 1998). Radiometric K-Ar dating of a sample gave an age of 1.59 Ma (Wolfe and Self, 1983).

SOUTHERN SIERRA MADRE (SG 6)

The stratigraphy of southern Sierra Madre is subdivided into two blocs, namely: (1) Polillo Group of Islands, including the coastal areas of the eastern part of the mainland (Infanta Strip), and (2) the southern Sierra Madre mainland that embraces portions of Aurora, Nueva Ecija, Bulacan, Rizal, and Quezon. Ophiolites constitute the basement of both blocs.

Table 2.8 Stratigraphic column for Southern Sierra Madre

PERIOD	EPOCH	AGE	Ма	POLILLO - INFANTA	MAINLAND
	HOLOCENE		0.0117		Manila Formation
	PLEISTOCENE	4 Late 3 Middle - 2 1 Early	0.0117 0.126 0.78 1.81		Guadalupe Formation Antipolo Basalt
	PLIOCENE	2 Late 1 Early	2.59 3.60 5.33	Karlagan Formation	
GENE		3 Late	7.25	Patnanongan Formation	
NEO	MIOCENE	2 Middle-	13.65		Madlum Formation
		1 Early	15.97 20.43	Langoyen Limestone	Angat Formation
		2 Late	23.03	Bordeos Formation	Binangonan Formation
	OLIGOCENE	1 Early	28.4	Polillo Diorite	Sta. Ines Diorite
UN EN	1	4 Late	37.2	Babacolan Formation	
PALEOGE	EOCENE	3 Middle – 2 1 Early	40.4 48.6	Anawan Formation	
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7		Maybangain Formation
EOUS	Upper	Late	05.5	Quidadanom Schist $\sim - \sim - \sim - \sim - \sim$ Buhang Ophiolitic Complex	Kinabuan Formation
CRETAC	Lower	Early	99.6	????	
JURASSIC	Upper	3 Late	161.2		
	Middle	2 Middle	175.6		
	Lower	1 Early	199.6		

SOUTHERN SIERRA MADRE

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Polillo Group of Islands – Infanta Strip

Buhang Ophiolitic Complex

Lithology	Pyroxenite, gabbro, amphibolite, pillow
Stratigraphic relations	Constitutes the basement of Polillo Island:
Stratigraphic relations	overlain by Bordeos Formation
Distribution	Buhang Point and Sabang Polillo Island;
_	Jomalig and Canaway Islands
Age	Cretaceous

Previous name	Buhang Point Meta-ophiolite (Billedo,
	1994)
Renamed by	MGB (this volume)
Correlation	Dibut Bay Metaophiolite of Isabela
	Ophiolite, Katablingan Metamorphics
	(Angeles and Perez, 1977)

The Buhang Ophiolitic Complex was named by Billedo (1994) Buhang Point Meta-ophiolite for the exposures of serpentinized pyroxenite, gabbros and minor amphibolite at Buhang Point, Polillo Island. Small exposures of isolated ultramafic rocks were also reported east-southeast of Barrio Sabang, south of Polillo town.

The volcanic carapace of the ophiolites is represented by outcrops of pillow basalts in Polillo Island, Jomalig Island and Canaway Island (at the eastern extremity of Jomalig Island). In Polillo Island, an outcrop along the beach shows pillow basalt together with its reddish pelagic interstices. It is intruded by a quartz monzonite probably belonging to the Polillo Diorite. The pillow basalts are unconformably overlain by Late Oligocene to Early Miocene arkosic limestone belonging to the Bordeos Formation. At Canaway Island, the rocks are composed of elongated chloritized and sericitized pillow basalt with reddish chert interstices. The pillow basalt and the chert seem to have undergone low-grade metamorphism characterized by greenschist facies. Jomalig Island is underlain entirely by volcanic flows and breccias, which have undergone greenschist facies metamorphism.

Radiometric K-Ar dating of a sample of highly foliated gabbro at Buhang Point was dated 63.68 ± 1.79 Ma equivalent to latest Cretaceous. Its geochemical characteristics show an island arc affinity (Billedo, 1994).

The Buhang Ophiolite is probably equivalent to the meta-ophiolites designated as **Katablingan Metamorphics** by Angeles and Perez (1977) and adopted by Revilla and Malaca (1987). It consists mainly of amphibolites with associated gabbros (Ringenbach, 1992) and exposed east of the Philippine Fault near Infanta, opposite Polillo Island. The Buhang is also correlated to the **Dibut Bay Meta-ophiolite** found in northeastern Luzon and is thought to represent the metamorphosed equivalent of the Isabela Ophiolite

Quidadanom Schist

Lithology	Tremolite-actinolite-chlorite schist,
	feldspar-mica schist phyllite
Stratigraphic relations	Unconformable over Buhang Ophiolitic
	Complex
Distribution	western part of Polillo Island
Age	Late Cretaceous
Named by	Fernandez and others (1967)
Correlation	Lubingan Formation

The Quidadanom Schist was named by Fernandez and others (1967) for the low-grade metamorphosed sedimentary rocks, including small lenses of marble exposed at barrio Quidadanom. The formation occupies the western portions of Polillo Island occurring as patches from Binibitinan

Malaki River in the north extending southwards to Barrio Masisi up to Barrio Agta on the south. In Anawan Malaki River, the Quidadanom Schist is composed of tremolite-actinolite-chlorite schist, phyllite and minor feldsparmica schist. The formation is apparently unconformable over the Buhang Ophiolitic Complex. The protolith of the Quidadanom Schist could even represent the sedimentary cover of the ophiolite.

A metamorphosed limestone sample was dated Late Cretaceous (?) on the basis of Radiolarians (Dewever, 1994). The Quidadanom Schist is correlated with the Late Cretaceous **Lubingan Formation** (see discussion under Northern Sierra Madre-Caraballo) in northeastern Luzon. The units described above are highly indurated and exhibit low-angle bedding schistosity dipping to the east.

Anawan Formation

Tuffaceous sandstone, shale, volcanic
breccia Unconformable over the Quidadanom
Schist; overlain by Babacolan Formation
Polillo Island
Early Eocene (?)
Fernandez and others (1967)
Lubi Formation (Magpantay, 1955)
Tamala Formation

The Anawan Formation was named by Fernandez and others (1967) for the volcano-sedimentary sequence at Anawan, Polillo Island. It consists of bedded tuffaceous sandstone and shale containing occasional volcanic breccia. This formation overlies unconformably the Quidadanom Schist. Fernandez and others (1967) divided the Anawan Formation into a lower volcanic member and an upper volcano-sedimentary member. The volcanic member is mainly exposed in the central portions of the island while outcrops of the sedimentary member found mainly along the western coastlines are very limited. Outcrops of basalts exhibiting pillow structures were likewise observed in barangays Tawi, Malagas and Milawid.

The lower undeformed portions of this formation, as observed northeast of Buhang Point, are made up of a basal conglomerate containing reworked clasts of gabbro, reddish pelagic limestone, greenschist, basalt, andesite and sandstone. A sub-vertical fault contact was inferred between the basal conglomerate of this formation and rocks of the Buhang Ophiolitic Complex.

The Anawan Formation has not been dated, but it rests below the Late Eocene Babacolan Formation. Considering the unconformable relation with the Quidadanom Schist and Buhang Point Ophiolite, it is considered here to have an Early Eocene age.

The Anawan Formation is equivalent to the **Lubi Formation** of Magpantay (1955) and BMG (1981). The Anawan Formation was given preference by Billedo (1994) and adopted here because the section at Anawan is considered more complete. The Anawan Formation is probably

equivalent or partly equivalent to the **Tamala Formation** on the Infanta strip opposite Polillo Island. The Tamala is a weakly metamorphosed sequence of basaltic volcanigenic conglomerates/breccias, sandstones, siltstones, basaltic flows (including pillow lavas) and minor marbleized limestones (Ringenbach, 1992). It is overlain by the **Marcelino Point Limestone**, which has been dated early Middle Eocene (Ringenbach, 1992). This limestone unit, which is a dark gray to black bioclastic limestone with numerous Nummulites and Alveolina, is considered by Ringenbach (1992) to be most likely unconformable over the Tamala Formation.

Babacolan Formation

Lithology	Limestone, calcareous shale, sandstone
Stratigraphic relations	Not reported
Distribution	Polillo Island
Age	Late Eocene
Thickness	160 m
Named by	De los Santos and Spencer (1957)

A sequence of thin lenticular bodies of limestone with interbeds of indurated dark gray calcareous shale and sandstone with interbeds of black calcareous layers were designated as Babacolan Formation by De los Santos and Spencer (1957) and adopted by BMG (1981). These lenticular limestone bodies were observed along Quinabawan Creek, Bayabas River, west of Bordeos along the shore south of Buhang Point, Panikulan and along the western and southern flanks of Anibawan River valley. The thickness of the formation was estimated to be 160 m. A sample of this limestone collected in Babacolan Creek, north of Bordeos, yielded Late Eocene assemblages as indicated by the presence of several species of *Pellatispira* and *Discocyclina* (BMG, 1981).

Billedo (1994) considers the limestone bodies as the upper member of the Anawan Formation and designated it as the *Babacolan Limestone Member*. The formation is reported to lie unconformably over the Lubi Formation of Magpantay (1955) and BMG (1981).

Polillo Diorite

Lithology	Quartz diorite, hornblende-biotite diorite, minor granodiorite, gabbro and aplites
Stratigraphic relations	Intrudes the Anawan Formation
Distribution	Polillo Island
Age	Early Oligocene
Named by	Fernandez and others (1967)
Synonymy	Bislian Quartz Diorite (Magpantay, 1955)
Correlation	Lupa Granodiorite (Revilla and Malaca,
	1987)

The Polillo Diorite was named by Fernandez and others (1967) for the plutonic intrusive complex intruding the Anawan Formation in the southern axial portion of the Polillo Island. The leucocratic rock in the southern Polillo Island named Bislian Quartz Diorite (Magpantay, 1955) refers to the same

intrusive body (BMG, 1981). The largest intrusive mass is exposed from Mount Malolod to the southern tip of Polillo Island (BMG, 1981).

Detailed investigation by geologists of Essex Mineral Company led to the distinction of five main types of intrusive rocks plus a number of subtypes (Burton, 1985). The main types consist of: (1) quartz diorite, (2) granodiorite, (3) granodiorite-monzonite, (4) a plug of quartz monzonite, and (5) quartz monzonite porphyry. Gabbroic phases occur as thin layers, and aplites as thin dikes. It is believed that these rocks are comagmatic and were probably intruded in the order as enumerated above, derived from a calc-alkaline magma of gabbroic composition (Tulleman's written communication to Burton, in Burton, 1985). Quartz diorite and hornblendebiotite diorite predominate over other associated phases of the intrusive.

The diorite consists principally of intermediate feldspar (70%) and minor hornblende (15%) and quartz (10%). Accessory minerals are sericite, magnetite, pyrite and apatite. The granodiorite phase crops out near contact zones. The granodiorite has about 10% potash feldspar, mainly anhedral orthoclase and rarely perthites. Ferromagnesian minerals are fresh green hornblende and minor amounts of chlorite and biotite. Intermediate plagioclase is about 40% and quartz is 20% of the rock volume. Accessory minerals are apatite, magnetite, zircon and epidote.

Radiometric Rb-Sr dating of this intrusive was reported by Knittel (1985) to be 34.4 ± 1.2 Ma (early Early Oligocene).

The **Lupa Granodiorite** of Revilla and Malaca (1987) could be equivalent to the Polillo Diorite.

Bordeos Formation

Lithology	Sandstone, shale and conglomerate with
	limestone lenses and coal seams
Stratigraphic relations	Unconformable over the Babacolan
	Formation
Distribution	Polillo Island
Age	Late Oligocene – Early Miocene
Thickness	160 m (maximum)
Named by	Magpantay (1955)

The Bordeos Formation, which was designated by Magpantay (1955), is found mainly on the eastern side of Polillo Island, where it forms an irregular sinuous belt extending from Barangay Maknit on the south to Anibawan River on the north. It is composed of well-bedded sandstone, shale and conglomerate with limestone lenses and coal seams (measuring an average of 35 cm thick and 8 m long) near the base. Sandstone dominates the series and is pale to dark gray in color, having clasts mostly of volcanic provenance and is often pebbly and sometimes grades into conglomerate. Minor limestone interbeds rarely exceed 10 m in thickness. The Bordeos Formation unconformably rests on the Babacolan Formation and the Polillo Diorite (Fernandez and Abarquez, 1967; Knittel, 1985). A well-defined unconformity is observed at the base of the Bordeos Formation, which is traceable for several kilometers. The thickness of this formation ranges from 15 m to 160 m. Alberding (1939), Magpantay (1955),

De los Santos and Spencer (1957) and Fernandez and others (1967) date the Bordeos as Early to Middle Miocene. However, BMG (1981) reexamined the fossils obtained from previous samples and found out that the age of this formation was actually Late Oligocene to Early Miocene. Microfossils in arkosic limestone sampled by Billedo (1994) also indicate a Late Oligocene to Early Miocene age for the formation.

Langoyen Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Bordeos
	Formation
Distribution	eastern coast of Polillo Island
Age	late Early Miocene – early Middle Miocene
Thickness	56 m (maximum)
Named by	Billedo (1994)

A limestone body underlying low gentle hills and scattered as small patches along the eastern coast, north and south of Bordeos was designated by Billedo (1994) as Langoyen Limestone. The Langoyen Limestone appears to be discontinuous, lenticular, and partly coralline, with a maximum thickness of 56 m. It crops out along Bordeos River, Sumuot Creek and at Sabang within the municipality of Bordeos. The limestone unconformably overlies a thin sequence of dark gray to green sandstone belonging to the upper portions of the Bordeos Formation. The unconformity is marked by a slight angular discordance, characterized by minor differences in the strike and dip of the beds near the contact. A dating of early Middle Miocene was assigned by BMG (1981) for this formation on the basis of large foraminifera (*Miogypsina, Lepidocyclina* and *Austrotrillana*) contained in some samples. An age range of late Early Miocene to early Middle Miocene is adopted here on the basis of recent determinations reported by Billedo (1994).

Patnanongan Formation

Lithology	Sandstone, shale, conglomerate,
	limestone, calcarenite
Stratigraphic relations	Not reported
Distribution	Patnanongan Island; Palasan and
	Karlagan Islands
Age	early Middle Miocene – Late Miocene
Thickness	350 m
Named by	Fernandez and others (1967)

The Patnanongan Formation was first described by Fernandez and others (1967) after the sedimentary sequence observed in the island of Patnanongan, east of Polillo Island. The bulk of the Patnanongan Formation is largely exposed in Patnanongan Island, the type locality, in Palasan Island, and east of Karlagan represented by small and scattered inliers of limestone patches in the Pliocene Karlagan Formation. The formation is composed of brown to gray, slightly indurated interbedded sandstone, shale, calcarenite, limestone and a molasse-type conglomerate. Molluscan fossils are present in the sandstones and shale beds. The limestone is of two types. The first is massive, buff to flesh to brown, hard, fine- to medium- grained and with abundant shells. The other is massive to crudely bedded with colors ranging from brown to flesh, cream and pink. The conglomerate contains pebbles and cobbles of previously emplaced and deposited rocks including the Langoyen Limestone. The formation can be divided into a lower sequence made up mostly of green calcareous sandstone and mudstone and an upper member consisting largely of molasse type conglomerate. The average thickness of this formation is 350 m. This sedimentary sequence was given an age ranging from late Middle Miocene to Late Miocene (BMG, 1981). Billedo (1994) reports a nannoplankton age dating of early Middle Miocene for the lower part of this formation. An age range of early Middle Miocene to Late Miocene is adopted here.

Karlagan Formation

Lithology	Shale and mudstone with occasional
	lenses of conglomerate and limestone
Stratigraphic relations	Unconformable over older formations
Distribution	Karlagan Island; Polillo Island
Age	Pliocene
Thickness	Not reported
Named by	Fernandez and others (1967)

The youngest formation, which blankets Karlagan Island and the northern portions of Polillo Island, is known as the Karlagan Formation (Fernandez and others, 1967). This rock unit is composed of pale to dark gray fossiliferous shale, mudstone, occasional lenses of conglomerate and limestone. Outcrops are characterized by a near-horizontal alternating sequence of thinly (few centimeters) to thickly bedded (2 m) shale and mudstone, with occasional lenses of conglomerate. The shale and mudstone are well-bedded, brown to dark gray and fossiliferous. The limestone is cream to flesh, coralline and fossiliferous. Fossil assemblages indicate a Pliocene age. The Karlagan Formation rests unconformably over the older rock units on Polillo Island.

Southern Sierra Madre Mainland

Montalban Ophiolitic Complex

Lithology	Gabbro, sheeted diabase dike complex, pillow basalt, pelagic sedimentary rocks, plagiogranite
Stratigraphic relations	Constitutes the basement of southern Sierra Madre
Distribution	Montalban, Rizal, Bulacan, Nueva Ecija
Age	early Late Cretaceous
Previous name	Angat Ophiolite (Karig, 1983)
Renamed by	MGB (this volume)

The oldest rocks in Southern Sierra Madre comprise an incomplete ophiolitic sequence called Angat Ophiolite by Karig (1983) for the gabbros exposed at Angat, Bulacan. Exposures of the components of the ophiolite define a nearly north-south belt from Montalban, Rizal through eastern Bulacan to Nueva Ecija, just south of the Laur-Dingalan portion of the Ringenbach (1992) asserts that the best known Philippine Fault. exposures are found in the Montalban area. Because of the precedence of the name Angat for the Early-Middle Miocene sedimentary rocks in the locality, the name Montalban Ophiolitic Complex is here proposed to replace the appellation of the ophiolitic unit. The ophiolitic sequence consists of layered and massive gabbro, sheeted diabase dike complex, pillow basalts and turbiditic sedimentary rocks (Arcilla, 1983). The gabbros include low level layered gabbro and upper level isotropic norites and olivine gabbros. Minor plagiogranites are localized at gabbro-diabase contacts. Arcilla (1983) proposed the name COGEO Basalt for the pillow basalts, which are typically exposed at COGEO (Confederation of Government Employees Organizations) housing area and vicinity, including Nangka River. Other good exposures could be found in Angono. Tavtav. Wawa area, as well as Puray and Tayabasan rivers. Pillow structures of the basalt average 1-1.5 m. The lower section of the basalt apparently grades into sheeted dike complex, while the upper sections are interlayered with thin beds of ferruginous, siliceous red mudstone (Arcilla, 1983, 1991). The aggregate thickness of the pillow basalts exceeds 300 m in some sections (Arcilla, 1983). According to Arcilla (1991), the lower basalts of the ophiolite have MORB characteristics while the upper andesite-basalt section has an Island Arc Tholeiite (IAT) signature. The sedimentary cover of the ophiolitic sequence is separately designated as the Kinabuan Formation.

A Turonian age (early Late Cretaceous) based on paleontologic dating of red siliceous mudstone intermixed with pillow basalt was reported by Revilla and Malaca (1987). Similarly, Arcilla (1991) gives a Turonian-Coniacian age for the turbidites just above the pillow basalts along Tayabasan River, on the basis of radiolarians and pelagic foraminifera. The Montalban is therefore dated early Late Cretaceous.

The **Barenas-Baito Formation** (see description under Central Luzon Basin-East) of Revilla and Malaca (1987) is a volcanic-sedimentary sequence, which includes the pillow basalts of the Montalban Ophiolitic Complex.

Kinabuan Formation

Lithology	Sandstone, shale, limestone, calcarenite, calcilutite
Stratigraphic relations	Comprises the sedimentary cover of the
	Montalban Ophiolitic Complex; overlain by
	the Maybangain Formation
Distribution	Kinabuan Creek, Sta. Ines, Antipolo, Rizal;
	Tatlong K, Pinugay (Philcomsat), Macaira,
	Sampaloc-Daraitan road and along
	Malinaw, Alas-Asin, Toyang and
	Mamuyao creeks
Age	Late Cretaceous
Thickness	> 800 m
Named by	Melendres and Versoza (1960)
Synonymy	Barenas-Baito Formation (Revilla and
	Malaca, 1987)

Tamala Formation (Angeles and Perez, 1977)

The Kinabuan Formation was named by Melendres and Versoza (1960) for the flysch-like sedimentary deposits along Kinabuan Creek, a tributary of Lenatin River, north of Santa Ines, Antipolo, Rizal. The basal part of the sedimentary sequence is associated with underlying pillow basalts and basaltic breccias. The basalts represent the volcanic carapace of the ophiolite, whereas the pelagic sedimentary sequence constitutes the sedimentary cover of the Montalban Ophiolitic Complex. This sedimentary sequence consists of thinly interbedded silty shale and calcareous sandstone with tuffaceous and siliceous layers capped by steeply dipping thin beds of limestone. Outcrops of the Kinabuan can also be found in Tatlong K, Marcos Highway from Masinag to Foremost Farms, Pinugay (Philcomsat), Macaira, Sampaloc-Daraitan road and along Malinaw, Alas-Asin, Toyang and Mamuyao creeks. The sedimentary sequence of Kinabuan has an estimated thickness of 800 m. Although the formation has not formally been subdivided, it is clear that there is a lower volcanic member, middle sandstone-shale member and an upper limestone member

Haeck (1987) described the lower part of the sedimentary sequence as composed of tan to gray, fine to medium-grained calcarenite and calcisilitie, buff to gray pelagic limestone and much less common, tan, medium- to coarse-grained calcareous lithic to feldspathic arenite interbedded with black organic to light gray calcareous shale.

The upper limestone member (Reyes and Ordoñez, 1970) is composed of white to buff (weathered), light to dark (fresh) pelagic limestones and minor light to dark gray calcarenite and calcisilitie with rare interbeds of calcareous shale. The limestones contain radiolarians, indicating a bathyal depositional environment (Ringenbach, 1992).

The Kinabuan has been dated Santonian to Early Maastrichtian based on planktonic foraminifera (Reyes and Ordonez, 1970; Hashimoto and others, 1979; Haeck, 1987). However, Arcilla (1992) reports a Turonian age for the formation on the basis of radiolarians and pelagic foraminifera.

The **Barenas-Baito Formation** (Revilla and Malaca, 1987) and **Tamala Formation** of Angeles and Perez (1977) are probably equivalent to the Kinabuan Formation.

Maybangain Formation

Lithology	Masungi Limestone member,
	Clastic-volcanic member – volcanic
	breccia, sandstone, siltstone, mudstone,
	conglomerate
Stratigraphic relations	Conformable over the Kinabuan
	Formation; unconformably overlain by the
	Binangonan Formation
Distribution	Maybangain Creek, Sampaloc, Antipolo,
	Rizal; Umiray, Limutan and Makalya

	Rivers; at Alas-asin, Macaira and along
	the Tanay-Daraitan road
Age	Middle Paleocene – Middle Eocene
Thickness	over 2,500 m
Named by	Melendres and Verzosa (1960)
Synonymy	Kanan Formation (Revilla and Malaca,
	1987), Marcelino Point Limestone
	(Ringenbach, 1992)
Correlation	Bayabas Formation (Revilla and Malaca,
	1987)

Conformably overlying the Kinabuan Formation is the Maybangain Formation. The name was introduced by Melendres and Versoza (1960) for the rocks typically exposed along Maybangain Creek between sitios Batangas and San Andres, Sampaloc, Tanay, Rizal. The type locality is about 3.5 kilometers north-northeast of Mt. Masungi. The formation crops out at the Midland Cement Company quarry site, along Umiray, Limutan and Makalya rivers, at Alas-asin, Macaira and along the Tanay-Daraitan road. Conformably overlying the Kinabuan, this formation consists of the lower Masungi Limestone Member and an overlying or partly intertonguing clastic-volcanic member.

A study by Ocampo and Martin (1967) regards the **Masungi Limestone** as biohermal. However, exposures encountered by Haeck (1987) are interpreted to be lower-slope or basin margin deposits in a forereef setting. The outcrops consist mainly of redeposited limestones, including debris flows and turbiditic strata, which are interbedded with calcareous and non-calcareous mudstones and minor volcaniclastic rocks. Ringenbach (1992) considers the biohermal limestone of Ocampo and Martin (1967) as an olistolith of the volcaniclastic member.

The clastic-volcanic member consists mostly of a thick sequence (more than 2,500 m) of volcanic and clastic rocks. It occupies much of the area west of the Masungi Limestone. It also occurs less extensively along Tanay River from Daranak Falls upstream to the western vicinity of Dagatdagatan. Schoell and Duyanen (1988) distinguish four sub-members. The Kay-ibon sub-member is a 1,200-m thick pile of turbiditic volcanogenic sandstones and siltstones with minor mudstones. This sub-member contains two major olistostromes, the lower layer consisting of the Masungi Limestone and the upper layer having gravity slides and olistoliths of the Kinabuan Formation. The Susongdalaga sub-member is a 400-m thick sequence of sandstones, volcanic breccias and conglomerate. The Kanumay sub-member is 900-m of turbiditic sandstones and siltstones while the uppermost 250-m thick San Ysiro sub-member is similar to the Susongdalaga.

The Maybangain Formation is probably equivalent to the Eocene Formation of Antonio (1967) in Sta. Ines, Antipolo, Rizal and the **Bayabas Formation** of Revilla and Malaca (1987) in the eastern part of the Central Luzon Basin.

An age range of uppermost Paleocene (Thanetian) to Middle Eocene (Lower Lutetian) was formerly assigned to this formation (BMG, 1981) on the basis of larger foraminifera as reported by Reyes and Ordoñez (1970)
and Hashimoto and others (1979). Haeck (1987) finds fossils of Middle Paleocene (*Igorina pusilla pusilla*) to Middle Eocene (*Globigerinatheca subconglobata*) ages in calcareous turbidites of the Masungi Limestone member of this formation. More recently Ringenbach (1992) gives a dating of Early/Middle Paleocene (*Subbotina pseudobulloides*) to Late Paleocene (*Igorina pusilla, Planorotalites pseudomenardii*) for the pelagic limestones west of Umiray, which he considers as part of the Masungi Limestone member of the Maybangain. An age range of Early/Middle Paleocene to Middle Eocene was adopted by MGB (2004) for this formation.

The **Marcelino Point Limestone** north of Infanta (Ringenbach, 1992) is probably equivalent to the Masungi Limestone. The **Kanan Formation** of Revilla and Malaca (1987), consisting of basaltic and andesitic volcanic rocks and volcaniclastics, is probably equivalent to the volcano-clastic member of the Maybangain Formation.

Sta. Ines Diorite

Lithology	Hornblende diorite; minor quartz diorite
Stratigraphic relations	Intrudes Kinabuan and Maybangain
	Formations
Distribution	Antipolo-Teresa road; Mt. Masarat at Sta.
	Ines; Mt. Mayapa, Mt. Retablo and Mt.
	Maon at Bulacan; Putingbato and
	Kaybagsik, Antipolo; along upper Mangga
	Creek (tributary of Madlum River),
	Talaguio River and Ipunan Creek (tributary
	of Angat River), Singalong Creek and
	upper Maputi and Magsuong Rivers
Age	Late Eocene
Previous name	Antipolo Diorite (BMG, 1981)
Renamed by	MGB (this volume)

The diorite intruding Cretaceous to Eocene sedimentary units along the Antipolo-Teresa road was designated by BMG (1981) as Antipolo Diorite. It is here renamed Sta. Ines Diorite. The Sta. Ines Diorite was named by Antonio (1967) for the exposures at Mt. Masarat in barrio Sta. Ines, Tanay, Rizal. The diorite, which intrudes limestone and clastic rocks, is associated with pyrometasomatic deposits of iron ore.

At Sta. Ines, the diorite occurs as a stock measuring about 3 km along its length on the eastern and northeastern slopes of Mt. Masarat. A much bigger body, however, underlies Mt. Mayapa and Mt. Maon in Doña Remedios Trinidad and Norzagaray, Bulacan. Exposures of the diorite are also found around Mt. Retablo; at Putingbato and Kaybagsik, Antipolo; along upper Mangga Creek (tributary of Madlum River), Talaguio River and Ipunan Creek (tributary of Angat River), Singalong Creek and upper Maputi and Magsuong Rivers (Revilla and Malaca, 1987). The dominant rock type is medium- to coarse-grained hornblende diorite with local quartz diorite, gabbro and diabase facies. Diorite also occurs as dikes and sills intruding sedimentary rocks. Antonio (1967) presumed that the sedimentary rock intruded by the diorite is equivalent to the Early Miocene Angat Formation. Revilla and Malaca (1987), however, report that the Angat Formation rests unconformably over the diorite in Bulacan. Radiometric K-Ar dating (36.9 Ma) reveals an Early Eocene age for the diorite (Wolfe, 1981).

Binangonan Formation

lower Teresa Siltstone member – siltstone, marl
upper Limestone Member
Unconformable over the Maybangain Formation
Binangonan, Teresa, and Antipolo in
Rizal; Coronel River and Mt. Dalumpa
west of Ligaya and Gabaldon, Nueva Ecija
Late Oligocene – Early Miocene
Teresa Siltstone – 350 m, Limestone –
900 m
Binangonan Limestone (Smith, 1906)
BMG (1981)
Maysawa Formation (Haeck, 1987),
Montalban Formation (Baumann and
others, 1976)
Bugnam Formation (Rutland, 1968), Villa
Wave Formation (Rutland, 1968)

The Binangonan Limestone of Smith (1906) was renamed by BMG (1981) as Binangonan Formation to include the Teresa Tuffaceous Silt of Corby and others (1951), which is here called Teresa Siltstone. The Binangonan Formation rests unconformably over the Maybangain Formation. On its western side, the formation is in fault contact with the Antipolo Diorite (Foronda and Schoell, 1987). Outcrops of Binangonan Formation are exposed in Binangonan, Teresa, and Antipolo, all in Rizal Province. Exposures were also observed on the N-S tributaries of the Coronel River, which flow in the Gabaldon Basin and also at Mt. Dalumpa.

The Teresa Siltstone and the limestone are treated here as the lower and upper members, respectively, of the Binangonan Formation. The **Teresa Siltstone** is essentially a 350-m thick sequence of tuffaceous calcareous siltstones and marl deposited by turbidity currents in a shallow basin (Schoell and Fuentes, 1989; Schoell and Casareo, 1989). The overall sedimentological characteristics of the unit, as observed by Foronda and Schoell (1987), suggest that the unit represents shallow water proximal turbidites. The **upper Limestone Member** is massive, light cream to pink to bluish gray and fossil-rich. This carbonate unit, which attains a thickness of 900 m, represents deposits of shallow-water reef complexes.

This formation shows facies variations in the northern part of the Southern Sierra Madre. Along the tributaries of Coronel River and Mt. Dalumpa west of Ligaya and Gabaldon, Nueva Ecija, the formation is characterized by smaller proportions of limestones compared with associated clastic rocks consisting of conglomerates, tuffaceous sandstones, siltstones and mudstones. West of Umiray, the limestone is locally more than 300 m thick topped by sandstones and conglomerates with reworked limestone clasts (Ringenbach, 1992). In Bugnam Creek east of Dalumpa Peak, volcanic rocks have been observed to be interbedded with the volcaniclastics of the Binangonan Formation (Ringenbach, 1992). Coal beds and lenses have also been noted by Revilla and Malaca (1987) in the sandstone-shale sequences in Makalya and Lagmak areas.

Previously this formation was assigned a Late Oligocene age (BMG, 1981) based on datings by Smith (1906), Yabe and Hanzawa (1929) and Hashimoto and Balce (1977). However, recent paleontological dating of samples from this formation reveals that it extends up to Early Miocene (Foronda and Schoell, 1987; Revilla and Malaca, 1987; Ringenbach, 1992). Radiometric K-Ar dating of a basalt flow associated with this formation gave 22.92 ± 1.12 Ma, equivalent to earliest Miocene (Ringenbach, 1992). An age range of Late Oligocene to Early Miocene is now adopted for this formation.

The **Maysawa Formation** of Haeck (1987) is considered to be a deeper facies of the Binangonan Formation although it does not have a clastic member. Also probably equivalent to the Binangonan Formation is the 1,300-m thick **Montalban Formation** of Baumann and others (1976), which consists of a basal limestone member, a late Late Oligocene wacke-mudstone member and an uppermost early Miocene micritic limestone member. In the northern part of Southern Sierra Madre, the Binangonan Formation is also probably equivalent to the **Bugnam** and **Villa Wave** formations of Rutland (1968), which consist of dark shales, conglomerates and minor limestones.

Angat Formation

Lithology	Lower clastic member – shale, sandstone, sandy limestone, Upper limestone member
Stratigraphic relations	Overlies Barenas-Baito, Bayabas and Binangonan formations and the Sta. Ines Diorite; conformably overlain by the Madlum Formation
Distribution	Angat River, Camachile River in Bulacan
Age	Early Miocene
Thickness	1,950 m
Previous name	Angat Limestone member of Quezon Formation
Named by	Corby and others, 1951)
Renamed by	Gonzales and others (1971)

Corby and others (1951) originally assigned the term Angat to the lower limestone member of the Quezon Formation in the Angat River area. Gonzales and others (1971) raise the rock unit to formation rank and included a lower clastic facies. The formation's type locality is along Angat River roughly 6 km east of Norzagaray. Along the western flank of Sierra Madre, the formation forms a more or less continuous and approximately north-south belt, which splits into two at the Camachile River in eastern Bulacan. The smaller western edge ends at Balite Creek about 4 km northeast of Norzagaray and the eastern strip stretches for about 1.5 km south of Angat River. In addition, outcrops of the formation have also been observed along the Rio Chico and Sumacbao rivers on the northwestern flank of the southern Sierra Madre. The thickness of the formation varies from one locality to another, but its maximum exposed thickness is about 1,950 meters. The formation consists of a lower clastic member representing a minor part of the formation and an upper limestone member.

The clastic member is made up of thin beds of calcareous shale and clayey sandstone with occasional lenses of sandy limestone. The sandstone is normally graded and well-cemented while the limestone lenses are dense, brittle and partly siliceous. Mollusks, coral stems and laminae of carbonaceous materials are dispersed within the section. These, together with the abundance of *Heliocosphaera* species, suggest shallow marine deposition. The sequence interfingers with the lower part of the upper limestone facies.

The limestone member is made up of a lower bedded reef-flank deposit and an upper biohermal mass. This member is characterized by local thickening and thinning over a fairly continuous belt. The lower bedded portion is dominantly calcareous rock detrita and fine slime with interbedded, finely siliceous layers. The biohermal portion is white to buff, occasionally gray to pink, cavernous and partly crystalline, consisting essentially of skeletal remains of reef-building organisms (corals and algae) with abundant molluscan fragments and bryozoan stems. Along Madlum River, the biohermal portion is approximately 100 m thick.

Recent age dating reported by Ringenbach (1992) conforms to the results obtained by Gonzales and others (1971) and Baumann and others (1976) indicating a late Early to early Middle Miocene age. Moreover, a sample from Minalungao yielded *Lepidocyclina* (Nephrolepidina) sumarensis and many Miogypsina sp., which point to a Late Burdigalian age. Likewise, pelagic foraminifera from the pelites in the clastic member taken along Rio Chico gave a precise Late Burdigalian age based on Globigerinatella insueta. Villanueva and others (1995) also report the presence of Globigerinoides sicanus De Stefani in the clastic facies, as as nannofossils including Heterosphaera mediterranea and well Sphenolithus cf. heteromorphous, which indicate an age of NN4-NN5, probably NN4, equivalent to Early Miocene (Burdigalian). Recent studies by Villanueva and others (1995) also indicate an Early Miocene age for the limestone based on the presence of Cycloclypeus (K.) transiens. Abundant large foraminifera, corals, algae and molluscan remains in the limestone and carbonaceous materials in the clastic facies indicate deposition in a shallow neritic environment.

Madlum Formation

Lower Clastic Member – sandstone, shale, conglomerate
Middle Alagao Volcanics - pyroclastic
breccia, tuff, argillite,
indurated graywacke and andesite flows,
Upper Buenacop Limestone Member
Conformable over the Angat Formation

Distribution	Madlum River, San Miguel, Bulacan;
	Angat and Peñaranda rivers, Bulacan;
	San Ildefonso, Bulacan
Age	Middle Miocene
Thickness	> 1,000 m
Named by	Williams (1960)
Synonymy	Sibul Formation (Corby and others (1951)

The Madlum formation conformably rests on top of the Angat Formation. This was first used by geologists of the San Jose Oil Company (Williams, 1960 in Gonzales and others, 1971) to designate the sequence of shale, siltstone, wacke and conglomerate exposed along Madlum River close to Barangay Madlum, San Miguel, Bulacan. They also included in this formation the upper metavolcanic member of the Sibul Formation and upper tuffaceous member of the Quezon Formation of Corby and others (1951) exposed in the Angat River area. Melendres and Verzosa (1960) subdivided the Madlum into the Angat River Limestone, Alagao Volcanics and Buenacop Limestone members. The middle and upper members were retained by Gonzales and others (1971) but changed the Angat River Limestone to Clastic Member.

• Clastic Member

The *Clastic Member* is extensively distributed in an almost continuously exposed belt between Angat and Peñaranda rivers. It is a thick sequence of thin to thick bedded sandstone and silty shale with minor basal conglomerate and occasional limy sandstone interbeds. The sandstone is fine- to medium-grained, fairly well-sorted, well-cemented and calcareous, with sub-anglar to subrounded fragments of mafic rock detrita, quartz and feldspar cemented by fine clayey material. The shale, which occurs in thinner beds compared to the sandstone, is calcareous. The basal conglomerate is massive with well rounded cobbles and pebbles of mafic igneous rocks, chert and limestone dispersed in a coarse calcareous matrix.

Two foraminiferal zones have been recognized in the Clastic Member by Villanueva and others (1995): *Globorotalia fohsi peripheroronda* Zone (N6-N10) and *Globorotalia fohsi fohsi* Zone (N10-N11) equivalent to Langhian, which were earlier reported by Gonzales and others (1971).

• Alagao Volcanics

Melendres and Verzosa (1960) used the term *Alagao Volcanics* to designate the sequence of pyroclastic breccia, tuffs, argillites, indurated graywacke and andesite flows exposed in Alagao, San Ildefonso, Bulacan. Its type locality, as designated by Gonzales and others (1971), is the section along the San Ildefonso-Akle road. The metavolcanic member of the Sibul Formation of Corby and others (1951) and the andesite-basalt sequence in the Rodriguez-Teresa area, Rizal, are included in this member. Generally, the rock unit is purplish gray in fresh surfaces but weathers into brick-red to purple shades. The pyroclastic breccia, the prevalent rock type, is massive and made up of angular to subrounded cobble to boulder sizes of andesite, basalt, chert and other volcanic rocks

set in a matrix of andesite. The tuffaceous beds weather into bentonitic clay. The volcanic flows are massive, fine-grained and vesicular. The vesicles are filled with calcite, chalcedony or chlorite. Along Bayabas River, the estimated thickness is about 175 m, although it could be thicker along Angat River further south.

• Buenacop Limestone

The *Buenacop Limestone* was originally used by Melendres and Verzosa (1960) to designate the limestone sequence exposed at Barangay Buenacop, San Ildefonso, Bulacan with type section along Ganlang River. It also occurs as narrow discontinuous strips formed by a series of almost north-south aligned low ridges and several small patches between Sta. Maria and Sumacbao rivers. The limestone in the lower part is thin to medium bedded, crystalline, slightly tuffaceous, porous with numerous fragments of volcanic rocks, chert nodules, and detrital crystals of mafic minerals. This characteristic distinguishes it from the other limestones in the area. The upper part is massive, cavernous, with dispersed occasional andesite fragments, volcanic debris and fossils of reef-building organisms such as corals, algae, mollusks and foraminifera. Fossils indicate an age of Middle Miocene for this limestone member, which was probably deposited in a shelf area. The estimated thickness at the type locality is 150 m.

Samples of the Buenacop Limestone yielded a number of foraminifera, including *Miogypsina polymorpha, Cycloclypeus (Metacycloclypeus) transiens, Lepidocyclina (N.) sumatrensis* and *L. (N.) ferreroi.* Thus an age of Middle Miocene is assigned to the Madlum Formation, although deposition could have started in early Middle Miocene. Deposition might have taken place in a progressively deepening environment probably from shelf-edge to upper bathyal depths. It is over 1,000 m thick in the type locality.

Guadalupe Formation

Lithology	Alat Conglomerate – conglomerate, silty
	mudstone, tunaceous sandstone
	Diliman Tuff – vitric tuff, ignimbrite,
	volcanic breccia
Stratigraphic relations	Unconformable over Miocene rocks
Distribution	Quezon City, Pasig, Makati; southern
	Rizal; eastern Bulacan; southeastern
	Nueva Ecija
Age	Pleistocene
Thickness:	1,500 - 2,000 m
Named by	Smith (1913)
Correlation	Laguna Formation (Schoell and others,
	1985), San Juan Formation (Rutland,
	1968)

This formation was named by Smith (1913) for the tuff sequence that crops out along Pasig River in Guadalupe, Makati, Metro Manila, which was earlier described by Von Drasche (1878). In the Angat-Novaliches region, Alvir (1929) describes the same sequence but referred to it as

Guadalupe Tuff Formation. Corby and others (1951) call it Guadalupe Tuffs and Teves and Gonzales (1950) adopt the name Guadalupe Formation with two members: a lower Alat Conglomerate and an upper Diliman Tuff member. The formation unconformably overlies Miocene rocks and on the basis of the presence of *Stegodon* fossils and other vertebrate remains, leaf imprints and artifacts, it is assigned a Pleistocene age.

• Alat Conglomerate

The *Alat Conglomerate* was first mapped and named by Alvir (1929) after the marine littoral conglomerate exposed along Sapang Alat about 3 km north of the Novaliches reservoir near Novaliches town where it unconformably overlies Miocene lavas. The Alat consists of massive conglomerate, deeply weathered silty mudstone and tuffaceous sandstone. Poorly sorted conglomerate, which is the most predominant rock type, consists of well rounded pebbles and small boulders of older rocks, including diorite, gabbro, basalt, andesite and limestone cemented by coarse-grained, calcareous sandy matrix. The interbedded sandstone is massive- to poorly- bedded, tuffaceous, fine- to medium-grained, loosely cemented, friable and exhibits cross bedding. The mudstone is medium to thin bedded, soft, silty and tuffaceous. The maximum estimated thickness of this member is 200 m. Ringenbach (1992) notes that the **San Juan Formation** of Rutland (1968), exposed southeast of Laur, is very similar in facies to the Alat Conglomerate.

• Diliman Tuff

The *Diliman Tuff* (Teves and Gonzales, 1950) exposed in Diliman, Quezon City and large portions of Makati, Pasig, Paranaque and adjoining areas, consists of volcanic ejecta with subordinate amounts of tuffaceous, fine- to medium-grained sandstone. It also underlies areas between Sta. Maria and Bulu rivers in Bulacan. Fossil plant leaves of the genus *Euphorbliaceae*, deer and elephant teeth, and bits of wood recovered in Guadalupe and Novaliches suggest a Pleistocene age.

The whole sequence is flat-lying, medium- to thin-bedded and consists of fine-grained vitric tuffs and welded pyroclastic breccias with minor fineto medium- grained tuffaceous sandstone. Dark mafic minerals and bits of pumiceous and scoriaceous materials are dispersed in the glassy tuff matrix. The thickness of the Diliman Tuff is 1,300-2,000 m.

More recent work in the area suggests that the **Laguna Formation** of Schoell and others (1985) is equivalent to the Guadalupe Formation. Schoell and others (1985) defined several facies of the Laguna Formation, as follows: a) air fall tephra, b) pyroclastic flow deposits, c) lahars, d) stream deposits, e) lake deposits, and f) basalt flows. Radiometric K-Ar and palynological datings give a Late Pliocene to Early Pleistocene age for this formation (Wolfe, 1981).

Antipolo Basalt

Lithology Basalt Stratigraphic relations Not reported

Distribution	Antipolo, Binangonan, Talim Island,
	Taytay, Morong in Rizal
Age	Pleistocene
Named by	Alvir (1928)

The Antipolo Basalt was named by Alvir (1928) for the basaltic rocks exposed on the hills around Antipolo, although the rock was already described earlier by Adams (1910). The rock is also exposed in surrounding areas such as Binangonan, Morong, Angat-Novaliches area and Talim Island. The basalt is frequently brecciated and in places amygdaloidal. The age is believed by Alvir (1928) to be Miocene, although it could be as late as Pleistocene in view of the very low degree of erosion despite its location on an elevated plateau in the Antipolo hills. Remnants of the wasting of the basalt terrain are manifested as scattered columns of basalts in Antipolo and vicinity, suggesting that the basalt was deposited as thick lava flows that underwent columnar jointing.

Manila Formation

Clay, silt, gravely sand, tuffaceous silt
Overlies the Diliman Tuff
Metro Manila
Holocene
800 m
Purser and Dlomampo (1995)

Overlying the Diliman Tuff is a sequence of unconsolidated fluvial, deltaic and marine deposits to which Purser and Diomampo (1995) proposed the name Manila Formation. This sequence is believed to have been laid down during Holocene time. Subsurface data from core drilling along the Light Rail Transit 2 (LRT 2) route from Santolan, Pasig to Recto, Manila indicate a thickness of about 800 m. The unconsolidated deposits consist of clay, silt, gravelly sand and tuffaceous silt.

SOUTHWEST LUZON UPLANDS (SG 7)

San Juan Formation

Lithology	Basalt, andesite, graywacke, shale, slate,
	paraschist, marble, hornfels
Stratigraphic relations	Intruded by the Tolos Diorite
Distribution	San Juan and Lobo, Batangas
Age	Oligocene
Previous name	San Juan Metavolcanics and
	Metasediments (Avila, 1980)
Renamed by	MGB (this volume)
Correlation	San Agapito Dacite (Verde Island)

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	SOUTHWEST LUZON UPLANDS
	HOLOCENE		0.0117	Banahaw
	PLEISTOCENE	4 Late 3 Middle 2 1 Early	0.126 0.78 1.81	Macolod Volcanic Complex Mataas na Gulod Volcanic Complex
	PLIOCENE	2 Late	2.59 3.60	Pinamucan
NEOGENE		1 Early	5.33 7.25	Calatagan Formation Corregidor Formation
	MIOCENE	2 Middle-	13.65	Nasugbu Volcanic Complex Dagatan Wacke
		1 Early	20.43	Tolos Quartz Diorite
PALEOGENE	OLIGOCENE	2 Late 1 Early	23.03 28.4	San Juan Formation
		4 Late	33.9	
	EOCENE	3 Middle - 2	40.4	
	PALEOCENE	1 Early 3 Late 2 Middle	55.8 58.7 61.7	
CEOUS	Upper	Late	65.5	
CRETAC	Lower	Early	145 5	
JURASSIC		3 Late	145.5	
		2 Middle		
		1 Early		

Table 2.9 Stratigraphic column for Southwest Luzon

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

The San Juan Formation was previously named San Juan Metavolcanics and Metasediments by Avila (1980) for the exposures at the headwaters of Calumpit River north-northeast of Lobo and along the junction of Lobo River with Malobo River in Batangas. The same units are also exposed at the upper reaches of Kipot River southwest of San Juan and could be traced northwestward to the headwaters of Igot River at Libato Creek. The metavolcanic rocks are dark gray to greenish-gray, fine-to medium-grained basalt and andesite. Some exposures exhibit porphyritic texture. Associated clastic rocks are gray to dark green, fine- to medium-grained, highly indurated graywacke and grayish to reddish brown fine-grained ferruginous shale. The formation also includes hornfels, slates, paraschists and marbles in contact metamorphic aureoles around quartz diorite intrusions. Wolfe and others (1980) mention a limestone sample, which could be a lense in the metasediments. It was dated by M. V. Reyes

of the Philippine Oil Development Company as Oligocene. The San Agapito Dacite of Verde Islands could be equivalent to this formation.

Tolos Quartz Diorite

Quartz diorite, quartz monzonite, diorite, dacite
Intrudes the San Juan Formation
San Juan, Taysan and Lobo, Batangas
Early Miocene
Tolos Batholith (Wolfe and others, 1980);
San Juan Quartz Diorite (Avila, 1980)
MGB (this volume)

The intrusive rock that mainly occupies the southern part of Batangas within San Juan, Taysan and Lobo was previously named San Juan Quartz Diorite by Avila (1980) and Tolos Batholith by Wolfe and others (1980). The Tolos is a batholithic body that reaches 12 km in width and 20 km in length.

The core zone consists mainly of biotite quartz diorite, which grades into hornblende quartz diorite and hornblende diorite towards the west and southwest (Wolfe, 1980). Smaller bodies of apophysal and hypabyssal dimensions also intrude the San Juan Formation. Associated quartz monzonite and dacite are also present. The batholith is foliated and gneissose near its contact with the metamorphosed intruded rock. On the other hand, the rocks intruded by this batholith are thermally metamorphosed into hornfels, marble and skarn with notable grossularite. In Mataas-na-Lupa and Sto. Niño, Taysan, north-northwest trending diorite bodies show prominent copper mineralization. Wolfe and others (1980) assign an Early Miocene age to this intrusive body. A post-mineral dacite dike intruding the batholith gives a whole rock ⁴⁰K-⁴⁰Ar age of 14.8 \pm 0.9 Ma, equivalent to early Middle Miocene (Langhian).

Looc Volcanic Complex

Agglomerate, tuff, andesite, dacite
Unconformable over the San Juan
Formation; overlain by the Calatagan
Formation
Looc, Taysan and Lobo, Batangas
Middle Miocene
500 m
Batangas Extrusives and Pyroclastics
Malicdem and others (1963)
MGB (this volume)
Batangas Volcanics (Corby and others,
1951), Talahib Andesite (Avila, 1980),
Banoy Volcanics (Wolfe and others, 1980)

The Nasugbu Volcanic Complex was previously named Batangas Extrusives and Pyroclastics by Malicdem and others (1963) for the exposures of volcanic rocks around the Looc lead-silver-antimony mine at Looc, Nasugbu, Batangas. Malicdem and others (1963) consider the unit equivalent to the Batangas Volcanics of Corby and others (1951) but it was renamed in recognition of its pyroclastic components. It is here renamed Nasugbu Volcanic Complex to indicate a more specific type locality. As described by Malicdem and others (1963), the section at the mine site may be divided into three members: andesitic pyroclastic member, andesitic pyroclastics and flows, and dacitic pyroclastics and flows. Altogether, the thickness of the three members totals about 500 m. It is assigned a Middle Miocene age. Near the mineral deposit, the rocks suffered various degrees of alteration, including chloritization, argillization and silicification. A small exposure of thinly bedded steeply dipping tuffaceous shale northeast of the Looc mine site is probably part of the formation.

The andesitic pyroclastic member consists of agglomerates, tuff and lapilli tuff. The andesitic fragments of the agglomerates range in size from a centimeter to as much as 50 cm. The thickness of this member is estimated at 220 m.

Andesitic flows, tuffs and tuff breccia comprise the *andesitic pyroclastics and flows*. The andesite flows constitute more than 50 per cent of the section. Hornblende needles define flow directions. The andesite is the main host of the mineral deposit. This member has a thickness of 110 m.

The *dacitic pyroclastics and flows* consist mostly of agglomerate and lapilli tuff with very minor amounts of ash tuff and dacitic flows. Fragments of the agglomerate and lapilli tuff are composed of dacite. The thickness of this member is estimated at 170 m.

The **Talahib Andesite** of Avila (1980) is considered equivalent to the Nasugbu Volcanic Complex. The Talahib is exposed in the west-central and southeastern parts of Batangas. It is overlain by the Mapulo Limestone (Avila, 1980), which is considered equivalent to the Calatagan Formation, at the upper reaches of the western tributary of Talahib River and also along Laiya River. The andesite is characteristically vesicular and amygdaloidal and exhibits flow banding. It also includes fine-grained, porphyritic and medium-grained equigranular phases. Thin pyroclastic layers are intercalated with the flows. Propylitization of the andesite is common, with remarkable development of chlorite and epidote. Moderate silicification and pyritization are localized generally along shear zones. This unit is apparently equivalent to the **Banoy Volcanics** of Wolfe and others (1980) to which they assign a Middle to Late Miocene age.

Dagatan Wacke

Lithology	Feldspathic and volcanic wacke;
	conglomerate
Stratigraphic relations	Rests on the San Juan Formation;
	overlain by the Calatagan Formation
Distribution	Taysan, Batangas
Age	Middle Miocene
Thickness	20 m
Named by	Wolfe and others (1980)

The Dagatan Wacke was named by Wolfe and others (1980) for the rocks exposed in road cuts at Sto. Niño, Taysan and the road from Dagatan to Lobo. The unit consists of feldspathic to volcanic wacke with fine to conglomeratic facies. Clasts of quartz diorite, metavolcanic rocks, andesite and dacites in the wacke have been noted (Wolfe and others, 1980). It has a maximum thickness of 20 m at the Taysan Porphyry Copper Mine. The base of this unit rests unconformably over the metavolcanic rocks of the San Juan Formation. The presence of a fossil mollusk, *Vicarya callosa Martin*, in samples from Lobo and Nanlobo rivers indicates an age no older than Middle Miocene (Wolfe and others, 1980). Other mollusks and plant remains were found, which indicate near-shore deposition of the Dagatan. The Wacke could be coeval to the Nasugbu Volcanic Complex. The top of the Dagatan Wacke is overlain by a Late Miocene limestone unit, the Dingle Limestone of Wolfe and others (1980), which is probably equivalent to the Calatagan Formation.

Corregidor Formation

Lithology	Conglomerate, tuffs
Stratigraphic relations	Rests on the Nasugbu Volcanic Complex
Distribution	Corregidor Peninsula; tip of Bataan
	Peninsula; Limbones Island; Patungan,
	Cavite; Looc, Batangas
Age	Late Miocene
Previous name	Corregidor Conglomerate (Corby and
	others, 1951)
Renamed by	MGB (this volume)
Synonymy	Cutad pyroclastics and sedimentary rocks
	(Malicdem and others, 1963)

The Corregidor Formation was previously named Corregidor Conglomerate by Corby and others (1951), which was described earlier by Adams (1910). Exposures of this unit, mainly in Corregidor Island and Limbones Island, describe a belt from the southeastern tip of Bataan Peninsula to Looc, Batangas. It consists principally of cobble to boulder conglomerate with interbeds of sandstone and shale that were apparently deposited in a littoral environment. The sandstone exhibits cross-bedding and the shale is silty and tuffaceous. As described by Adams (1910), the conglomerate near Ternate and Naic (in Cavite) apparently grade into tuffs.

Malicdem and others (1963) consider their **Cutad pyroclastics and sedimentary rocks** to be equivalent to the Corregidor Conglomerate. As mapped by Malicdem and others (1963), the Cutad covers the western coast of the area from Patungan, Cavite (including Limbones Island) to a point south of Looc Cove in Batangas. The pyroclastics of the Cutad consist of agglomerates with minor amounts of ash tuff and lapilli tuff. A 30m thick oxyhornblende andesite flow is intercalated with the tuff at Pasong Creek. The upper portion of the Cutad is composed mostly of tuffaceous boulder conglomerate with thin lenses of tuffaceous sandstone exhibiting graded bedding and cross bedding. Towards the south, the boulders become smaller with increasing percentage of finer materials (Malicdem and others, 1963). Corby and others (1951) assign a probable Late Miocene age to the Corregidor Conglomerate. It is probably partly coeval with the Calatagan Formation.

Calatagan Formation

Lithology	Limestone, marl, siltstone
Stratigraphic relations	Rests on the Nasugbu Volcanic Complex
Distribution	Calatagan Peninsula; Taysan; Conde
	Mataas; Mt. Banoy, peninsulas and
	islands south and east of Mabini,
	Batangas province
Age	Late Miocene – Early Pliocene
Previous name	Calatagan Marl (Corby and others, 1951)
Renamed by	MGB (this volume)
Synonymy	Mapulo Limestone (Avila, 1980), Dingle
	Limestone (Wolfe and others, 1980)

The Calatagan Formation was previously named Calatagan Marl by Corby and others (1951) for the exposures at Calatagan Peninsula. It is equivalent to the **Mapulo Limestone** of Avila (1980). The formation may also be found in the peninsulas and islands south and east of Mabini, Batangas, as well as other areas of the province such as Taysan, Conde Mataas and Mt. Banoy. The lithology varies from soft tuffaceous marine siltstone to coralline limestone. The limestone crops out at Brgy. Mapulo in Taysan, along the roadcut at Conde Mataas, Batangas City, and at the upper reaches of a major tributary of Talahib River and Laiya River where it overlies the Talahib Andesite. It is massive, white to buff, soft and porous with abundant coral fingers. Corby and others (1951) assign it an age of Late Miocene to Early Pliocene. It is also equivalent to the **Dingle Formation** of Wolfe and others (1980), which was estimated to be 100 m thick.

Pinamucan Formation

Lithology	Conglomerate, sandstone, shale, pyroclastic rocks
Stratigraphic relations	Unconformable over the Tolos Quartz
Distribution	Upper Pinamucan, upper Calumpit and middle Lobo rivers: Batangas
Age Named by	Pliocene Avila (1980)

The Pinamucan Formation was named by Avila (1980) for the interbedded sequence of conglomerate, sandstone and shale that crop out in the vicinity of upper Pinamucan, upper Calumpit and middle Lobo rivers, where they rest unconformably over the Tolos Quartz Diorite and metavolcanic rocks of the San Juan Formation. The conglomerate is poorly indurated but well-sorted with pebbles of andesite, diorite and metasediments set in a sandy tuffaceous matrix. The sandstone and shale are well-bedded, light brown to grayish, poorly indurated and tuffaceous. The upper horizon of this unit is intercalated with pyroclastic rocks designated by Avila (1980) as **Lobo Agglomerate**, which is here considered part of the Pinamucan. The formation is assigned a Pliocene age.

Mataas na Gulod Volcanic Complex

Lithology	Basalt, andesite, breccia, pyroclastic
Stratigraphic relations	Intrudes/covers Miccono rocks
Distribution	Cavite, Batangas
Age	Pliocene - Pleistocene
Named by	MGB (this volume)

In the western portion of Cavite, the Mataas na Gulod caldera complex, with a diameter of 3 km to 4.5 km, consists of pyroclastic flows and lahars. Breccia pipes cut through the western and southern flanks. The Mataas na Gulod belongs to the Bataan Volcanic Arc complex. South of the Mataas na Gulod, the Nasugbu plain is surrounded by the composite cones of Mt. Palay-Palay, Mt. Caluya, Mt. Cariliao and Mt. Batulao. Whole rock radiometric K-Ar ages derived from basalts and andesites of Mataas na Gulod, Mt. Batulao and Mt. Cariliao range from 3.4 to 1.34 Ma (De Boer and others, 1980; Wolfe and Self, 1983). Radiometric dating of the basalt flows from the volcano is reported to average 2.9 Ma (Wolfe and Self, 1983). The younger volcanic products are andesitic and a resurgent dome has risen 300 m above the caldera floor.

Macolod Volcanic Complex

Basalt, andesite, dacite, trachyandesite,
rhyolite, pyroclastic rocks, lahar
Intrudes/covers Miocene and older rocks
Batangas, Laguna, Rizal, Quezon
Pliocene - Recent
MGB (this volume)

Numerous Pliocene-Pleistocene volcanic centers, here grouped into the Macolod Volcanic Complex, are confined within a narrow structurally bounded northeast trending lineament called the Macolod Corridor (Förster and others, 1990). This corridor is believed to be an across-the-arc extension region, a pull-apart type structure related to the sinistral movements of the Philippine Fault to the northeast and the Sibuyan Sea Fault to the southwest (Forster and others, 1990). The rifting process along this corridor is accompanied by profuse volcanism, which could be associated with the subduction of the South China Sea Plate along the Manila Trench. Recent studies by Sudo and others (2000) indicate that there was a migration of active volcanism from the Laguna de Bay area and Taal to the area of monogenetic volcanoes as a result of steepening of the subducted slab at the Manila Trench.

Major element data reveal that the volcanic rocks comprising the Macolod volcanic field have a wide range of composition from basalt to rhyolite, i.e., $SiO_2 = 47-74\%$. Intermediate rocks, however, are the most common. Basalts occur only in small monogenetic centers in the Macolod Corridor, while dacites and rhyolites seem to be exclusively present in the Laguna de Bay area and Mt. Makiling. The most primitive basalts attain MgO contents of 10-12% and Cr concentrations of 580 ppm. The basalts are mostly calc-alkaline, evolving to high-K calc-alkaline for intermediate

and evolved lavas. The Laguna de Bay lavas, in turn, are andesites to rhyolites that are bimodally calc-alkaline and high-K calk-alkaline. In summary, the geochemistry of the Macolod Volcanic Complex reflects that of subduction-related rocks. The rocks are characterized by low amounts of TiO_2 (< 1.1%), enrichments in the large ion lithopile elements (Rb, Ba, Sr), Th and light rare earth elements (La, Ce), and depletion in high field strength elements (Nb, Zr, Ta) and heavy rare earth elements (Er, Yb, Lu). Variations in enrichment of incompatible elements, however, are interpreted to be due to crustal contamination and the involvement of sediments entrained by the subduction along the Manila Trench. In addition, the involvement of continental material in the subduction process cannot be discounted due to the impingement of the Palawan-Mindoro continental block against southern Luzon. Radiometric K-Ar dating indicates that volcanic activities in the Macolod Corridor had started since 2.2 Ma (Sudo and others, 2000).

• Taal Volcano

Lake Taal is a volcano-tectonic depression with an approximate area of 300 km^2 , formed by numerous explosions, collapse craters and a system of tectonic grabens. Base surges and pyroclastic flows of the maar/caldera eruptions spread over an area of more than 2000 km^2 ; crossing the 640 m-high Tagaytay ridge towards Manila Bay to the north; flowing southward to Balayan and Batangas bays; depositing up to 300 m of pyroclastics to the east in the Mt. Makiling - Mt. Malepunyo - San Pablo area; and entering the Nasugbu plain through a gap between Mt. Batulao and Mt. Cariliao to the west. Two composite cones, Mts. Sungay and Macolod, developed on the eastern side of the lake. Radiometric K-Ar dating of samples from Mt. Macolod gave values of 2.22 ± 0.10 Ma (Sudo and others, 2000) and 2.03 ± 0.30 Ma (Oles and others, 1991), indicating that volcanic activity started since 2.2 Ma.

Near the center of Taal Lake is Taal volcano, an active volcano covering around 23 km² and reaching up to 311 masl high (PHIVOLCS, 1995). Numerous tuff and scoria cones and depressions formed by explosion, collapse or ground subsidence are distributed on the volcano island. Of the 35 identified cones, 26 are tuff cones, 5 are cinder cones and 4 are maars. The main crater, 1.9 km in diameter, is a lake with a 100 m^2 islet interpreted to be a lava needle (Oles and others, 1991). Altered grounds and steaming vents attest to the thermal activity in the island, whereas base surge and airfall deposits indicate past phreatic and phreatomagmatic eruptions. At least 33 historic eruptions of Taal volcano have been recorded from 1572 to 1977. Aside from the main crater, other major eruption centers are Binintiang Malaki, Binintiang Munti, Pira-piraso, Calauit and Mt. Tabaro (PHIVOLCS, 1995). Caldera formation was characterized by voluminous unloading of calc-alkaline andesitic to dacitic magma that deposited pumice flows, ignimbrite, scoria agglutinate and scoria flows (Listanco, 1994). The current active phase of the volcano culminated in the development of Volcano Island. Recent eruptions of Taal produced basaltic and andesitic deposits.

• Makiling – Malepunyo

Mt Makiling, located on the southwest rim of Laguna de Bay, is a stratovolcano with a 16-km diameter that reaches up to 1115 masl elevation. Pyroclastic flow, lahar, airfall and lava deposits comprise the cone. The lavas consist of trachyandesites, trachydacites and rhyolite. Plinian-type eruption is evidenced by welded ash-flow tuffs. Radiometric K-Ar ages of 0.51 to 0.18 Ma have been determined for andesites and dacites of Mt. Makiling (Wolfe and Self, 1983). Smaller satellitic edifices include La Mesa tuff ring, Bijiang, Mapinggon and Masaia.

Immediately south of Mt. Makiling is a deeply eroded north-south trending volcanic range that includes Mapinggon, Bulalo and Malepunyo. This composite volcano consists predominantly of lava flows and breccias at the upper portions and pyroclastic flows and lahars on its eastern flanks. Andesites from Mt. Malepunyo are dated from 1.10 Ma to 0.63 Ma (De Boer and others, 1980; Oles and others, 1991).

Other smaller monogenetic cones in the Macolod Corridor erupted basaltic lava. Scoria cones and tuff cones are common, the former being formed from strombolian-type eruptions. Maars and tuff rings in the San Pablo area show typical features of base surge and airfall deposits resulting from phreatic or phreatomagmatic eruptions. Andesites from Mt. Atimbia, one of the cones in San Pablo, gave an age range of 1.08 to 0.95 Ma. The youngest radiometric K-Ar dating obtained from a dacite sample from Mt. Mapinggon gave an age of 0.10 \pm 0.02 Ma. Scoria cones in Batangas include Anilao Hill, Tombol Hill and Sorosoro Hill. A radiometric K-Ar age of 0.87 Ma was obtained from a sample of basalt from Anilao Hill (Oles and others, 1991).

• Laguna de Bai

Northeast of Taal Volcano is Laguna de Bai, the largest volcanotectonic depression in this region formed by caldera eruptions and extension tectonics. Collapse structures bounding this lake suggest that it is probably a relic of a much larger ancient caldera system. To the west and south of the lake are the volcanic and pyroclastic deposits of the Taal-Banahaw area. The Calirava plateau on the eastern side of the lake represents a >400-m thick volcano-sedimentary sequence composed of welded and unwelded pyroclastic flows intercalated with lava flows, lahars, airfall tuff, base surges and fluvial and lacustrine sediments. To the north, limestones and small plutons are exposed within the pyroclastic series. Graben tectonics divided the lake into three bays. The East and Middle bays are separated by the Jala-Jala peninsula, which hosts three domes including Mt. Sembrano. Talim Island, intruded by the Mt. Sangunsalaga dome and the Binangonan peninsula, isolates the Middle from the West bay. Andesites from around Laguna de Bai give radiometric K-Ar whole rock ages of 2.3 to 1.7 Ma (Sudo and others, 2000). Recent studies by Catane and Arpa (1999) suggest a resumption of volcanic activity in the Laguna de Bai area 47,000 to 27,000 yrs BP after a cessation of volcanic activity that could have lasted for a million years.

Banahaw Volcanic Complex

Lithology	Basalt, andesite, breccia, pyroclastic
	flows, lahar
Stratigraphic relations	Intrudes/covers Miocene rocks
Distribution	Laguna and Quezon
Age	Pleistocene - Recent
Named by	MGB (this volume)

Mt. Banahaw is the highest volcanic center in southwestern Luzon, reaching up to 2158 masl. This stratovolcano includes two major flank cones, Mt. San Cristobal (1470 m) and Banahaw de Lucban (1870 m). Low-lying domes (Buho and Masalakot) and Mt. Mayabobo, a cinder cone, are also part of this volcanic complex. The Banahaw Volcanic Complex is considered part of the southern segment of the Luzon volcanic arc associated with the subduction of the South China Sea plate along the Manila Trench. The segment to which Banahaw belongs was designated by Defant and others (1988) as the eastern counterpart of the Mindoro volcanic belt.

Mt. Banahaw consists of lava flows and breccias on the upper regions and lahars and pyroclastic flows below elevations of 800 to 600 masl. While Mt. San Cristobal is a complex lava dome structure, Mt. Banahaw de Lucban is characterized by a dome that caused debris-avalanche on the eastern flanks. Mt. San Cristobal basalts and andesites range in age from 1.71 to 1.29 Ma (Oles and others, 1991). Accounts of Mt Banahaw eruptions date back to 1730, 1743 and 1909 (PHIVOLCS, 1997).

MARINDUQUE ISLAND (SG 7)

Marinduque is part of the Southwest Luzon Tectono-Stratigraphic Group that includes southwestern Luzon, Bataan, northern Mindoro and Lubang Island.

Marinduque Formation

Andesite, spilite, basalt, fragmental
volcanic rocks, graywacke, siltstone
Comprises the basement of Marinduque
west-central section of the island
Cretaceous (?)
Marinduque Basement (Gervasio, 1958)
MGB (this volume)

The basement rocks of Marinduque, as described by Gervasio (1958), consist of undifferentiated metamorphosed volcanic rocks and minor graywackes and siltstones. The volcanic rocks are primarily and esitic but

PERIOD	EPOCH	AGE	Ма	MARINDUQUE	BONDOC PENINSULA
NEOGENE	HOLOCENE	4 Late	0.0117	Malindig Volcanic Complex	
	PLEISTOCENE	3 2 Middle -	0.126 0.78		Malumbang Formation
	PLIOCENE	1 Early 2 Late 1 Early	2.59	Boac Formation	Vinas Formation Hondagua Formation
		3 Late	7.25 11.61	Gasan Formation Porvado Conglomerate	Canguinsa Formation
	MIOCENE	2 Middle-	13.65		
		1 Early	20.43	Lobo Quartz. Diorite Torrijos Formation	
ALEOGENE	OLIGOCENE	2 Late	23.03 28.4		Panaon Limestone
		1 Early 4 Late	33.9 37.2	San Antonio Formation Tuluntunan-Tumicob Formation	Unisan Formation
	EOCENE	3 Middle - 2	40.4		
Ľ	PALEOCENE	1 Early 3 Late 2 Middle 1 Early	55.8 58.7 61.7		
ceous	Upper	Late	00.6	Magapua Limestone Marinduque Formation	
CRETAC	Lower	Early	35.0		Gumaca Schist
JURASSIC	Upper	3 Late	145.5		
-	Middle	2 Middle	175.6		
	Lower	1 Early	199.6		

Table 2.10 Stratigraphic column for Marinduque Island

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

also include basaltic, spilitic and fragmental members. The andesite is usually chloritized and in places schistose. Epidotization is often pronounced. Gervasio (1970) also included serpentinite and greenschists in his Marinduque Basement. The age of the formation is probably Cretaceous.

Magapua Limestone

Lithology	Limestone, marble
Stratigraphic relations	Overlies the Marinduque Formation
Distribution	Magapua, Mangamnan, Mogpog, Boac
Age	Late Cretaceous
Named by	Tumanda and others (1984)

This limestone unit was previously included as part of the Marinduque Basement of Gervasio (1958). Later, Gervasio (1970) and Motegi (1975) consider the limestone as part of the Eocene Taluntunan-Tumicob and Binunga formations, respectively. However, Tumanda and others (1986) consider it as a separate unit and named it Magapua Limestone. This formation consists primarily of gray micritic limestone that is marbleized in places. *Globotruncana*, indicative of Late Cretaceous age, was identified by Hashimoto (1981) in the limestone south of Mangamnan, on the main road connecting Boac and Sta. Cruz. Certain species of *Globotruncana* and *Heterohelix* were also identified from exposures along Mangamnan, Mogpog and Boac rivers near Barangay Binunga. The Late Cretaceous age suggested by the fossil assemblage led Aurelio (1992) to consider the limestone as the carbonaceous capping of the Marinduque basement rocks.

Taluntunan-Tumicob Formation

Lithology	Wacke, shale, turbidite, limestone,
	andesite, dacite
Stratigraphic relations	Unconformably overlain by the San
	Antonio Formation
Distribution	Silangan Point up to midway between
	Buenavista and Malibago in the south
Age	Late Eocene
Named by	Gervasio (1958)

The Taluntunan-Tumicob Formation, as defined by Gervasio (1958), is a broadly folded and faulted thick sequence of volcanic wackes, shale and fine turbidites with intercalated limestone and minor dacite/andesite flows. The limestone is marbleized and occurs as lenses in the clastic rocks. Exposures of the formation can be traced from Silangan Point in the northwest to midway between Buenavista and Malibago on the south and also occur as inliers along a northwest-southeast trending belt, about 16 km wide that constitute the core of the island. Hashimoto and Hanzawa (1970) identified from the vicinity of the abandoned Marinduque Iron Mines *Distichoplax biserialis Dietrich*, an algal species associated with *Nummulites* sp., *Assilina* cf. *expones* (Sowerby), *Discocyclina* sp., *Pellatispira* sp. and others, an assemblage indicating a Late Eocene age. Tumanda and others (1986) and Aurelio (1992) also report limestone containing *Nummulites* and *Assilina* at Boac and Makulapnit rivers.

San Antonio Formation

Lithology	Andesite, dacite, pyroclastic rocks, wacke, chert
Stratigraphic relations	Unconformable over Taluntunan-Tumicob
Distribution	San Antonio; outcrops define an arcuate belt from La Mesa to Marlanga Bay
Age	Early Oligocene
Named by	Gervasio (1970)

This formation was named by Gervasio (1970) for the rocks exposed in an arcuate belt from north of La Mesa to Marlanga Bay, with the major part occupying the northeast flank of the island. Its type locality is San Antonio, located about 8 km south of Dolores. The unit consists principally of andesitic flows, some dacitic layers, pyroclastic rocks and welded tuff, and minor volcanic wacke, including the Sabong Clastics. Its upper part is capped in many places by volcanic chert and silicified pyroclastic rocks. The associated chert, called Palompon Chert, is massive, pinkish to buff and occurs as small bodies and float (Sto. Domingo and others, 1990). The San Antonio unconformably overlies the Eocene Taluntunan-Tumicob Formation and is intruded by diorite and andesite porphyry. The formation is broadly warped, faulted and fractured and small exposures occur as erosional windows underneath the Upper Miocene Gasan Formation. Nannofossil zone NP21 (Early Oligocene) was reported by Aurelio (1992), which is equivalent to the age of the San Antonio Andesite of Motegi (1975).

Torrijos Formation

Lithology	Volcanic sedimentary rocks, including conglomerate, sandstone, limestone, shale; volcanic flows, agglomerate
Stratigraphic relations	Not reported
Distribution	Torrijos, Mt. Marlanga, western and
Δαρ	Farly Miccone
Thickness	2 300 m
Named by	Corby and others (1951)
Nameu by	Corby and others (1901)

The Torrijos Formation was named by Corby and others (1951) for the well bedded volcanic and sedimentary rocks at Torrijos. The unit consists of volcanic sedimentary rocks, including conglomerate and sandstones, shale, intercalated volcanic flows and agglomerates. Exposures of the unit extend from the vicinity of Torrijos to Mt. Marlanga (Malindig). Gervasio (1958) includes, as part of the formation, the reef limestone and basaltic volcanic flows exposed largely at the western and northwestern parts of Marinduque Island. Clasts in the conglomerate of the basal section often include cobbles of chert and volcanic rocks similar and probably belonging to the San Antonio Formation. The formation also includes the Sayao Volcanics, considered as upper member consisting of volcanic rocks intercalated with shale, sandstone and conglomerate exposed in Barrio Sayao, Mogpog. Andesite porphyry dikes cut the basal section of the Torrijos (BMG, 1981).

The reef limestone contains abundant *Miogypsina* with *Austrotrillina howchini* (Schlumberger), *Bordinia septentrionalis* Hanzawa, *Lepidocyclina* (*E.*) *formosa* (Schlumberger) and others (BMG, 1981), indicating an Early Miocene age. Tumanda and others (1984) date the patchy limestone exposures along the Sta. Cruz-Mogpog road, particularly in Dolores and Lamesa, Early Miocene to probable Middle Miocene. The thickness of the Torrijos is approximately 2,300 m.

Lobo Quartz Diorite

Lithology	Hornblende quartz diorite, andesite porphyry, biotite tonalite porphyry and
Stratigraphic relations	other intermediate porphyries Intrudes Marinduque, Taluntunan-
	Tumicob, San Antonio and Torrijos
	Formations
Distribution	Lobo, Mahinhin-Puting Buhangin,
	Tumagabok
Age	late Early Miocene
Named by	MGB (this volume)

The core of Marinduque Island is an igneous complex intruding the Marinduque, Taluntunan-Tumicob, San Antonio and Torrijos formations. The complex consists of hornblende quartz diorite stocks such as those at Lobo, Mahinhin-Puting Buhangin, Tumagabok, and other places, as well as andesite porphyry, biotite tonalite porphyry and other porphyries of intermediate composition occurring as apophyses, sills and dikes (Gervasio, 1970). The intrusive contacts are generally characterized by silicification, pyritization, recrystallization and induration. These are steeply dipping and/or outlined by faults. In Barrio Lobo, Sta. Cruz, a quartz diorite stock intrudes a sequence of sedimentary and volcanic rocks. The quartz diorite is ellipsoidal in plan, covering about 33 km². Its major axis is oriented northwest-southeast. Northwest and southwest of the stock are numerous smaller bodies of diorite forming a belt of intrusive rocks.

The quartz diorite occurs either as coarse-grained porphyry and a medium-grained even-textured rock. The porphyry is along the road to Sibukao and in at least two points along roadcuts past Mogpog River towards Santa Cruz. The phenocrysts are plagioclase, biotite and hornblende. Quartz, pyrite and magnetite are the accessory minerals. The even-textured variety is along Bocboc Creek and its tributaries. The rock is traversed by closely spaced, northwesterly trending joints (Oca, 1952). It is leucocratic, hypidiomorphic-granular and composed of 70% plagioclase feldspar (An₄₀), 12% hornblende, 10% quartz, 6% biotite and 3% accessory magnetite, pyrite and chlorite (Irving, 1950). The age of the quartz diorite is probably late Early Miocene as indicated by radiometric K-Ar dating by Walther and others (1981) of a tonalite sample from Tapian deposit, which gave an age of 20.8 Ma.

Porvado Conglomerate

Lithology	Conglomerate with minor sandstone and shale
Stratigraphic relations	Unconformable over truncated diorites
Distribution	Porvado
Age	Late Miocene
Named by	Gervasio (1958)

The Porvado Conglomerate, named by Gervasio (1958), caps the wedge-shaped horst block of Marinduque outlined by the principal northwest faults. It overlies unconformably truncated intrusive rocks (BMG,

1981). The formation consists of conglomerate, sandstone and shale. The basal part of the conglomerate is dark-colored. It grades upward to arenaceous and slightly arkosic beds with diorite pebbles. Nannofossil datings mentioned by Aurelio (1992) confirm a Late Miocene age already mentioned by earlier workers.

Gasan Formation

Lithology	Siltstone, shale, conglomerate
Stratigraphic relations	Overlies truncated quartz diorite bodies
Distribution	Gasan
Age	Late Miocene
Thickness	1,400 m
Previous name	Gasan Tuffaceous Shale (Corby and
	others, 1951)
Renamed by	MGB (this volume)
Synonymy	Tabionan Formation

This formation was originally named Gasan Tuffaceous Shale by Corby and others (1951). It consists of light gray laminated tuffaceous siltstone and shale and unconformably overlies truncated quartz diorite bodies. The base of the formation is a thick conglomerate with serpentinite clasts. The Gasan, previously dated Middle Miocene, is now dated Late Miocene. Its estimated thickness is 1,400 meters. Also, along the southwest flank of the island are Upper Miocene pyroclastic sedimentary rocks called **Tabionan Formation** by Gervasio (1970). In BMG (1981), the Tabionan is considered equivalent to the Gasan.

Boac Formation

Lithology	Siltstone, sandstone, conglomerate
Stratigraphic relations	Unconformable over the Gasan Formation
Distribution	Boac; northwestern coastal area
Age	Early Pliocene - Pleistocene
Thickness	400 m
Previous name	Boac Silt (Corby and others, 1951)
Renamed by	MGB (this volume

This formation was originally named Boac Silt by Corby and others (1951). It is a sequence of low-dipping marine siltstone and sandstone with conglomerate at the base. It unconformably overlies the Gasan Formation and is confined to the northwestern coastal area. The Boac contains abundant shells and foraminifera, which indicate a rather young geologic age. Nannozones NN15 to NN19 have been mentioned by Aurelio (1992) indicating an age ranging from Early Pliocene to Pleistocene. Its thickness is about 400 meters.

Malindig Volcanic Complex

Andesite, tuff, agglomerate
Mt. Malindig
Pleistocene
MGB (this volume)

The Malindig Volcanic Complex consists of andesite, tuff and agglomerate, which constitute the slopes of Mt. Malindig (formerly Marlanga), an inactive volcano at the southern extremity of Marinduque. The volcano is considered Pleistocene. Hot and sulfur springs are found about 2 km from the western foot of the volcano.

BONDOC PENINSULA (SG 8)

The stratigraphic grouping for Bondoc Peninsula (SG 8) includes Burias Island, Ticao Island and southern Masbate of the Masbate Island Group.

Gumaca Schist

Lithology	Quartzofeldspathic schist, greenschist, amphibolite
Stratigraphic relations	Constitutes the basement rocks
Distribution	Gumaca, Unisan
Age	Cretaceous
Named by	MGB (this volume)

The Gumaca Schist consists chiefly of quartzofeldspathic schist, greenschist and amphibolites. The schists occur as small irregular bodies in Gumaca and Unisan. The typical mineral assemblage of the quartzofeldspathic schists is chlorite, sericite, quartz and albite. West of Unisan albite-epidote-amphibole schist is in contact with metagabbro. The amphibolite schists commonly border ultramafic rocks and might represent the metamorphic sole of an ophiolitic body, possibly the Cadig Ophiolitic Complex of southeastern Luzon. Aurelio (1992) has reported the existence of pillow basalts about 4 km east of Unisan, which are capped by thin pelagic limestone deposits containing *Globotruncana*. This indicates that the associated ophiolitic formation is not younger than Late Cretaceous.

Unisan Formation

The Unisan Formation was previously named by Banogon (1974) as Unisan Volcanics for the exposures along the Unisan – Pitogo road. It is also exposed near Panaon as well as the provincial road to Guinayangan, in the vicinity of the Manato railroad station. The formation consists of porphyritic andesite and amygdaloidal basalt with occasional interbeds of tuffaceous sandstone and conglomerate. Banogon (1974) suggests an Oligocene age for the Unisan. However, nannofossil determinations by Müller (in Aurelio, 1992) indicate the presence of *Reticulofenestra umbilica*, *Cyclicargolithus floridanus*, *Sphenolithus predistentus*, *S. moniformis*, *Helicosphaera euphratis, Discoaster tanonodifier,* suggesting a longer age range from Late Eocene to Early Oligocene.

Panaon Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Unisan Formation
Distribution	Panaon (northwestern part of the
	peninsula)
Age	Late Oligocene – Early Miocene
Named by	Antonio (1961)

The Panaon Limestone was named by Antonio (1961) for the exposures at Panaon, Quezon. The Limestone also outcrops along Plaridel Road, Unisan - Panaon Road, Tumagay and Malicboy. The formation consists of medium- to thickly bedded bioclastic limestone, which unconformably overlies the Unisan Formation. Fossil assemblage in the limestone include *Lepidocyclina (Eulepidina) formosa, Spiroclypeus maragaritatus, Lepidocyclina* (Nephrolepidina) parva, Cycloclypeus sp. and few *Miogypsina sp.*, indicating Late Oligocene – Early Miocene age (Lubas and others, 1998).

Vigo Formation

Lithology	Sandstone, shale, mudstone, limestone,
	conglomerate
Stratigraphic relations	Unconformable over the Panaon
	Limestone
Distribution	Vigo River Valley; widespread along the
	length of the peninsula
Age	Early – Middle Miocene
Thickness	2,530 m
Previous name	Vigo Shale (Pratt and Smith, 1913)
Renamed by	Corby and others (1951)

The Vigo Formation was initially named by Pratt and Smith (1913) as Vigo Shale. The type locality is at the Vigo River Valley in the southeast. It is widely exposed in the peninsula in a belt extending from the southern end of the peninsula to the northern end at Gumaca. The formation consists mainly of sandstones and shales with interbeds of conglomerate and lenses of limestone. Lubas and others (1998) subdivide the Vigo into two members – Lower Vigo and Upper Vigo. Comprising the Lower Vigo are shales and sandstones with lenses of limestone. The sandstones grade laterally from feldspathic wackes into calcareous wackes. Constituting the Upper Vigo are medium to thickly bedded clast-supported polymictic poorly sorted conglomerates interbedded with siltstones and sandstones. Foraminiferal and nannoplankton assemblage indicates an age of Early Miocene for the Lower Vigo and Middle Miocene for the Upper Vigo (Aurelio, 1992; Lubas and others, 1998). The total thickness of the Vigo Formation is 2,530 m (BMG, 1981).

Canguinsa Formation

Lithology	Sandstone, shale, conglomerate
Stratigraphic relations	Unconformable over the Vigo Formation
Distribution	Canguinsa River; Mulanay, San Narciso;
	Gumaca, Pitogo,
Age	Late Miocene - Pliocene
Thickness	2,280 m
Previous name	Canguinsa Sandstone (Pratt and Smith,
	1913)
Renamed by	Corby and others (1951)

The Canguinsa Formation was previously named by Pratt and Smith (1913) as Canguinsa Sandstone for the exposures in and around Canquinsa River. The formation is also well exposed along the Mulanav-San Narciso road and Gumaca-Pitogo road. It unconformably overlies the Vigo Formation. The Canquinsa predominantly consists of sandstones (about 75 per cent) rhythmically interbedded with shale, pebble conglomerate and limestone. The pebbles in the conglomerate are mostly basalt and andesite and few calcareous sandstone and limestone cemented by coarse calcareous sandy matrix. The formation is subdivided into two members by Santiago (1968) and the Philippine Oil Development Company (1978), while Lubas and others (1998) subdivide it into three members. Here, the formation is subdivided into Lower Canguinsa and Upper Canquinsa. The Lower Canquinsa is predominantly medium- to coarse-grained sandstone. Local conglomerate beds have been observed at the base of the unit. Carbonaceous layers of siltstone and mudstone often occur between thick sandstone beds. The Upper Canquinsa consists of finer-grained sandstone and siltstone. Based on foraminifera and nannoplankton assemblage, the Lower and Upper Canguinsa were dated Late Miocene and Pliocene, respectively (BMG, 1981; Aurelio, 1992; Lubas and others, 1998). The Canguinsa has a thickness of 2,280 m along the Mulanay-San Narciso road section.

The **Pitogo Conglomerate** of Punay (1960) is probably equivalent to the basal portion of the Lower Canguinsa. The Pitogo was described as a sequence of conglomerate, sandstone and shale with occasional thin beds of detrital limestone. It conformably overlies the Vigo Formation in the northwestern portion of the peninsula. The **Aloneros Conglomerate** of Corby and others (1951) between Sto. Domingo and Aloneros is apparently equivalent to the Pitogo.

Hondagua Formation

The Hondagua Formation was previously named by Corby and others (1951) as Hondagua Silt for the exposures in the vicinity of the railway station at Hondagua, between Lopez and Calauag towns. The formation is also well exposed along the Lopez-Sumulong-Guinayangan road. It conformably overlies the Canguinsa Formation. The Hondagua consists of siltstone, shale and calcareous sandstone with interbeds of conglomerate and argillaceous limestone. The siltstone is medium to thick bedded and highly indurated. The conglomerate is massive with pebbles of basalt, andesite, sandstone and limestone set in a coarse calcareous sandy matrix. Foraminifera in samples of the formation indicate a Pliocene age. It is 1,100 m thick along the Sumulong-Lopez road (Espiritu and others, 1968), while a thickness of 1,750 m is reported by BMG (1981).

Viñas Formation

Sandstone, mudstone, conglomerate,
limestone
Conformably underlain by the Hondagua
Formation and overlain by the Malumbang
Formation
Viñas, Sumulong; Doña Aurora, Calauag
Pliocene
475 m
Corby and others (1951)

This formation was named by Corby and others (1951) for the rocks typically exposed between Sumulong and Viñas, northeast of Calauag, Quezon. It also crops out as far as Doña Aurora, Calauag. The Viñas rests conformably on the Hondagua Formation and is disconformably overlain by the Pleistocene Malumbang Formation. As described by Espiritu and others (1968), it consists of basal beds of limestone and conglomerate succeeded by a series of poorly bedded, sandy and fossiliferous limestone, calcareous sandstone and mudstones, with interbeds of pebble and cobble conglomerates. The sandstone is medium to thick bedded, coarse-grained to pebbly, and poorly to fairly consolidated, and in places, conglomeratic. Comprising the mudstones are thin to medium bedded siltstones, claystones and shale. The conglomerates contain sub-angular to rounded pebbles and cobbles in a coarse calcareous matrix. At the type locality, the shale contains large fossils of helical and conical shells. On the basis of its fossil content and stratigraphic position, the age of the Viñas Formation is placed at Pliocene. It has a thickness of 475 m as measured along the Sumulong – Doña Aurora road section (Espiritu and others, 1968).

Malumbang Formation

Lithology	Limestone, sandstone, siltstone, shale,
Stratigraphic relations	marı Disconformably overlies the Viñas
Onaligraphic relations	Formation
Distribution	Malumbang Plains; Sumulong –
	Guinayangan road
Age	Pleistocene
Thickness	1,610 m

Previous name	Malumbang Series (Pratt and Smith,
	1913)
Renamed by	Espiritu and others (1968)

The Malumbang Formation was originally named by Pratt and Smith (1913) as Malumbang Series in reference to the limestone exposures in the Malumbang Plains in the southeastern part of the peninsula. It is also well exposed along the Sumulong – Guinayangan road where its thickness reaches 1,610 m. The formation disconformably overlies the Viñas Formation. The Malumbang consists predominantly of limestone with interbeds of sandstone, siltstone and shale. Light gray to brownish marl is also present in the lower part of the formation. The limestone is cream, buff or dirty white, medium to thick bedded, sandy and porous to reefal and crystalline. The sandstone is massive to medium bedded. The faunal assemblages correspond to nannozone NN19 (Aurelio, 1992) indicating a Pleistocene age.

SOUTHEASTERN LUZON (SG 9, SG 10)

Southeastern Luzon consists mainly of Bicol Peninsula and the outlying islands with two stratigraphic groupings, namely, Ancient Southeastern Luzon Arc and Recent Southeastern Luzon Arc. The ancient



Table 2.11 Stratigraphic column of Southeastern Luzon

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

arc may be subdivided into several blocks with their own distinctive stratigraphic sequences, namely: Quezon-Camarines Norte, Caramoan Peninsula, Catanduanes Island, Cagraray Group of Islands and southern Bicol Peninsula. The basement of all these blocks, except for Catanduanes, is underlain by ophiolites/ophiolitic rocks. Some of the lithologic units belonging to the ophiolite sequence, especially the volcanic carapace and sedimentary cover, have been subjected to low-grade metamorphism, producing greenschists, albite-epidote-amphibolites and quartzofeldspathic mica schists. These occur in Camarines Norte-Quezon, Caramoan Peninsula and Rapu Rapu Island. The Recent arc includes the segment of the active volcanic arc in the Bicol region associated with subduction of the Philippine Sea Plate along the Philippine Trench.

Quezon-Camarines Norte

Malaguit Schist

Lithology	Amphibolite schist, greenschist
Stratigraphic relations	Thrusted against ultramafic rocks
Distribution	Lower Malaguit River, Tanao Islands; Jose
	Panganiban, Paracale, Calambayungan
	Island, Calaguas Group of Islands, Bunog
	Peninsula, Siruma Island
Age	Jurassic (?)
Named by	MGB (this volume)

Metamorphic rocks in Camarines Norte consisting of amphibolites and greenschists were previously described by Miranda and Caleon (1979). The unit is named in reference to the schist exposures on both sides of the lower reaches of Malaguit River, extending westward to Port Mambulao. The amphibolites are limited in occurrence to the northeastern offshore islands of Camarines Norte, namely, Tanao, Tailon and Pulong Bato Islands. On the other hand, the greenschists are more widely distributed, as in Jose Panganiban, Paracale, Calambayungan Island, Calaguas Group of Islands, Bunog Peninsula and Canimog Island. The typical assemblages of the amphibolite are muscovite-quartz-garnet and hornblende-quartzgarnet. Hornblende metacrysts may reach up to 2 cm long. Large crystals of potash feldspar are sometimes present. These high-grade schists are disposed in an east-west direction.

The greenschists consist principally of quartz-epidote-chlorite schist and hornblende-epidote-albite-calcite schists. Quartzite is also associated with the schists at the southern tip of Calambayugan Island and Bunog peninsula. The schists are commonly thrusted against the ultramafic rocks and closely associated with the Tigbinan Formation. These associations suggest that these rock units, or some of the schists and the spilite-chert sequence of the Tigbinan, could be part of a dismembered ophiolitic suite.

Cadig Ophiolitic Complex

Lithology	Serpentinized peridotite, gabbro
Stratigraphic relations	Thrusted against schists; intruded by the
	Paracale Granodiorite
Distribution	Mt. Cadig in Quezon; Paracale-Jose
	Panganiban area, Guintinua, Canimog
	and Canton Islands, Camarines Norte
Age	Cretaceous
Named by	MGB (this volume)

The ophiolitic complex underlying Mt. Cadig in Quezon and Paracale-Jose Panganiban area was previously described by Miranda and Caleon (1979). The complex is also exposed in Guintinua, Canimog and Canton Islands and other northeastern offshore islands of Camarines Norte. The exposures underlying Mt. Cadig extends along an almost north-south direction for 24 km, tapering at both ends, with a maximum width of 10 km. The ophiolitic suite consists principally of peridotites, dunite, pyroxenite and layered gabbro. The ultramafic rocks have undergone extensive serpentinization. Layered gabbro was also observed in some of the offshore island of the Calaguas Group and along the road from Paraiso to Minasag. The complex is intruded by the Paracale Granodiorite at Paracale, Camarines Norte. It is assigned a Cretaceous age.

The ophiolitic complex is designated as **Camarines Norte Ophiolite Complex** by Tamayo and others (1998), in reference to the exposures of the ultramafic suite and associated gabbros in the northern part of Camarines Norte, including the offshore islands comprising the Calaguas Island group. As described by Tamayo and others (1998), the ultramafic rocks consist of harzburgites (representing the residual upper mantle rocks) and layered websterites with rare orthopyroxenite (representing the ultramafic cumulate rocks).

Amphibolites of the Malaguit Schist and the spilite-chert sequence of the Tigbinan Formation could represent the metamorphic sole and volcanic-sedimentary carapace, respectively, of the Cadig Ophiolitic Complex.

Lithology	Graywacke, spilite, andesite, chert, cherty limestone, black shale and arkosic sandstone
Stratigraphic relation	Not reported
Distribution	Tigbinan, Labo, in the Bulala-Paraiso
	area; Capalonga, Camarines Norte;
	northeastern Islands of the Calaguas
	Group
Age	Late Cretaceous
Named by	Miranda and Caleon (1979)
Correlation	Pagsangahan Formation (Caramoan
	Peninsula), Yop Formation (Catanduanes
	Island)

The Tigbinan Formation of Miranda and Caleon (1979) consists principally of graywacke-spilite-chert sequence exposed as thrusted bodies in Tigbinan, Labo, in the Bulala-Paraiso area, and Capalonga, Camarines Norte and as windows in the northeastern islands of the Calaguas Group. In places, interbeds of cherty limestone, black shale and arkosic sandstone are present. Pillow lavas are common. The chert is dark reddish to chocolate brown and associated with manganese oxides. The limestone is thinly bedded, light ash gray, coralline and fossiliferous. Several species of *Globotruncana* in the limestone indicate a Late Cretaceous age for the formation. In places, the formation grades into greenschists, slates and semi-schist. The spilite-chert sequence of the formation could represent the volcanic-sedimentary carapace of the Cadig Ophiolitic Complex.

Other formations in southeastern Luzon that could be considered equivalent to the Tigbinan Formation in Camarines Norte are the **Pagsangahan Formation** in Caramoan Peninsula and the **Yop Formation** in Catanduanes Island.

Tumbaga Formation

Lithology	Lower clastic member – conglomerate, arkose, shale, wacke
	Upper calcareous member – limestone,
Stratigraphia relationa	Inali, Shale
Stratigraphic relations	Oncontormable over Cadig Ophiolitic
	Complex and Malaguit Schist, and
	conformably overlain by the Larap
	Formation
Distribution	Tumbaga, Camarines Norte;
	Calambayungan Island and Larap
	Peninsula
Age	Eocene
Previous name	Universal Formation (Meek, 1941)
Renamed by	MGB (this volume)
Correlation	Guijalo Limestone (Caramoan Peninsula),
	Payo Formation (Catanduanes Island),
	Sula Formation (Cagraray), Pantao
	Limestone (couthern Ricel Deningula)

This formation was previously named Universal Formation by Meek (1941) for the sedimentary rocks exposed at the defunct Universal Exploration and Mining Company site in Tumbaga within the Paracale-Jose Panganiban Mining District, renamed here as Tumbaga Formation. It also crops out in the northern part of Calambayungan Island and Larap Peninsula. The Tumbaga unconformably overlies the Cadig Ophiolitc Complex and Malaguit Schist and is conformably overlain by the Larap Volcanic Complex at its southern and eastern contacts.

The formation consists of two members. The *lower member* is made up of conglomerate, arkose and shale and occasional graywacke interbeds. The conglomerate occurs in lenticular beds with rounded to subrounded pebbles of schist, chert, graywacke, peridotite, spilite and limestone set in indurated sandy feldspathic matrix. The arkose is interbedded with the shale and is green to gray and fine- to medium- grained. The shale is silty, tuffaceous and calcareous. The *upper member* consists of limestone, marl and shale. The shale is thin to medium bedded and green to black. In places, this member has been subjected to thermal metamorphism, producing skarns, hornfels and marble.

The age of the formation is not well constrained. A Paleocene to Eocene age was assigned for the formation by BMG (1981) and earlier workers (Miranda and Caleon, 1979) apparently on the basis of stratigraphic position. However, on the basis of stratigraphic correlation

with other sequences in the region, the Tumbaga is hereby assigned a probable Eocene age. The limestone member of the Tumbaga may be correlated with the **Guijalo Limestone** in Caramoan Peninsula, the **Hilawan Limestone** member of the **Payo Formation** in Catanduanes, the **Sula Formation** in Cagraray Island and the **Pantao Limestone** of southern Bicol Peninsula.

Larap Volcanic Complex

Andesite, andesitic flow breccia, tuff,
Conformable over the Tumbaga Formation
and unconformably overlain by the
Bosigon Formation
Larap, Camarines Norte; Calambayugan
Island and Enchanted Island
Oligocene (?)
Larap Volcanics (Meek, 1941)
MGB (this volume)

The formation was previously named Larap Volcanics by Meek (1941) and Frost (1959) for the thermally altered andesite and andesitic flow breccias and tuffs in Larap, Camarines Norte. The Larap consists of fragmental andesite, tuff breccia, andesitic and trachytic crystal tuff, lapilli tuff and welded tuff. The welded tuff is intercalated with altered andesite in Bosigon River. Miranda and Caleon (1977) retained the name but excluded the basaltic flows intercalated with volcanic sandstone, chert, shale and altered spilite southeast of Larap. The welded tuff and trachyte tuff of the **Barangay Andesite** of Meek (1941) in Batobalane and San Isidro are included in this formation. The Larap crops out in Larap Peninsula as well as the western edge of Calambayugan Island and Enchanted Island. It is also in the area south of Larap, extending 30 km southeast. The exposures follow a belt parallel to the contact with the conformably underlying Tumbaga Formation.

Bosigon Formation

Lithology	Lower member – conglomerate, sandstone, shale, limestone Upper member – basalt, volcanic wacke, tuff breccia, chert, limestone
Stratigraphic relations	Unconformable over the Larap Volcanic Complex and unconformably overlain by the Sta. Elena Formation
Distribution	Labo, Camarines Norte
Age	Early Miocene
Thickness	1,500 m
Named by	BMG (1981)

This formation was described by Miranda and Caleon (1979) as a sequence of conglomerate, shale, arkose, limestone, basaltic flows, wackes, tuffaceous shale and chert typically exposed along Bosigon River, Labo, Camarines Norte, which was later named Bosigon Formation (BMG, 1981). It unconformably overlies the *Larap Volcanic Complex* and is

unconformably overlain by the *Sta. Elena Formation*. A lower and an upper member have been recognized. The lower member consists of interbedded conglomerate, sandstone, shale and limestone. The conglomerate is made up of angular to subrounded pebbles of andesite, welded tuff, quartz, schist and skarn cemented by calcareous and ferruginous material. The sandstone is arkosic, gray and fine- to medium-grained. The shale is ash gray to black, silty to fine-grained, tuffaceous and calcareous. The limestone is coralline, dirty white to black, dense and fine-grained. The upper member consists of intercalated basaltic flows, volcanic wackes, tuff breccia, chert and limestone. The chert and limestone occur as minor thin beds in the sequence. The chert at Bosigon River attains a thickness of 10 m. The total thickness of the formation probably exceeds 1500m. Paleontological dating of foraminifera in the limestone indicates an Early Miocene age (Miranda and Caleon, 1979).

Paracale Granodiorite

Lithology	Granodiorite
Stratigraphic relations	Intrudes serpentinized peridotites
Distribution	Paracale, Camarines Norte
Age	Early - Middle Miocene
Named by	Meek (1941)

The Paracale Granodiorite was named by Meek (1941) for the granodiorite stock intruding serpentinized peridotites in the Jose Panganiban-Paracale Mining District. It is an ovoid body about 17 km long and 4 km wide. The granodiorite is medium- to coarse-grained with albite-oligoclase, orthoclase, biotite and quartz as major components. The core of the stock is massive with no pronounced mineral lineation, but the peripheral zone is characterized by mineral foliation and lineation. The rock is highly fractured and faulted where bleaching and pyritization are common.

The emplacement of the granodiorite has been assigned various ages, from Paleozoic (Alvir, 1950) to Pleistocene (Meek, 1941). Frost (1959) suggested that the intrusion of the stock took place after the deposition of the Universal Formation and continued after the emplacement of the Larap Volcanic Complex, which overlie the Universal Formation. Miranda and Caleon (1979) postulate an Early Oligocene age of intrusion for the stock, the same age as the quartz diorite in Caramoan and Batalay intrusive in Catanduanes (Miranda and Vargas, 1967). Radiometric dating of samples of the granodiorite gave values that range from 14.4 Ma (Giese and others, 1986) to 18.6 Ma (Geary and others, 1988) equivalent to late Early Miocene (Burdigalian) to early Middle Miocene (Langhian). Results of other radiometric K-Ar determinations are: 14.9 Ma (Wolfe, 1981), 17.1 Ma (UNDP, 1987) and 17.20 Ma (MMAJ-JICA, 1999).

The underground mapping of the 350-foot level of the Paracale Gumaus Gold Mine revealed that the granodiorite is cut by numerous pegmatites, aplites and lamprophyres. The pegmatites occur as thin discontinuous dikes that intrude both the granodiorite and aplites. They contain abundant large sodic orthoclase and quartz crystals with grain sizes up to 2 cm. The aplite dikes consist of biotite, ferromagnesian minerals and anhedral garnet grains. These are not generally mineralized although in places where these dikes are numerous, the granodiorite is extremely bleached. The dikes are 2-10 m thick, pinch and swell along a northwest direction and normally cut across the foliation planes of the granodiorite. The lamprophyres are dark gray fine-grained dikes 0.3 - 1.5 m thick that cut across the foliation of the granodiorite and some of the aplites.

Tamisan Diorite

Quartz diorite, diorite, andesite, dacite,
syenite
Intrudes Tumbaga, Larap and Bosigon
Formations
Tamisan, Camarines Norte
early Late Miocene
BMG (1981)

The Tamisan Diorite is named after the quartz diorite outcrops in the tributaries of Bosigon, Bayabas and Lobo rivers in Tamisan area, Camarines Norte. The intrusive varies in composition from hornblende diorite to hornblende quartz diorite. Related rocks include andesite, syenite and dacite porphyries, which occur as stocks, dikes and sills. These intruded the Tumbaga Formation, Larap Volcanic Complex and Bosigon Formation. Recent radiometric K-Ar dating of hornblende of the diorite by MMAJ-JICA (1999) gives values of 6.96 Ma (Messinian) and 10.60 Ma (Tortonian), equivalent to early Late Miocene age.

Sta. Elena Formation

Lithology	Conglomerate, sandstone, siltstone, shale, limestone
Stratigraphic relations	Unconformable over the Bosigon Formation; conformably overlain by the
	Viñas and Macogon formations
Distribution	Sto.Tomas-Sta. Elena Road, Macogon-
	Kanapawan Road in Camarines Norte and upper Kilbay Creek in Quezon province
Age	Late Miocene
Named by	BMG (1981)

The Sta. Elena Formation was described by Miranda and Caleon (1979) in reference to the sedimentary sequence exposed along the Sto. Tomas-Sta. Elena Road. This is also exposed along the Macogon-Kanapawan Road in Camarines Norte and upper Kilbay Creek in Quezon province. The formation consists of interbedded conglomerates, sandstones with minor siltstone and shale. The shale comprises about 50 per cent of the formation. Limestone, interbedded with shale and siltstone, was observed only at upper Kilbay River in Tagkawayan, Quezon. The conglomerate contains rounded to subrounded pebbles of basalt, diorite, volcanic sandstone, limestone and chert. The conglomerate is well-sorted with pebble clasts averaging 2-3 cm long. The sandstone is massive, dark gray, medium- to coarse-grained. The limestone is fine- to medium-grained

and fossiliferous. Paleontologic dating of foraminifera in the limestone indicates a Late Miocene age for the formation (Miranda and Caleon, 1979).

Viñas Formation

Lithology	Conglomerate, sandstone, siltstone, shale
Stratigraphic relations	Conformable over the Sta. Elena
	Formation
Distribution	Calauag, Quezon; Labo and Daet,
	Camarines Norte
Age	Pliocene
Thickness	475 m
Named by	Corby and others (1951)

The formation was introduced by Corby and others (1951) to designate the poorly consolidated, sandstone, siltstone and conglomerate along the highway between Sumulong and Viñas northeast of Calauag, Quezon. It is also exposed as far as Doña Aurora, Calauag. The Viñas rests conformably on the Hondagua Formation and is overlain disconformably by the Pleistocene Malumbang Formation at Bondoc Peninsula. As described by Espiritu and others (1968), the formation consists of basal beds of limestone and conglomerate succeeded by a series of poorly bedded, sandy and fossiliferous limestone, calcareous sandstone and mudstones with interbeds of pebble and cobble conglomerates. The sandstone is thick to medium bedded, light greenish gray to brown, poorly to fairly consolidated, and in places conglomeratic. Comprising the mudstones are thin to medium bedded siltstones, claystones and shale. The conglomerate contains sub-angular to rounded pebbles and cobbles set in a calcareous matrix. The limestone is gravelly while the shale is thick to thin bedded, gray to brown, soft and friable. At the type locality and in Labo and Daet rivers, the shale contains large fossils of helical and conical shells. Field and faunal evidence suggest a Pliocene age (Miranda and Caleon, 1979). It has a thickness of 475 m as measured along the Sumulong - Doña Aurora road section (Espiritu and others, 1968).

Caramoan Peninsula

Siruma Schist

Lithology	Greenschist, marble, metaconglomerate
Stratigraphic relations	Thrusted against the Lagonoy Ophiolite
Distribution	Siruma Peninsula, Butuanan Island,
	portions of Tinambac and Lagonoy
	municipalities, Caramoan Peninsula
Age	Jurassic
Previous name	Lagonoy Schist (Miranda, 1976)
Renamed by	MGB (this volume)

The Siruma Schist was previously named Lagonoy Schist by Miranda (1976) for the metamorphic rocks at Lagonoy. The schists also underlie considerable portions of Siruma Peninsula, including the area west and southwest of Mt. Putianay, northwest of Caramoan Peninsula, as well as

Butuanan Island and portions of Tinambac municipality. Because of the current usage of Lagonoy Ophiolite, and in view of the distribution of the schist in the northwestern corner of the Caramoan Peninsula, these metamorphic rocks are here renamed Siruma Schist. These rocks consist of greenschists, marbles, phyllites and meta-conglomerates. The mineral assemblages of the greenschists include quartz-epidote-actinolite, chlorite-epidote-albite-calcite and actinolite-epidote-albite. The schists display prominent foliation and banding manifested as alternation of chlorite-epidote-actinolite and layers rich in quartz and/or albite. Marble occurs as lenses in the schist, and may be thin-bedded in places. Metamorphosed conglomerate consists of elongated pebbles and cobbles of basaltic rocks, marble and greenstone that are flattened parallel to the foliation. The Siruma is assigned a Jurassic age on the basis of the dating of the Lagonoy Ophiolite (Jurassic-Early Cretaceous).

Lagonoy Ophiolite

Lithology	Dunite, pyroxenite, peridotite, gabbro, basaltic dike complex, pillow basalt, palaric sodimentary rocks
Distribution	Mt. Dutieness Legeness and Tembergy
Distribution	Nit. Putlanay, Lagonoy and Tambang;
	Siruma Peninsula
Age	Jurassic – Early Cretaceous
Named by	David (1994)
Synonymy	Cadig Ophiolitic Complex, Panganiran
	Ultramafics (De Guzman, 1963);
	Camarines Norte Ophiolitic Complex
	(Tamayo and others, 1998)

The Lagonov Ophiolite was named by David (1994) for the exposures of ultramafic and mafic rocks in Caramoan Peninsula. The Lagonov is a complete ophiolite sequence characterized by an imbricated series of ultramafic rocks (dunite with chromite layers, pyroxenites and peridotite), gabbro (massive and cumulate sequence), pillow basalt and its sedimentary cover. Exposures are mostly in the northwestern part of the peninsula, traceable from Lagonov northward to Tambang Point. It also underlies a large portion of Siruma Peninsula in the northwest, including Mt. Putianay. Localized low-grade metamorphism also affected the sequence. Along the eastern bank of Tambang River, in Mapid, massive to layered gabbro are intruded by basaltic dikes. These are overlain by pillow basalts with some brecciated layers. Westward, at Barangay Denrika, the gabbroic unit is overlain by slightly metamorphosed interbedded pyroclastic rocks with some reworked blocks of basaltic rocks. These then pass upstream into turbiditic clastic rocks, which probably correspond to the sedimentary cover of the ophiolite. Metamorphosed units of the Lagonoy Ophiolite were previously lumped with the Lagonoy Schist of Miranda (1976) and BMG (1981). A metamorphosed leucodiabase and gabbro east of Alto Point revealed a radiometric (Ar-Ar) date range of 151-156 Ma, equivalent to Jurassic (Geary, 1986; Geary and others, 1988). Radiometric (K-Ar) dating of a gabbro in Mayon Mines in Siruma Peninsula gave a value of 117 Ma, equivalent to Early Cretaceous.

Lithology	Graywacke, conglomerate, pillow basalt,
Stratigraphic relations	tuff, pelagic limestone, chert Represents the volcanic carapace and sedimentary cover of the Lagonov
	Ophiolite
Distribution	Eastern part of Caramoan Peninsula, from
	Guijaio to Tinambac
Age	Late Cretaceous
Named by	David (1994)
Synonymy	Garchitorena Formation (Miranda, 1976)

Pagsangahan Formation

The Pagsangahan Formation in Caramoan Peninsula outcrops mainly on the eastern part of the peninsula, from Guijalo up to Tinambac. On the northern coast, this formation is represented by indurated fine and coarse graywacke and conglomerates with volcanic and tuffaceous clasts and some intercalations of pillow lavas. Northwestward in Daldagon, on the eastern side of San Vicente Bay, andesitic lava flows, agglomerates and basalts. breccia coarse graywacke vesicular and overlie the metamorphosed sequence of the Lagonov Ophiolite. On the southern end of the Caramoan Peninsula, this formation is characterized by weakly metamorphosed graywacke, tuffs and conglomerates with volcanic clasts. These persist eastward to Maangas where the formation gives way to a sequence of lava flows with interbedded conglomerates and fine and coarse graywackes. In Parabcan and Bitaongan the sequence is dominated by lava flows with some pillow structures. The degree of metamorphism of the unit decreases eastward. Limestones are interbedded with the volcaniclastic sequence in the southern part of the peninsula. The limestone exhibits various facies, from white to gray massive limestone to reddish, bedded pelagic limestone with cherty interlayers. It is usually marbleized but fossils of Globotruncana of Late Cretaceous age have been obtained from some samples. An intertonguing of the limestone with reddish interbeds of graywacke and siltstone has been observed at the mouth of Langha River east of Maangas. The Pagsangahan represents the volcanic carapace and pelagic sedimentary cover of the Lagonov Ophiolite.

Late Cretaceous limestones in the eastern part of the peninsula, which were previously interpreted to be part of the formation (BMG, 1981) were found by later studies to be large olistoliths in an olistostrome sequence formed later (David, 1994). A sequence of graywacke and conglomerates near the town of Parabcan, which was previously attributed to the *Garchitorena Formation* was found to be contiguous with the Pagsangahan Formation. The Pagsangahan is separated from the Garchitorena Formation by the west-northwest trending Minas Fault, although they may be considered coeval.

Garchitorena Formation

Lithology Volcanic wacke, shale, limestone, chert, basalt, tuff, agglomerate *Stratigraphic relations* Not reported
Distribution	Northeastern part of the peninsula, from
	Garchitorena to Parabcan
Age	Late Cretaceous
Thickness	1,500 m
Named by	Miranda (1976)
Synonymy	Pagsangahan Formation

A sequence of volcanic wacke, chert, shale, limestone and basaltic flows designated by Miranda (1976) as the Garchitorena Formation underlie a wide belt in the northeastern part of the peninsula, from Garchitorena in the north to Parabcan in the south. The shale is medium bedded, light gray, highly indurated and slightly carbonaceous. The limestone is generally massive to medium bedded and dirty white to light brown. The chert is thin bedded, light brown to chocolate brown. At Tinajuagan Point and in the interior part of Tabgon, the unit is characterized by a turbidite sequence with interbeds of reddish to gray tuff and intercalations of agglomerates containing andesite clasts. Coral fragments are present in the coarser sandstone layers. Some small islands southeast of Lahuy show similar stratigraphy, particularly Haponan Island where limestone with cherty layers is interbedded with agglomerate. The thickness of the formation is estimated to be 1,500 m. The formation was previously dated Paleocene (BMG, 1981) but recent studies indicate a Late Cretaceous age on the basis of nannofossils in the interbedded shales. An and esitic clast in the applomerate has been dated 91.1 \pm 0.5 Ma by ⁴⁰Ar-³⁹Ar radiometric method, confirming the Late Cretaceous age (Turonian) of the Formation (David, 1994). The formation is equivalent to the Pagsangahan Formation.

Guijalo Limestone

Limestone
Unconformably overlies Cretaceous
sedimentary formations
Guijalo and Minas Point, in the southeast
Middle Eocene
100-200 m
Guijalo Formation (Miranda, 1976)
David (1994)

The Guijalo Limestone was designated by David (1994) for the limestone capping west of Minas Point, which unconformably overlies the volcanic and volcaniclastic rocks of the Pagsangahan Formation. East of Guijalo, karstic topography characterize the massive limestone unit, where it unconformably overlies graywacke and Cretaceous calcareous hemipelagic sedimentary rocks at Palag Bay and Cretaceous limestone in the north at Pandacan Cove. This was previously included in the Guijalo Formation of Miranda (1976), which is here redefined, with its clastic units being included in the Caramoan Formation discussed below. The limestone is cream to grayish and generally massive with facies variations from algal limestone to bioclastic limestone. Part of the limestone east of Guijalo is most probably a megablock in an olistostrome unit (Ragas Olistostrome, discussed below). Numerous datings of large foraminifera in limestone samples indicate an age of Upper Lutetian-Lower Bartonian

(Foraminiferal Zone P12-P13) equivalent to Middle Eocene. It is around 100 m thick in the Minas Point area and 200 m thick east of Guijalo.

Caramoan Formation

Lithology	Tabgon Flysch – conglomerate, graywacke, shale, siltstone Ragas Olistostrome – sandstone, siltstone, shale matrix with blocks of limestone, andesites, wackes, siltstone
Stratigraphic relations	Not reported
Distribution	Easternmost part of the peninsula from Tabgon to Ragas Point and from Guijalo to Rungus Point
Age Named by	Middle – Late Eocene David (1994)

This formation was designated by David (1994) for a sequence of turbidites and an olistostrome unit exposed from Barangay Tabgon to Ragas Point in the northern part of the peninsula and from Barangay Minas to Rungus Point in the south. This includes Late Cretacaous limestones in the eastern part of the peninsula previously mapped as part of the *Pagsangahan Formation* as well as the conglomerates and limestones of what was previously thought to be part of the Eocene Guijalo Formation (BMG, 1981). The Caramoan Formation consists of two members - *Tabgon Flysch* and *Ragas Olistostrome*, which was previously named Ragas Point Olistostrome (David, 1994).

• Tabgon Flysch

At the cape immediately northwest of Tabgon, a rhythmically interbedded sequence of fine and coarse graywacke, siltstone, shale and conglomerates shows a typical flysch sequence. The conglomerates, which form the lower part of the sequence, contain clasts of volcanic rocks, quartz and occasional metamorphic rocks. The upper part consists of regular interbeds of graywacke and shale. The thickness of individual graywacke beds are 5-15 cm. Sedimentary structures such as graded bedding, flute casts and convolute laminations are present. In Guijalo, the flysch appears as a well stratified, folded sequence of graywacke, siltstone, shale and conglomerate. The clasts in the conglomerate include limestones with Globotruncana Nummulites, nummulitic and conglomerates, andesites, fine and coarse graywackes, diorites, quartz and minor metamorphic rocks. Studies made on the nummulitic clasts of limestone and conglomerates indicate an age of early Lutetian-late Bartonian (foraminiferal zone P17-P18), equivalent to Middle Eocene. Age determinations based on nannofossils from the shale interbeds of the flysch sequence indicate a Middle Eocene to earliest Late Eocene age (NP17-NP18).

Ragas Olistostrome

The Ragas Olistostrome is characterized by large reworked blocks of nummulitic conglomerates, limestones with *Orbitolina, Globotruncana*bearing limestone with cherty layers, andesites, volcanoclastic rocks and siltstones. These blocks are generally found to be embedded in a calcareous shaly and silty matrix. The sequence represents a typical olistostrome (Abbate and others, 1970). The olistostrome underlies mostly the easternmost part of the peninsula from Guijalo to Rungus Point in the south and from Bikal to Ragas Point in the north. The limestone olistoliths attain sizes in the order of 50 m. In Tinajuagan, channel conglomerates with blocks of nummulitic limestones in the shale-siltstone sequence confirm the association of the olisostrome with the Tabgon Flysch. The matrix of the olistostrome generally consists of interbedded calcareous sandstone, siltstone and shale. Some calcite veinlets parallel to the shale sequence can be interpreted as the result of sediment dewatering. Along Ragas Point the matrix is composed of reddish siltstone and gravish shale. Reddish calcareous mudstones are intercalated with slumped limestone blocks or megaclasts and limestone breccias. Nannoplankton studies made on the matrix of the different units of olistostrome indicate ages of latest Middle Eocene to earliest Late Eocene (Nannofossil zone NP17-NP18).

Tambang Diorite

Lithology	Hornblende diorite, hornblende quartz
	diorite
Stratigraphic relations	Intrudes Cretaceous – Eocene rocks
Distribution	Tambang Point, Tinambac, Butuanan
	Island
Age	Early Oligocene
Previous name	Tambang Point Diorite (Miranda, 1976)
Renamed by	MGB (this volume)

The Tambang Diorite was previously named Tambang Point Diorite by Miranda (1976) for the diorite exposures at Tambang Point in the northwestern part of Caramoan Peninsula. The biggest exposures are at Tambang Point, Tinambac and Butuanan Island. The Tambang consists of hornblende diorite and hornblende quartz diorite that intrude schists and other older rock units. The diorites occur as stocks as well as dikes and sills having a maximum thickness of 10 m. It is assigned an age of Early Oligocene. Radiometric K-Ar dating of a diorite sample from Bulalacao, eastern Caramoan gave a value of 26.4 Ma, equivalent to Early Oligocene (MMAJ-JICA, 1999).

Del Pilar Formation

Conglomerate, volcanic wacke, limestone
Unconformable over the Garchitorena
Formation
Del Pilar area; Quinabagan Island and
other islands in the north
Early Miocene
BMG (1981)

The Del Pilar Formation, named by BMG (1981) with type locality in the Del Pilar area northwest of Garchitorena, fringes the peninsula and underlies Quinabagan and other islands in the north. It consists of conglomerate, volcanic wacke and limestone. The conglomerate is

generally massive with well-cemented sub-angular to subrounded pebbles and cobbles of volcanic rocks, graywacke, limestone, quartz and schist set in a calcareous matrix. The wacke is medium bedded, coarse-grained and brownish red. The limestone is thin-bedded, dirty white or gray to buff and fine-grained. BMG (1981) assigns an Early Miocene age for this formation.

Lahuy Formation

Lithology	Basalt, dacite, sandstone
Stratigraphic relations	Not reported
Distribution	Lahuy Island and adjoining islands
Age	Middle – Late Miocene
Named by	BMG (1981)
-	

The intercalated sandstone, basalt and dacite flows reported by Miranda (1976) in the southwestern part of Lahuy Island and in some of the adjoining islands are called Lahuy Formation by BMG (1981). The sandstone is well bedded, light gray, fairly indurated, tuffaceous and rich in magnetite sand. The formation was assigned an age of Middle to Late Miocene by BMG (1981).

Catanduanes Island

Yop Formation

Lithology	Basalt, andesite, volcaniclastic rocks,
	limestone, pyroclastic breccia
Stratigraphic relations	constitutes the basement of the island
Distribution	Yop Point, southern Catanduanes
Age	late Early Cretaceous – Late Cretaceous
Thickness	2,000 m
Named by	Miranda (1976)
Synonymy	Catanduanes Formation

The Yop Formation is a sequence of volcanic rocks, volcaniclastic rocks and limestone, which constitutes the substratum of Catanduanes Island. Previous authors have regarded the Catanduanes Formation as the basement of the island (Miranda and Vargas, 1967; Miranda, 1976; BMG, 1981), underlying the Yop Formation. The Catanduanes was named by Miranda and Vargas (1967) for the rocks exposed from Bacon on the northwest to Baras on the southeast and portions of outlying islands. It consists of schist, argillite and sandstone with local interbeds of conglomerate.

Recent studies, however, show that the volcaniclastic rocks of the Catanduanes Formation are intercalated with the volcanic rocks of the Yop Formation (Rangin and others, 1988; David, 1994), and therefore part of the Yop Formation. At the southern tip of the island, from Yop Point to Baldoc, the formation is represented by a sequence of volcanic and volcaniclastic rocks that attain a thickness of 2,000 m. It includes pillow basalts, which is overlain by conglomerates mainly containing andesitic clasts with minor limestones. This is followed by fine and coarse graywacke interbeds. Calcareous interfills in the pillow lavas and limestone

clasts contain *Orbitolina* that indicate a late Early Cretaceous age, probably Barremian-Aptian (P. Saint-Marc, pers. comm., cited in David, 1994). Calcareous siltstones occurring as lenses in the graywackes overlying pyroclastic breccia yielded Cretaceous nannofossils but no precision was given on its age (C. Muller, 1993, cited in David, 1994). To the south in Bugao, some of the intercalated calcareous siltstones contain rare nannofossils of *Micula Staurofora* and *Eprolithus Floralis* indicating a Late Cretaceous age, probably Turonian (David, 1994).

Along the southeastern part of Catanduanes, in Bote, fine and coarse volcaniclastic rocks, which were considered to be part of the Catanduanes Formation, were found to be intercalated with andesitic lava flows. This is followed by a sequence of graywacke and interbedded pillow lavas. A grayish limestone lense in the graywacke sequence was found to contain early Late Cretaceous *Orbitolina* (David, 1994; Fernandez and others, 1994). Further south it continues into reddish bedded siltstones and pillow lavas. The Catanduanes Formation and the Yop Formation are therefore regarded as a single formation with an age range of late Early Cretaceous to Late Cretaceous.

Codon Formation

Olistostrome (volcanic blocks and
limestone in graywacke matrix)
Unconformably overlain by the Payo
Fullialiuli
Codon, Sialat Point, Bonagbonag Point,
Nagumbuaya Point in southern
Catanduanes
late Late Cretaceous
David (1994)

An olistostromic sequence consisting of blocks of volcanic rocks and reworked limestone in a volcaniclastic matrix was designated as Codon Formation by David (1994). It outcrops mainly in the southern part of Catanduanes Island north of the Virac Basin, which is generally underlain by younger Miocene to Pliocene sedimentary rocks. The formation is best exposed in Codon, along the coast of Sialat Point and in Bonagbonag Point. Towards the southwest, the sequence underlies Nagumbuava Point where a megablock of bedded limestone is associated with bedded calcareous siltstone, volcaniclastic rocks and agglomerates enclosed in fine-grained graywacke. The Bonagbonag Limestone of De los Santos and Weller (1955) are apparently olistoliths of megablock proportions within the Codon olistostrome. Facies variations include pebbly graywackes with limestone clasts to limestone breccias and megabreccias, which are enveloped in a graywacke matrix. The majority of the olistoliths in this formation contain Early Cretaceous Orbitolina and Late Cretaceous (Campanian-Maastrichtian) Globotruncana, but the matrix had not yielded any fossils with which to date the formation. The olistostrome does not contain any exotic block from the younger Eocene formation. Instead, the Eocene Payo Formation was found to unconformably overlie the olistostrome. Stratigraphic correlation with other sequences in the region indicates that the Paleocene series is apparently absent, so that an age of latest Cretaceous or late Maastrichtian is postulated for this chaotic sequence.

Payo Formation

Lithology	Manamrag volcanic and volcaniclastic
	facies – sandstone, conglomerate,
	siltstone, andesite,
	Hilawan Limestone facies
Stratigraphic relations	Unconformable over the Codon Formation
Distribution	Manamrag, Bat, Caramoran, Hilawan,
	Viga and the southern part of the
	municipality of Gigmoto
Age	Early Eocene – Late Eocene
Thickness	1,500 m
Named by	Miranda and Vargas (1967)

The Payo Formation, as defined by Miranda and Vargas (1967), is characterized by fine to coarse andesitic graywackes, andesitic flows and limestones. The formation mainly underlies the central part of the island in Manamrag, extending to Bat, in Caramoran in the north, and in the southern part of the town of Gigmoto in the east. The sequence is more than 1,500 m thick. Radiometric and paleontological dating indicates an age range of Early to Late Eocene for the formation. The Payo was subdivided by Miranda and Vargas into three members, namely, Cabugao Subgraywacke, Hitoma-Payo Coal Measures, and Sipi Limestone. In lieu of the subdivision into three members, two main facies have been recognized - volcanic and volcaniclastic facies and a limestone facies.

• Manamrag volcanics and volcaniclastics facies

From Hilawan to Manamrag, the Payo Formation is characterized by a 1500-m thick pile of fine and coarse graywacke and conglomerates, which grade into interbeds of sandstone and siltstone. This rock sequence is overlain by pillow lavas with intercalations of graywacke. Occasionally, reddish calcareous fine-grained siltstones occur in interstices of the pillows. Along Cobo River in Caramoran, this facies is characterized by andesitic graywackes and siltstones with some intercalated andesitic lava flows. A similar sequence was observed east of the island at Gigmoto overlying the deformed sequence of the Yop Formation. Radiometric K/Ar dating of pillow basalt underlying the limestone indicates an age date of 49.88 Ma, equivalent to Ypresian or Early Eocene. The Manambrag facies is equivalent to the Cabugao Subgraywacke of Miranda and Vargas (1967), which they consider as the lower member of the Payo Formation.

Hilawan Limestone facies

Directly overlying the pillow lavas in Manamrag is a white to yellowish bedded limestone unit. The coralline, yellowish limestone directly overlying the pillow lavas gives way to bedded algal limestone and bioclastic limestone with few nummulites, capped by nummulitic limestone. The limestone sequence is around 150 m thick. North of the island in Bagamanok, nummulitic limestone rests on interbedded graywackes and calcareous siltstones. Bioclastic limestone is also interbedded with the volcaniclastic sequence along Cobo River in Caramoran. Paleontological analysis on limestone samples along the section from Manamrag to Hilawan yielded an age of late Lutetian or early Bartonian (P12 or P13, equivalent to Middle Eocene). However, some isolated outcrops of limestone interbedded with graywacke along Viga in the north indicate Late Eocene ages.

Middle to Late Eocene limestone in Cabugao in the eastern part of Virac could be considered equivalent to the Hilawan Limestone. The limestone outcrops are limited in extent and are not mappable. They occur as cappings on the rolling hills, which sit unconformably over the olistostrome of the Codon Formation. The limestone cappings are grayish to white with facies variations of conglomeratic limestones and nummulitic limestones

Batalay Diorite

Lithology	Diorite, andesite, dacite
Stratigraphic relations	Intrudes Yop and Codon Formations
Distribution	Gigmoto, Pajo River
Age	Early Oligocene
Previous name	Batalay Intrusives (Miranda and Vargas,
Renamed bv	MGB (this volume)
,	

The Batalay Diorite with associated andesites and dacites were previously grouped together as Batalay Intrusives by Miranda and Vargas (1967). These intrusive rocks are exposed in the vicinity of Gigmoto in the northeastern part of the island where it intrudes the Yop Formation. Diorites and andesites in the upper reaches of Pajo River also intrude the Codon Formation. Rangin and others (1988) report radiometric K/Ar dating of some samples that indicate an early Oligocene age (30-36 Ma). Later radiometric (K/Ar and ³⁹Ar/⁴⁰Ar) dating by David (1994) likewise yielded an age range of 30-36 Ma.

Bote Limestone

Lithology	Limestone, calcarenite
Stratigraphic relations	Not reported
Distribution	Bote Hill, Locot Island,
Age	Late Oligocene – Early Miocene
Thickness	120 m
Previous name	Bote Hill Limestone (David, 1994)
Renamed by	MGB (this volume)

The Bote Limestone is exposed on Bote Hill in the southeastern part of the island and on the small islands (Locot Islands) east of Bote. The formation consists of cream to white, fossiliferous neritic limestones and calcarenites and attain a thickness of around 120 m. Calcarenites constitute the base of the limestone while the top is represented by algal limestone. The limestone unconformably overlies the sedimentary and volcanic rocks of the Yop Formation. In Locot Islands the limestone is fossiliferous and is around 50 m thick. The limestone has been dated Chattian to Aquitanian or Late Oligocene to Early Miocene (David, 1994).

San Vicente Conglomerate

Lithology	Conglomerate
Stratigraphic relations	Unconformable over the Codon Formation
Distribution	San Vicente, Virac, Catanduanes
Age	Middle Miocene
Named by	Miranda and Vargas (1967)

The San Vicente Conglomerate was named by Miranda and Vargas (1967) for the polymictic conglomerates exposed in the eastern coast of Virac town proper. The conglomerates unconformably overlie olistostromes of the Codon Formation. Clasts of the conglomerates include Cretaceous limestones, Eocene limestones, volcanic rocks and diorites. Samples did not yield fossils but Miranda and Vargas (1967) consider the formation as Middle Miocene.

Sto. Domingo Limestone

Lithology	Limestone, calcarenite
Stratigraphic relations	Unconformable over the Codon Formation
	and San Vicente Conglomerate
Distribution	Sto. Domingo, San Andres, Virac, Igang,
	Magnesia
Age	Middle – Late Miocene
Thickness	200 m
Named by	David (1994)

Limestone underlying the karstic terrain in the southwestern part of the island from San Andres to the town proper of Virac was designated by David (1994) as Sto. Domingo Limestone. The formation unconformably rests on the Codon Formation at the southwestern part of the island and on the San Vicente Conglomerates east of the town of Virac. The limestone is characterized by white to yellowish bedded calcarenites and bioclastic limestone with algae and large foraminifera on the southwestern tip of the island along Igang. These rocks were also observed along the coast in Magnesia where calcarenites and limestones contain very few foraminifera. Coralline and bedded limestones are exposed along the road going to San Andres in the interior part of the island. The formation attains more than 200 m in thickness. Paleontological dating of samples of the limestone indicates an age of Middle to Late Miocene.

Viga Conglomerate

Lithology	Conglomerate, sandstone
Stratigraphic relations	Unconformable over Yop and Payo
	formations
Distribution	Viga, northeastern Catanduanes
Age	Pliocene - Pleistocene
Thickness	150 m
Named by	David (1994)

Outcropping in the northeastern part of Catanduanes Island is a 150-m thick sequence of polymictic conglomerates named Viga Conglomerates by David (1994), which unconformably overlies the Yop and Payo formations.

The clasts are poorly sorted and mainly characterized by volcanic and volcaniclastic rocks of the older formations. Some sandstone beds are interbedded with the conglomerate. The formation could not be dated but it is presumed here to be Pliocene-Pleistocene on account of its poorly indurated character.

Cagraray, Batan, Rapu-Rapu Islands

Rapu-Rapu Schist

Lithology	Greenschist, quartzofeldspathic schist
Distribution	Eastern part of Rapu-Rapu Island
Age	Cretaceous
Named by	Wolfe (in Motegi, 1975)

The Rapu-Rapu Schist was named by Wolfe (in Motegi, 1975) for the metamorphic rocks that underlie the eastern two-thirds of the island. It consists mainly of quartz-chlorite schist and quartz-feldspar-muscovite schist. In places, relict pillow structures can be discerned. Layering due to changes in grain size and composition is common. Finer-grained layers consist principally of chlorite, epidote and feldspar. A typical greenschist is composed of the following mineral proportions: feldspar (30%), epidote (20%), actinolite (20%), chlorite (15%) and muscovite (15%). The quartzofeldspathic muscovite schist may display gneissic texture due to the segregation of quartz from layers of feldspar-chlorite-epidote-actinolite.

Cagraray Peridotite

Lithology	Serpentinized peridotites
Stratigraphic relations	Thrusted against schists
Distribution	southern Cagraray, northern Batan Island,
	western part of
	Rapu-Rapu Island
Age	Cretaceous
Named by	MGB (this volume)

Serpentinized peridotite crops out at the southern part of Cagraray Island and the western end of Rapu-Rapu Island where it is thrusted against schists. In Batan Island, the peridotites crop out in the Calanaga-Naglahongpalay area at the northeastern part and at the southern coast west of Caracaran, as well as at Liguan Point. The peridotites could represent portions of an ophiolitic body that may be correlated with the Lagonoy Ophiolite. These schists in Rapu Rapu include Besshi-type massive pyrite bodies. The peridotite at Rapu-Rapu is intruded by diorite, which gave a radiometric dating of 79 Ma (equivalent to Campanian). This suggests that the peridotite is no younger than Late Cretaceous.

Libog Formation

Lithology	Tuff, agglomerate, volcanic flows,
Stratigraphic relations	graywacke, conglomerate, siltstone Conformably overlain by the Sula Formation

Distribution	Cagraray Island; Libog, Albay
Age	Late Cretaceous (?)
Previous name	Libog Volcanics (Corby and others, 1951)
Renamed by	MGB (this volume)

The Libog Formation was previously named Libog Volcanics by Corby and others (1951) for the volcanic and pyroclastic rocks in Libog, Albay. The Libog includes the outcrops of tuffs with some flows and agglomerates near the Sula lighthouse in Cagraray. In the eastern part of Cagraray Island opposite Sula Strait, a thick sequence of interbedded fine and coarse graywacke, siltstone and conglomerates is included in this formation. The clasts of the conglomerate are mainly andesitic. Owing to the composite nature of the unit, it is renamed as Libog Formation. It probably represents the carapace of the ophiolitic basement. A Late Cretaceous age is assigned for the Libog Formation.

Sula Formation

Lithology	Limestone
Stratigraphic relations	Conformable over the Libog Formation
Distribution	Sula Point and southwestern part of
	Cagraray Island
Age	Middle Eocene
Thickness	~ 220 m
Named by	Corby and others (1951)

The Sula Formation was named by Corby and others (1951) for the limestone at Cagraray, which conformably rests on the Libog Formation. This unit can be observed mainly in the southwestern part of Cagraray Island with Port Sula as the type locality. It consists of white, massive fossiliferous limestone, which pinches out northward into coal measures. A tuffaceous sequence has also been observed. It also crops out in the eastern part of Cagraray Island and on the western coast of Batan Island where it occurs as capping on volcaniclastic rocks. The Sula Formation was dated Eocene by Corby and others (1951) on the basis of the presence of *Nummulites, Discocyclina, Assilina, Asterocyclina, Operculina* and *Fasciolites*. A probable Middle Eocene age is adopted here on the basis of the fossil assemblage. The limestone is around 220 m thick.

Coal Harbor Limestone

Lithology	Limestone
Stratigraphic relations	Not reported
Distribution	Central part to southeastern tip of
	Cagraray Island
Age	Late Oligocene – Early Miocene
Thickness	< 100 m
Named by	Corby and others (1951)

The Coal Harbor Limestone was named by Corby and others (1951) for the limestone exposed from the central part of Cagraray Island to the southeastern tip at Cagraray Point. It is massive pink to buff limestone with a thickness of less than 100 m. Hashimoto and others (1981) recognize

Spiroclypeus-rich and *Eulipidina-Miogypsina-Flosculinella* assemblages for which a Late Oligocene to Early Miocene age was given to the unit.

Liguan Formation

Lithology	lower Coast Limestone – Limestone; middle Coal Measures – Sandstone, shale, coal, upper Hill Limestone – Limestone
Stratigraphic relations	Coal measures grade into the Caracaran Siltstone
Distribution	Batan Island; northern coast of Rapu- Rapu Island
Age	Early Miocene
Thickness	~ 700 m
Named by	Corby and others (1951)

The Liguan Formation was named by Corby and others (1951) for the sedimentary sequence along the southern part of Batan Island. It is made up of three members, namely: the lower Coast Limestone, the middle Coal Measures, and the upper Hill Limestone. Fossils in the formation indicate an Early Miocene age.

Coast Limestone

This lower member was named after the limestone along the southern coast of Cagraray Island. It crops out east of Liguan Point, in the vicinity of Manila and Barat and across Caracaran to Bugtong Point. The limestone is white to gray, massive to thinly bedded. *Miogypsina* and *Lepidocyclina* were identified in samples from this member. The thickness is around 50 m.

Coal Measures

This middle member is exposed as a continuous belt from Liguan to Caracaran in the southwest. It is equivalent to the Coal Measures of Smith (1908). The Coal Measures has an estimated thickness of 300 m (Corby and others, 1951). The Lower Miocene limestone and basal sandstone with interbedded coal seam cropping out 1 km west of Morocborocan along the northern coast of Rapu-Rapu Island is probably a lateral extension of the Coal Measure (Irving and Cruz, 1950).

Hill Limestone

This member consists of massive gray to white limestone forming cliffs from north Liguan Point to the area north of Caracaran. *Miogypsina*, *Lepidocyclina* (*Nephrolepidina* and *Trybliolepidina*) and *Operculina* characterize the fossil assemblages of this unit. It is about 350 m thick.

Caracaran Siltstone

Lithology	Siltstone, coal, limestone
Stratigraphic relations	Grades into the coal measures of Liguan
	Formation
Distribution	Caracaran River, Batan Island
Age	Early Miocene
Thickness	90 m
Previous name	Caracaran Silt (Corby and others, 1951)
Renamed by	MGB (this volume)

This formation was named Caracaran Silt by Corby and others (1951) for the fine-grained clastic rocks along Caracaran River, Batan Island. It consists of thin bedded lignite-bearing siltstone with lenticular limestone interbeds and coal beds. The Caracaran was dated Early Miocene based on the presence of *Lepidocylina*, *Miogypsina* and *Operculinella* in the limestone. The thickness is about 90 m. It grades into the coal measures of the Liguan Formation and could represent a facies of the latter.

Bilbao Formation

lower limestone member – Limestone, sandstone, siltstone, shale
Galicia Sandstone – Sandstone, minor shale
Bilbao Coal Measures – Sandstone, shale, coal
upper limestone member – Limestone,
sandstone, shale
Overlies Caracaran Siltstone
northern part of Batan Island
Middle Miocene
1,490 m
Corby and others (1951)

The Bilbao Formation was named by Corby and others (1951) for the rocks that rest on top of the Caracaran Siltstone. Four members have been recognized: lower limestone member, Galicia Sandstone, Bilbao Coal Measures, and upper limestone member. It is dated Middle Miocene and has an overall thickness of 1,490 m.

The lower limestone member crops out as a continuous belt from Gabon Bay to Calanaga Bay along the northern coast of Batan Island. It is rubbly to conglomeratic, coralline with occasional lenses of carbonaceous sandstone, siltstone and shale. *Cycloclypeus* and its different subgenera of *Lepidocyclina* such as *Nephrolepidina* and *Trybliolepidina* characterize the assemblages. It is 650 m thick. The limestone lies below the coal measures. The *Cycloclypeus*-bearing limestone exposed on a small knoll one kilometer northeast of the town of Rapu Rapu may be equivalent to the lower limestone member (Irving and Cruz, 1950).

The Galicia Sandstone at the northern coast underlies a wide belt from Mancao on the west to the area north of Gaba. It consists of sandstone, which is locally conglomeratic, with interbeds of shale. The Galicia has a thickness of 470 m.

The Gaba Coal Measures consists of beds of brown sandstone and carbonaceous shale with coal seams, which overlie the lower limestone. It is exposed on the slopes of Mt. Bilbao and the vicinity of Gaba at the western coast of Gaba Bay, north of the area underlain by the lower limestone member. It has a thickness of 200 m.

The upper limestone member is exposed as a thick belt north of the coal measures between Gaba and Cakanaga bays. It overlies the coal measures at Mt. Bilbao. It has a similar lithology as the lower limestone member but is only 170 m thick.

Southern Bicol Peninsula

Panganiran Peridotite

Lithology	Serpentinized peridotite, pyroxenite
Stratigraphic relations	Constitutes the basement of the peninsula
Distribution	Panganiran, Albay
Age	Cretaceous
Previous name	Panganiran Ultramafics (De Guzman,
	1963)
Renamed by	MGB (this volume)
Correlation	Cadig Ophiolitic Complex, Cagraray
	Peridotite

This formation was previously named Panganiran Ultramafics by De Guzman (1963) for the serpentinized pyroxene peridotites and pyroxenites along Panganiran River, Albay. Later De Guzman (1968) renames the unit Panganiran Serpentinite, but BMG (1981) retains the name Panganiran Ultramafics. There are two northwest trending lensoid bodies of serpentinized peridotites exposed on the ground on both sides of the lower reaches of Panganiran River, north of Panganiran town. These two bodies could be contiguous beneath the alluvium separating the two. The bigger body on the northeast has a surface exposure measuring 4 km long and 1 km across. Serpentinization is intense in narrow shear zones, while the central zone is only slightly serpentinized. It is probably equivalent to a portion of the Cadig Ophiolitic Complex and the Cagraray Peridotite and likewise dated Cretaceous.

Pantao Limestone

Limestone
Unconformable over peridotites
Barrio Apud to Maonon at Pantao, Albay
Eocene
BM Petroleum Division (1966)
Apud Limestone (De Guzman, 1963)

Pantao Limestone was named by the Bureau of Mines Petroleum Division (1966) for the limestone in Pantao, western Albay, which occurs

as patches fringing the coast. It is disposed along a southeast trending belt from Barrio Apud to Maonon and rests unconformably over peridotites. The limestone is thin bedded, recrystallized and intensely fractured. The fractures are filled with calcite. Fossil assemblages indicate an Eocene age (BMG, 1981). This unit is equivalent to the **Apud Limestone** of de Guzman (1963).

Ragay Andesite

Andesitic flows and agglomerate
Conformable over the Pantao Limestone;
intruded by Panganiran Diorite
Western Albay, from Tinalmud to
Panganiran (Pio Duran)
Early Oligocene
Ragay Volcanics (Corby and others, 1951)
De Guzman (1968)

The Ragay Andesite was previously named Ragay Volcanics by Corby and others (1951) for the discontinuous belt of andesitic volcanic flows and agglomerates underlying most of Bicol Peninsula, especially western Albay. Lit-par-lit bands of andesite along the bedding of older limestone have been noted by De Guzman (1963). It is intruded by the Late Oligocene *Maonon Diorite*. The volcanic flows are largely fine-grained and light green to light greenish gray when fresh. The andesite contains both clinopyroxene and hornblende, which are chloritized in varying degrees. Cherty nodules are present in the formation. The andesite in contact with the limestone is highly ferruginous and characteristically brick-colored.

Maonon Diorite

Lithology	Hornblende diorite, hornblende quartz diorite
Stratigraphic relations	Intrudes Ragay Andesite
Distribution	Coastal area of southern Albay, from
	Santa Gomez eastward to Magragondong,
	extending northwest to the vicinity of Apud
Age	Late Oligocene
Previous name	Panganiran Diorite (De Guzman, 1963)
Renamed by	MGB (this volume)

The Maonon Diorite was previously named Panganiran Diorite by De Guzman (1963), for the diorite exposures west of Panganiran. However, this was renamed Maonon Diorite in recognition of the priority given to Panganiran Peridotite. The diorite is a three-pronged body covering 95 sq km that appears to represent the apophyses of a main diorite stock in the southern part of Albay. The longest and broadest of these intrusive offshoots extends northwestward from Magragondong to the area north of Apud. The unit consists of hornblende diorite and hornblende quartz diorite. Varieties of the hornblende diorite include a porphyritic type and coarse-grained to pegmatitic types. Porphyritic hornblende quartz diorite constitutes the main bulk of the rock and is well represented in the vicinity of Panganiran Bay. Pegmatitic quartz-bearing hornblende diorite may be found as dikes at the Magragondong-Basicao coast. The diorite intruded the Ragay Andesite probably during Late Oligocene time. Hornfels are common near intrusive contacts.

Tinalmud Formation

Lithology	Conglomerate and sandstone with coal stringers; limestone; sandstone with argillite and coal lenses; slate and meta- sandstone with marble lenses
Stratigraphic relations	Unconformably overlain by the Talisay Formation
Distribution	Exposures may be traced from Camia Bay, Camarines Sur on the north to the area southeast of Pantao, Albay in the south; west of Daraga, Albay to west of Libon in northwestern Albay
Age	Early Miocene – Middle Miocene
Thickness	1,200 m
Previous names	Bicol Coal Measures (Corby and others, 1951); Bicol Formation (Bureau of Mines Petroleum Division, 1975)
Renamed by	MGB (this volume)

This formation was previously named Bicol Coal Measures by Corby and others (1951) and later renamed Bicol Formation by the Petroleum Division of the Bureau of Mines (1975). It is hereby renamed Tinalmud Formation to imbue it with a more definite geographic attribute compared to the regional appellation, which it used to carry. Outcrops of the formation define two distinct belts. One verges on the coast of Ragay Gulf, from Camia Bay, Camarines Sur in the north to the area southeast of Pantao, Albay in the south. Within this belt, the Tinalmud River in Pasacao, Camarines Sur cuts through this formation in the entirety of its course. The other belt extends from west of Daraga, Albay to west of Libon, in northwestern Albay.

The formation has four distinct lithologic units. The basal unit consists of thinly bedded, well-cemented, poorly sorted, well-graded conglomerate and sandstone. Lenticular stringers of coal may be found between conglomerate beds. Limestone, the next unit, is exposed east of Panganiran, Albay. It is highly jointed, brecciated and occurs as lenticular masses. Sandstone with argillite and coal lenses makes up the next younger unit. It occurs northeast of Pantao, Albay and is fairly bedded, buff to gray, fossiliferous and calcareous. The youngest unit is made up of slate and meta-sandstone with occasional marble lenses. The slate is considerably altered, thinly laminated, fissile and black to gray; the metasandstone is highly jointed, brown and pebbly. Fossil assemblages indicate an Early to Middle Miocene age. It has a thickness of 1,200 m and was deposited within shallow marine depths.

Talisay Formation

Lithology

limestone member Aliang Siltstone

	Paulba Sandstone
	Malama Siltstone
Stratigraphic relations	Unconformable over the Tinalmud
	Formation
Distribution	Talisay River (Oas and Ligao, Albay);
	Nabua and Bato, Camarines Sur; Libon,
	Oas and Ligao in Albay
Age	Late Miocene - Pliocene
Thickness	2,440 - 2,640 m
Previous name	Talisay Limestone (Corby and others,
	1951)
Renamed by	MMAJ-JICA (1999)

This unit was previously named Talisay Limestone by Corby and others (1951) for the limestone exposure at Talisay River that traverses the municipalities of Oas and Ligao in Albay. The limestone unit, together with associated clastic units, were aggregated into the Albay Group by the Bureau of Mines Petroleum Division (1966, 1975) and BMG (1981). The Albay Group was demoted to formational rank and renamed Talisay Formation by MMAJ-JICA (1999). The Talisay Formation has a gentle northwest-trending synclinal structure that extends from Panganiran area in Ligao, Albay up to Nabua, Camarines Sur, west of Lake Bato. The Talisay is an assemblage of calcareous and highly fossiliferous rocks unconformably overlying the Tinalmud Formation. As described by BMG (1981), its sub-units include the Talisay Limestone, Aliang Siltstone, Paulba Sandstone and Malama Siltstone. Here, these sub-units are considered members of the Talisay Formation, and the limestone is designated merely in an informal sense as the limestone member. Paleontological dating of foraminifera indicates that the age of the limestone is Late Miocene while that of the clastic rocks is Pliocene.

The *limestone unit* is thin bedded and grades from a lower sandy facies through a middle crystalline and coralline facies to an upper marly section. The limestone is the lowermost member and unconformably overlies the Tinalmud Formation. It occurs on both flanks of the Albay Syncline and has an overall thickness of 290 m. The Aliang Siltstone forms a narrow valley between the Talisay hogback on the northeast and the Paulba hogback on the southwest. It is disconformably capped by the Ligao Formation, and in some sections, merges with the Malama Siltstone. The Aliang is thin bedded, calcareous and includes thin interbeds of coarse-grained arkosic and resistant sandstone. It has a thickness of 250-350 m and was dated Pliocene. The Paulba Sandstone underlies a series of aligned ridges between Paulba and San Jose and thins out in the northeast limb of the Albay Syncline. It is thin bedded and includes a considerable amount of volcanic materials. Included are beds of conglomerate with angular pebbles of pumice, cinder and corals set in a fine tuffaceous matrix. The thickness ranges from 100-200 m. The Malama Siltstone is distributed in the southern part of the Albay Syncline, forming rolling hills and vallevs between the Pantao mountains and the Ligao-Oas ranges. The siltstone is thick bedded, gray to brown and fossiliferous with calcareous shale interbeds. It is about 1,800 m thick. Farther north, it is unconformable to the underlying Tinalmud Formation and either conformably overlies the Paulba or merges with the Aliang Siltstone.

Ligao Formation

Lithology	Limestone, pyroclastic rocks, marly shale
Stratigraphic relations	Overlies Talisay Formation
Distribution	Ligao and Oas, Albay
Age	Pliocene - Pleistocene
Thickness	500 m
Previous name	Ligao Limestone (Corby and others, 1951)
Renamed by	De Guzman (1963)
Synonymy	Nabua Formation (Corby and others,
	1951), Sorsogon Marl (Corby and others,
	1951)

The Ligao Formation was previously named Ligao Limestone by Corby and others (1951) to designate the limestone in the canyon of Talisay River in Ligao, Albay. It was called Ligao Formation by de Guzman (1963) to include both the limestone capping the Ligao Range and pyroclastic rocks. The limestone is thick bedded to massive, coralline, white to pink and cliffforming. The pyroclastic rocks underlie the limestone and also occur as interbeds in the limestone. The Ligao is about 500 m thick and is considered Pliocene-Pleistocene in age.

The **Nabua Formation** of Corby and others (1951) in Camarines Sur and northwestern Albay may be considered as facies equivalent of the Ligao Formation. The Nabua consists of calcareous sandstone, siltstone, marly claystone and massive limestone. Likewise, the **Sorsogon Marl** of Corby and others (1951) is also considered equivalent to the Ligao Formation. The Sorsogon Marl is an assemblage of flat-lying loosely consolidated calcareous tuffs, calcarenites and calcisilities, which could represent the near-shore facies of the Malama Siltstone of the Ligao Formation. Francisco (1961) renames it Sorsogon Formation with three members, namely: *clastic and tuff member*, including cross-bedded, loosely consolidated coarse sandstone, tuffs and finer clastic rocks; *basalt member*, and *marly shale and limestone member*, equivalent to the Sorsogon Marl of Corby and others (1951).

Bicol Volcanic Arc Complex

The Bicol Volcanic Arc Complex consists of a number of active and inactive volcanoes and volcanic centers that are disposed along a northwest trending belt from Mt. Labo in Camarines Norte to Mt. Bulusan in Sorsogon. Among the active volcanoes within this arc complex are Mayon (Albay), Bulusan (Sorsogon) and Iriga (Camarines Sur). Inactive volcanoes include Mounts Labo, Bagacay and Nalusbitan in Camarines Norte; Cone, Culasi and Isarog in Camarines Sur; Malinao, Masaraga, Manito and Ligon Hill in Albay; and Binitican, Gate, Jormajan, Juban, Maraut-Banua and Pocdol in Sorsogon.

The volcances and volcanic centers within the Bicol Volcanic Arc Complex are formed from the outpouring of lavas and other volcanic ejecta that were produced as a result of partial melting of the subducting slab of the Bicol segment of the Philippine Sea Plate along the Philippine Trench. Volcanism could have commenced in the Pliocene and continues to the present time.

Susong Dalaga Volcanic Complex

Lithology	Andesite, dacite, agglomerate, tuff
Stratigraphic relations	Overlies Sta. Elena Formation
Distribution	Susong Dalaga Mountains, Labo,
	Nalesbitan, Bayabas, Camarines Norte
Age	Early Pliocene
Previous name	Susong Dalaga Formation (Zaide-Delfin
	and others, 1995)
Renamed by	MGB (this volume)

The Susong Dalaga Volcanic Complex was previously named Susong Dalaga Formation by Zaide-Delfin and others (1995) for the volcanic rocks that underlie the Susong Dalaga mountains west of Mt. Labo, Camarines Norte. As described by Zaide-Delfin and others (1995), the formation consists of andesitic lava flows, agglomerates, tuffs and sedimentary rocks. inclusion of sedimentary rocks consisting of fossiliferous, The carbonaceous mudstones, sandstones, conglomerate and limestone was based on subsurface data and dated Late Miocene. These sedimentary rocks could be equivalent to the Sta. Elena Formation upon which the Susong Dalaga Volcanic Complex was deposited. Radiometric K-Ar dating of biotite from samples of dacite and whole rock dating of andesite range from 4.10 Ma to 5.80 Ma equivalent to latest Miocene to Early Pliocene (Zanclean). An Early Pliocene age for the Susong Dalaga is adopted here. The volcanic rocks around Mt. Nalesbitan and Bayabas are considered equivalent to the Susong Dalaga Volcanic Complex.

Macogon Formation

Lithology Stratigraphic relations	Pyroclastic rocks, shale, basalt flows
Stratigraphic relations	Formation
Distribution	Kanapawan-Macogon Road; Bosigon and
	Palali rivers, Bagong Silang Road,
	Camarines Norte
Age	Pliocene
Named by	Miranda and Caleon (1979)

The Macogon Formation was named by Miranda and Caleon (1979) for the rocks typically exposed along the Kanapawan-Macogon Road. It also crops out at Kanapawan and Malatap creeks, Bosigon River and along Bagong Silang Road. The formation is composed of andesitic to dacitic pyroclastic rocks, black tuffaceous shale and basaltic flows. It unconformably overlies the Bosigon Formation and hosts the Nalesbitan epithermal gold deposit. It is dated Pliocene (BMG, 1981).

Bagacay Andesite

Lithology	Hornblende andesite, volcanic breccia
Stratigraphic relations	Not reported

Distribution	Mt. Bagacay, southeast of Paracale,
	Camarines Norte
Age	Pliocene
Named by	Meek (1941)

The name Bagacay Andesite was used by Meek (1941) for the massive and fragmental andesite extensively exposed in Mt. Bagacay southeast of Paracale. The formation occurs as massive flows of finegrained porphyritic hornblende andesite. It has an ash gray to dark gray matrix and becomes brick red when weathered. This type comprises the upper slopes of Mt. Bagacay and underlies some parts of the Basud-Mercedes area. The lower slopes of Mt. Bagacay are underlain by volcanic breccia. Pyritization and chloritization are confined along faults. The formation is believed to have been emplaced during the Pliocene.

Polangui Volcanic Complex

Lithology	Basalt, andesite, pyroclastic rocks
Stratigraphic relations	Covers older rocks
Distribution	Polangui, Oas, Ligao, Tabaco in Albay,
	including Mt. Malinao, Mt. Masaraga and
	Ligon Hill
Age	Pliocene - Pleistocene
Previous name Renamed by	Polangui Volcanics (De Guzman, 1963) MGB (this volume)

The Polangui Volcanic Complex was previously named Polangui Volcanics by De Guzman (1963) for the volcanic rocks covering parts of Oas, Polangui, Ligao and Tabaco. It consists of volcanic flows with pyroclastic fragmental facies that subsequently built up the land forms constituting the volcanic region. Lithologically, the volcanic flows consist of pyroxene andesites and scoriaceous olivine-bearing basalts. The volcanic complex includes other inactive volcanoes in Albay represented by Mt. Masaraga in Ligao, Mt. Malinao in Tiwi and Ligon Hill in Legaspi City. The San Roque Tuff of Corby and others (1951) is also considered a facies of this formation. The volcanic rocks of this formation were probably extruded as early as mid-Pliocene.

Isarog Volcanic Complex

Lithology	Andesite, pyroclastic rocks
Stratigraphic relations	Unconformable over the Lagonoy
	Ophiolite and Tambang Diorite
Distribution	Mt. Isarog, Camarines Sur
Age	Pleistocene
Renamed by	MGB (this volume)
Previous name	Isarog Volcanics (David, 1994)

The Isarog Volcanic Complex was previously named Isarog Volcanics by David (1994) for the volcanic rocks underlying Mt. Isarog at the southern part of Caramoan Peninsula. It consists of alternating layers of pyroxene andesite and hornblende andesite flows, tuffs, volcanic breccias and agglomerates around the lower slopes, which are blanketed by basaltic andesite and pyroxene basalt flows that outcrop in the central highlands. Massive andesitic lava flows intercalated with fine to coarse, dark gray to light brown pyroclastic rocks extend up to Tambang. The andesite is closely jointed and exhibits extensive silicification and kaolinization. Some outcrops are altered into siliceous clay and opaline rocks. The intercalated pyroclastic rocks contain angular to subrounded andesitic fragments. These occur as veneer over the older rock formations, including Lagonoy Ophiolite and Tambang Diorite, in the northern part of Caramoan Peninsula. They weather to yellowish brown to brownish red lateritic soil. The formation is considered to be Pleistocene in age.

Labo Volcanic Complex

Lithology	Interlayered andesite, dacite and minor basalt flows intercalated with tuff and other
	pyroclastics containing andesite fragments
Stratigraphic relations	Unconformable over the Susong Dalaga
	Volcanic Complex
Distribution	Mt. Labo, Bosigon River; Camarines
	Norte, Mt. Kaayunan, Mt. Cone and Mt.
	Culasi in Camarines Sur
Age	Pleistocene
Previous name	Labo Volcanics (Miranda and Caleon,
	1979)
Renamed by	MGB (this volume)

The Labo Volcanic Complex was previously named Labo Volcanics by Miranda and Caleon (1979) for the volcanic rocks around Mt. Labo, Camarines Norte. The best exposures of this unit are in the vicinities of Mt. Labo, Bosigon River and Mt. Susong Dalaga. The formation extends to Mt. Kaayunan, Mt. Cone and Mt. Culasi in Camarines Sur. The volcanic complex consists of interlayered andesite, dacite and minor basalt flows intercalated with tuff and other pyroclastics containing andesite fragments. The following sub-units have been recognized by Delfin and Alincastre (1988): (1) basal unit of weathered and altered andesite, basalt and dacite lavas and lahars; (2) lava domes of biotite-bearing hornblende dacite and andesite extruded over the basal unit; (3) central cone of pyroxene andesite, hornblende andesite and dacite lavas with associated laharic breccia; and (4) and esitic to dacitic block and ash flows erupted about 80,000 years ago. The andesite contains minute phenocrysts of hornblende and plagioclase embedded in a vesicular and porous tuffaceous glassy matrix. The dacite is coarsely porphyritic with plagioclase, biotite and minor quartz as phenocrysts. Along fault zones, the andesite and dacite are silicified and bleached and serve as host rocks for lead and gold mineralization. The pyroclastic flows occur at the periphery of Mt. Labo. These are light green, gray to buff where fresh, and reddish brown where weathered. Some tuff layers contain hornblende, biotite and plagioclase. This rock type thins out farther away from the periphery. The pyroclastic rocks also occur on low lying hills as remnants above the Upper Miocene and Pliocene formations. They are well-bedded and often display minor cross-bedding. In places, the pyroclastic rocks contain huge boulders of massive andesite. Delfin and Alincastre (1988) cite radiometric

dating of 0.416 Ma to 0.08 Ma while the dating given by Los Baños and others (1996) goes back to 0.6 Ma, equivalent to Pleistocene.

Pocdol Volcanic Complex

Andesite, dacite, basalt, pyroclastic rocks
Covers Late-Miocene – Pliocene formation
Pocdol mountains, Bacon, Sorsogon;
Manito, Albay
Pliocene - Pleistocene
2,600 m
Pocdol Volcanics (Alincastre, 1983)
MGB (this volume)

The Pocdol Volcanic Complex was named by Alincastre (1983) for the volcanic rocks underlying the Pocdol Mountains and areas around Bacon in northeastern Sorsogon and Manito in southeastern Albay. The Pocdol consists of a thick sequence of lavas and pyroclastic rocks that overlie the Late Miocene – Pliocene **San Lorenzo Sediments** of Alincastre (1983), equivalent to the Ligao Formation. Tebar (1988) distinguishes seven lithostratigraphic units, modified from Panem and Alincastre (1985), based on field relations and radiometric K-Ar dating. These are Malobago Volcanics, Suminandig Volcanics, Pangas Volcanics, Lison Volcanics, Kayabon Volcanics, Cawayan Volcanics and Pulog Volcanics. The table below gives a summary description of the various units of the Pocdol Volcanic Complex.

Unit	Lithology	Age / dating
Pulog	Pyroclastic flows, tuff breccias, basaltic agglomerate	< 0.040 Ma
Cawayan	Lava flows, tuff breccias with minor lahars	0.040 Ma
Kayabon	Tuff breccias with minor basaltic andesite lavas	0.065 Ma
Lison	Tuff breccias and laharic breccias with minor lavas, pyroclastic breccias and agglomerates	0.478 Ma
Pangas	Andesitic flows	1.5 Ma
Suminandig	Andesitic to dacitic flows with intercalated sedimentary rocks	Early to Middle Pliocene
Malobago	Basaltic flows	Early Pliocene

Table 2.34 Lithology and age dating units of the Podcol Volcanic Complex, Bicol Region

Together with Botong Dome, Mt. Pangas is considered as the core of a large stratovolcano designated by Tebar (1988) as Pangas Volcano. Flank eruptions from Ranga, Tanawon, Palayang Bayan and Osiao craters account for the volcanic deposits of Pangas, as well as those that now form the Matanga Dome and Osiao Dome. Basalt occurs in Mt. Pulog towards the northeast while dacite was noted in the eastern sector. Drillhole data indicate that the volcanic complex attains a thickness of 2,600 m. The volcanic complex seems to have been active from Early Pliocene to Late Pleistocene.

Bulusan Volcanic Complex

Lithology	Andesite, dacite, basalt, rhyolite, tuff,
	breccia
Distribution	Bulusan, Jormajan, Maraut-Banua, Sharp
	Peak and Irosin in Sorsogon
Age	Late Pliocene - Recent
Named by	PHIVOLCS (1988)

The Bulusan Volcanic Complex in Sorsogon consists of Bulusan stratovolcano with adjacent domes and adventive cones that formed on the floor of a prehistoric caldera. The ejecta from these volcanic centers cover an overall area of 400 sq km. Aside from the main Bulusan stratovolcano, the other volcanic centers that comprise the complex are Mts. Jormajan, Maraut-Banua, Sharp Peak and Irosin Caldera. The Bulusan Volcanic Complex may be subdivided into three informal stratigraphic units, namely: (1) pre-caldera volcanics; (2) caldera pumice; and (3) post-caldera volcanics (Panem and Delfin, 1988).

The pre-caldera volcanics consist of older basalt and pyroxene andesites intercalated with tuffs and laharic breccia and younger pyroxene andesites, some of them hornblende-bearing. Volcanism began as far back as 2.14 Ma with the eruption of high-K basaltic andesites and andesites, tuff breccias and tuffs that built the Gate Mountains in the southern part of the complex (Delfin, 1991). The pre-caldera volcanics include Mt. Calaunan (dated 1.1 Ma) and Mt. Homahan (dated 0.4 Ma), a small plug-like edifice consisting of basaltic lavas (Delfin, 1991). The 11-km wide Irosin Caldera was formed around 40,000 years ago following the calderagenic expulsion of dacitic and rhyolitic pumice that covered most of Sorsogon province. The minimum amount of subsidence along the caldera walls was estimated by Panem and Delfin (1988) to be 100 m in the west, 150 m in the southwest and 560 m in the southeast. Mt. Bulusan, Mt. Jormajan and Sharp Peak grew from resurgent extrusion of pyroxene andesite after the caldera floor formed.

The Bulusan stratovolcano (1,559 masl) consists of lava flows, lava domes, pyroclastic air fall deposits and flows, lahars and piedmont deposits. The year 1852 marks the start of Bulusan's recorded explosive activity. Its eruption in 1978 was characterized by andesitic basalt ash, which was carried by winds as far as Barcelona, Spain. The succeeding eruptions in 1979, 1980, 1981 and 1983 were all phreatic and mild (PHIVOLCS, 1995). Its eruption in 1992 was mild as well and of short duration. Among the lava domes and cones, the most notable are Mt.

Jormajan, Maraut-Banua and Sharp Peak. Other lava domes at the western, southern and southeastern flanks are typically bulbous masses, some with central collapse features.

Mt. Juban, located east-northeast of Mt. Jormajan, and Mt. Gate in Matnog, Sorsogon, were probably also formed during the Pleistocene but are now regarded as inactive volcanoes.

Iriga Volcano

Lithology	Basalt, tuff, volcanic breccia
Distribution	Mt. Iriga, Camarines Sur
Age	Pleistocene – Recent

Mt. Iriga (1,143 masl) is an active volcano consisting of olivinepyroxene basalt lavas intercalated with thin layers of tuff and volcanic breccias (Panem and Cabel, 1998). Airfall bombs and scoriaceous hornblende-bearing pyroxene basalt overlie the basaltic debris avalanche inside the crater area. Debris avalanche and a small phreatic eruption were reported in 1642 (PHIVOLCS, 1988, 1997). The debris avalanche dammed the Barit (Buhi) River, which caused the creation of Lake Buhi.

Mayon Volcano

Mayon is a stratovolcano or composite cone formed from lava flows, pyroclastic flows, airfall deposits and debris flows. It stands around 2,462 masl and has a base circumference of 62.8 km (PHIVOLCS, 1995). Minor cinder deposits are also found in the northeastern flanks of Mayon's cone (PHIVOLCS, 1988). It is a very active volcano, with at least 47 recorded eruptions since 1616 (PHIVOLCS, 2002). It covers an area of 250 sq. km with a base circumference of 63 km encompassing the towns of Sto. Domingo, Malilipot and Camalig. The 1984 eruption of Mayon was characterized by initial Strombolian activity (September 9-18) with effusion of andesitic lava and pyroclastic flows on the northwest and southwest flanks of the volcano (PHIVOLCS, 1988). After a few days, this was followed by Vulcanian eruptions (September 22-29) that produced pyroclastic flows. The final outburst occurred on October 6 with the eruption of an ash column and effusion of pyroclastic flows.

MASBATE GROUP OF ISLANDS (SG 8, 16, 17)

The Masbate Group of Islands include Masbate, Burias and Ticao, which belong largely to the Southeast Luzon Basin tectonostratigraphic terrane, except for the peninsular portion in northeastern Masbate. The latter is considered part of the Recent Negros Arc stratigraphic grouping.

					MASBATE	
PERIOD	EPOCH	STAGE	Ма	MASBATE MAINLAND	TICAO ISLAND	BURIAS AND ADJACENT ISLAND
	HOLOCENE					
	PLEISTOCENE	4 Late 3 Middle	0.0117 0.126 0.78 1.81	Masbate Limestone Port Barrera Formation	Matabao Formation	
ш	PLIOCENE	2 Late	2.59			Baybay Limestone
OGEN		1 Early	5.33	Nabongsuran Andesite	San Jacinto Formation	Daybay Limestone
BN		— 3 Late —	7.25	Buyag Formation	Ticao Limestone	
	MIOCENE	-2 Middle-	13.65	Mobo Diorite Lanang Formation	Pilar Formation	San Pascual Formation
		— 1 Early —	20.43	Mountain Maid Limestone	Nap Conglomerate	Quilla Formation
	OLIGOCENE	2 Late	28.4	Nabangig Formation		Makalawang Limestone
		1 Early	33.9			
빌		4 Late	37.2	Aroroy Diorite		
PALEOGE	EOCENE	3 Middle 2 1 Early	40.4 48.6	Kaal Formation		
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7			
CEOUS	Upper	Late	99.6		Talian Online	
CRETA	Lower	Early	1.4E E		Tansay SChist	
JURASSIC		3 Late	145.5	Calumpang Formation		
		2 Middle		Manapao Basalt		
		1 Early		Baleno Schist		

Table 2.12 Stratigraphic column of Masbate, Ticao and Burias Islands

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Masbate Mainland

Baleno Schist

Lithology	Amphibolite, hornblende clinopyroxenite
Stratigraphic relations	Comprises the basement of Masbate
	Island
Distribution	Mabunga, Aroroy
Age	Cretaceous (?)
Previous name	Aroroy Schist (Barcelona, 1981)
Renamed by	MMAJ-JICA (1990)

The oldest formation in Masbate was named by Barcelona (1981) as Aroroy Schist, observed mostly along the beach at Mabunga, Aroroy. The formation was renamed Baleno Schist by MMAJ-JICA (1990). The formation consists of amphibolite and hornblende clinopyroxenite. Hornblende in the amphibolite comprises 40-45% of the rock and the rest

is made up of calcic plagioclase, quartz and epidote. The hornblende clinopyroxenite is composed mainly of diopsidic pyroxene, comprising 50% of the rock, large hornblende crystals and finer grains of plagioclase with minor amounts of tremolite and magnetite. MMAJ-JICA (1990) assigned a Jurassic age for the schist.

At the Masbate Forest Reservation, quartz diorite intrudes the schist as well as peridotite and gabbro. The association of the schist with peridotite and gabbro as well as pillow basalts (Manapao Basalt) and pelagic sedimentary rocks (Calumpang Formation) led MMAJ-JICA (1990) to postulate the occurrence of an ophiolitic complex in the area. However, this is little studied and has yet to be validated. The Schist is probably Cretaceous in age (Porth et al, 1989).

Manapao Basalt

Lithology	Basalt
Stratigraphic relations	Overlain by Calumpang Formation
Distribution	Mt. Manapao, southwest limb of Masbate,
	Pulanduta and Calumpang; tributary of
	Jangan River
Age	Cretaceous (?)
Previous name Renamed by	Mt. Manapao Basalt (MMAJ-JICA, 1986) MGB (this volume)

The Manapao Basalt was previously named by MMAJ-JICA (1986) as Mt. Manapao Basalt. The formation underlies Mt. Manapao and is also exposed along the coastal strip at Pulanduta and Calumpang and at the tributary of Jangan River probably as windows of the basement. The Manapao consists mainly of pillow basalt. The pillow structures, approximately 0.5 meters in diameter, are weathered and cut by various veins of quartz, zeolite, and calcite. In the absence of radiometrically datable rocks due to the intense degree of weathering and alteration, a Jurassic age was assigned by MMAJ-JICA (1986) to the Manapao, but Porth et al (1989) assign a Cretaceous age for the Manapao.

Calumpang Formation

Lithology	Chert, conglomerate, sandstone, siltstone, mudstone, tuff, basaltic flow breccia
Stratigraphic relations	Overlies Manapao Basalt
Distribution	Barrio Calumpang; Barrio Bangad,
	Milagros, Barrio Jangan, Balud
Age	Late Cretaceous (?)
Previous name	Boracay Formation (MMAJ-JICA, 1986)
Renamed by	MGB (this volume)

The Calumpang Formation was previously designated as Boracay Formation by MMAJ-JICA (1986), renamed here as Calumpang Formation for the exposures near Barrio Calumpang. It consists of chert, conglomerate, sandstone, siltstone, mudstone, tuff and basaltic flow breccia. Chert beds are usually 10 cm thick and vary in color from red, greenish yellow to various shades of gray. Syngenetic manganese beds are occasionally associated with the chert (Baybayan and Matos, 1986). Polymictic conglomerate contain pebbles and cobbles of basalt and limestone. The upper part of the formation is characterized by dark gray siltstones and mudstones and light gray tuff beds.

Exposures are strung along a 23-km belt parallel to the southeastern coast of the southwestern leg of the island, from Barrio Bangad, Milagros to Barrio Jangan, Balud. The sequence is intensely folded and faulted such that the bedding is commonly disjointed. The formation overlies the

Manapao Basalt and is in a NE-trending and SE-dipping thrust (upthrust) contact with the Kaal Formation that corresponds to the Mandaon Formation of MMAJ-JICA (1986). It is probably Late Cretaceous in age (Porth et al, 1989).

Kaal Formation

Lithology	Slate, graywacke, basalt, andesite, dacite
Stratigraphic relations	Overlies Manapao Basalt
Distribution	Kaal creek, Aroroy; Masbate Forest
	Reservation
Age	Eocene
Named by	Ferguson (1911)
Synonymy	Mandaon Formation (MMAJ-JICA, 1990)

The Kaal Formation was named by Ferguson (1911) for the red and dark purple slate and graywacke exposed at Kaal Creek, Aroroy at the northern part of Masbate. Some of the slates contain psilomelane lenses parallel to the cleavage. The sequence of volcanic rocks occurring with thermally metamorphosed sedimentary rocks within the Masbate Forest Reservation could be considered part of the Kaal Formation (Duna, 1968). These volcanic rocks are mainly basalt, with andesitic and dacitic facies. At Cawayan creek, along the eastern border of the Forest Reservation, interbeds of sedimentary rocks occur with the volcanic rocks, which probably correspond to the metavolcanics and metasediments of Barcelona (1981).

The *Mandaon Formation* of MMAJ-JICA (1990) may be considered equivalent to the Kaal Formation. It consists of a thick sequence of dark, well-indurated volcanic sandstone and conglomerate, fragmental flows, volcanic rocks, and occasional parallel-bedded red calcarenites and manganese beds that is unconformably (?) overlain by the Late Oligocene-Early Miocene Sambulawan Formation of UNDP (1984) at Mandaon. This formation is in thrust contact (underthrust) with the older Manapao Basalt and Calumpang Formation in the southwestern leg of the island. The Mandaon Formation is in a Y-shaped, NE-trending position at Balud-Mandaon, as a U-shaped body at Aroroy, and in peripheral position in Milagros. It is intruded by the Aroroy Quartz Diorite, which gave a radiometric dating of 38 Ma (Middle-Late Eocene). The formation is therefore assigned an Eocene age, probably Early – Middle Eocene.

Aroroy Quartz Diorite

Lithology	Quartz diorite
Stratigraphic relations	Intrudes Kaal Formation
Distribution	Aroroy area, Masbate
Age	Middle - Late Eocene
Previous name	Aroroy Diorite (Ferguson, 1911)
Renamed by	MGB (1981)

The Aroroy Diorite was named by Ferguson (1911) for the quartz diorite stock in the northern portion of Aroroy, Masbate. As described in Corby and others (1951), the intrusive body is a hornblende quartz diorite consisting of sodic plagioclase, quartz, hornblende and minor orthoclase. The rock shows pervasive silicification and pyritization near its contact with the intruded rooks. Associated minor rock types include hornblende diorite, granodiorite, tonalite and gabbro. Barcelona (1981) reports that this stock intrudes the Kaal unit. At Aroroy, this was also observed to intrude the Mandaon Formation of MMAJ-JICA (1986), which is equivalent to the Kaal Formation. Radiometric dating of a sample of the quartz diorite gave an age of 38 Ma, which corresponds to Bartonian (the third of four stages comprising the Eocene).

Nabangig Formation

Lithology	Siltstone, shale, minor sandstone
Stratigraphic relations	Unconformable over the Kaal Formation
Distribution	Nabangig; Santa Cruz River, south of
	Malibas; Mabunga, Aroroy
Age	Late Oligocene
Named by	Porth and others (1989)

The Nabangig Formation was named by Porth and others (1989) in reference to shale and siltstone exposures in the vicinity of Sitio Peña west of Nabangig. Similar exposures were also encountered in Santa Cruz River south of Malibas. Samples of the Nabangig were found to contain foraminifera and nannoplankton fossils equivalent to lower N4 and NP25 zones, corresponding to Late Oligocene age. The formation is probably equivalent to the Masbate Formation of Barcelona (1981), which he described as bedded siltstone with minor interbeds of sandstone at Mabunga, Aroroy unconformably overlying the Kaal Formation.

The **Sambulawan Formation** of UNDP (1984) could also correspond to the Nabangig Formation. The Sambulawan is described as a sequence of conglomerate, siltstone, limestone, wackes, minor mudstones, and basalt breccia. Paleontological dating indicates a Late Oligocene-Early Miocene age for the Sambulawan (MMAJ-JICA, 1990). This unit is exposed on the beach north of Bituon. High angle crossbedding observed at Sambulawan River suggests a fluvial or shallow marine depositional environment. The formation is unconformably overlain by Middle Miocene Lamon Andesites of MMAJ-JICA (1990) as observed along Lamon, Tugbo, and Sambulawan Rivers.

Mountain Maid Limestone

Lithology	Limestone (micrite, biomicrite, packstone)
Stratigraphic relations	Not reported
Distribution	Guinobatan River, Mt. Bagadilla;
	Caitangan, between Milagros
	and Masbate; Batungan Hill; vicinity of
	Tigbao Point
Age	Late Oligocene – Early Miocene
Thickness	60 - 80 m
Named by	Ferguson (1911)

Mountain Maid Limestone was designated by Ferguson (1911) in reference to the dark blue limestone similar to those found in places along the main range of the island. The main lithological types of the Mountain Maid vary from massive biomicrites, to bedded packstones to local micritic limestones. The type locality is a southerly spur of Mt. Bagadilla, at the western end of the gorge of Guinobatan River. The formation is also exposed at Caitangan, in Asid River between Milagros and Masbate, and near Tigbao Point. It also forms Batungan Hill at Aroroy. An Oligocene-Early Miocene age has been assigned by Corby and others (1951) to the Mountain Maid Limestone. Cosico and others (1989) dated the formation as Middle Oligocene-Early Miocene while Porth and others (1989) give a probable age of Late Oligocene-Early Miocene for the limestone. The maximum exposed thickness of this unit is 60 - 80 m.

Other units that may be considered equivalent to the Mountain Maid include the Lourdes Limestone at Bo. Lourdes, Milagros (Martin and dela Cruz, 1976) and the Uson Limestone in eastern Masbate (MMAJ-JICA, 1986; Baybayan and Matos, 1986).

Lanang Formation

Lithology	Conglomerate, sandstone, shale,
	limestone, calcarenite
Stratigraphic relations	Overlies Kaal Formation
Distribution	Lanang River; Buenavista-Cawayan area;
	Napayawan River;
Age	Middle Miocene
Named by	Ferguson (1911)
Synonymy	Lanang Conglomerate (Porth and others,
	1989), NW Lower Buyag Formation (Porth
	and others, 1989)

Lanang Formation was named by Ferguson (1911) after its type locality at Lanang River. The formation is equivalent to the Lanang Conglomerate of Porth and others (1989). Exposures of the formation are also found along the Aroroy-Mandaon road, Napayawan River, and east of the Buenavista-Cawayan area in southern Masbate. It consists of conglomerates composed of well consolidated, poorly sorted, wellrounded, basalt and andesite as well as white orbitoidal limestone boulders and pebbles set in a tuffaceous sandstone matrix. Interbeds of coarse sandstone, shale, and coralline limestone are present in the conglomerate. The orbitoidal limestone pebbles in the conglomerate yielded Early Miocene large foraminifera. Corby and others (1951) assign a Middle Miocene age to this formation. Porth and others (1989) note the presence of a few specimens of Orbulina universa, indicating an age of Middle Miocene or younger. The conglomerate of Lanang overlies the Kaal Formation (Mandaon Formation of MMAJ-JICA, 1990) at Aroroy and Baleno.

The Middle Miocene *Lower Buyag Formation* of Porth and others (1989) in the southeast probably corresponds to the Lanang. At Buenavista and Banga River, it consists of massive limestone with red chert as fracture fillings, tuffaceous sandstone, bedded limestone, arenite

and conglomeratic limestone. Dark gray to black shale and fine- to medium-grained sandstone, biodetrital sandstone and limestone breccia in Segundo River are also considered part of this unit. These interfinger with basinal, white to light brown, tuffaceous marls and shales. The nannoplankton assemblage and foraminiferal zones in several sections of the Lower Buyag indicates an age of NN5-NN6 and N9 to N12, respectively (Middle Miocene). This is apparently equivalent also to the Buyag Limestone of MMAJ-JICA (1989).

Mobo Diorite

Lithology	Hornblende diorite, biotite diorite
Stratigraphic relations	Intrudes Nabangig Formation
	(Sambulawan Formation of UNDP,
	1984)
Distribution	Mobo; Malbug; Masbate town
Age	Middle Miocene
Named by	MMAJ-JICA (1986)

This diorite stock at Mobo has a roughly circular pattern and varies from hornblende diorite to biotite diorite. Smaller bodies are exposed at Matagbak Creek, Malbug and Asid River in Masbate town. It intrudes the Nabangig Formation (Sambulawan Formation of UNDP, 1984). Radiometric dating by MMAJ-JICA (1990) gives 12 Ma, equivalent to Middle Miocene (Serravallian).

Buyag Formation

Conglomerate, sandstone, mudstone,
Unconformably overlain by Port Barrera
Formation and Masbate Limestone
In two belts from Dimasalang to Cataingan
Late Miocene – Early Pliocene
400 – 1,000 m
Corby and others (1951)

The name Buyag Formation was introduced by Corby and others (1951) for the clastic rocks at Barrio Buyag in Dimasalang, Masbate, Exposures of the formation define two narrow belts - a southwestern belt and a coastal belt - on either side of a strip of volcanic rocks. These belts extend southeast from Dimasalang to Cataingan. The Buyag consists of clastic rocks that fine upwards from basal massive pebble conglomerate grading to coarse calcareous sandstone and an upper interbedded tuffaceous, carbonaceous, sandy siltstone and silty claystone with lignitic seams. The formation may be subdivided into a lower member composed mainly of thinly bedded conglomerates and sandstones, and an upper member characterized by thickly bedded to massive mudstone with interbeds of calcarenites (Corby and others, 1951; Martin and dela Cruz, 1976). Exposures of the latter belong mostly to the coastal belt while those of the coarser clastic rocks are concentrated in the southwest belt. Corby and others (1951) give a Late Miocene - Early Pliocene age for the formation, which they estimate to have a thickness of 400 -1,000 m.

The **Upper Buyag Formation** of Porth and others (1989) apparently corresponds to the Buyag Formation of Corby and others (1951). As described by Porth and others (1989), the formation consists of marls with intercalated limestones in southeastern Masbate and west of Nabangig. The foraminiferal and nannoplankton assemblages as reported by Porth and others (1989) are bracketed by zones N16 to N19 (Serravallian to Zanclean) and NN11 to NN15? (Serravallian – Tortonian), respectively, corresponding to Middle Miocene to Early Pliocene.

Nabongsuran Andesite

Lithology	Andesite porphyry
Stratigraphic relations	Intrudes Masbate Formation (Sambulawan
	Formation of UNDP, 1984) and Lanang
	Formation
Distribution	Mt. Nabongsuran; Aroroy; Baleno;
	Mandaon
Age	Early Pliocene
Previous name	Mt. Nabongsoran Andesite Porphyry
	(MMAJ-JICA, 1986)
Renamed by	MGB (this volume)

The Nabongsoran Andesite was originally named by MMAJ-JICA (1986) as Mt. Nabongsoran Andesite Porphyry. It consists of andesitic stocks, plugs, flows, and pyroclastic rocks. These plugs and stocks are located within Aroroy, Baleno, and Mandaon, intruding the Lanang Formation and Nabangig Formation in the north. The diameters of the plugs and small stocks, as exposed on the surface, range from 0.5 km to 2 km (Baybayan and Matos, 1986). The Nabongsoran is considered Early Pliocene in age.

Port Barrera Formation

Lithology	Siltstone, marl, limestone
Stratigraphic relations	Unconformable over the Buyag Formation
	and overlain by the Masbate Limestone
Distribution	Port Barrera
Age	Pleistocene
Named by	Ferguson (1911)

The Port Barrera Formation was named by Ferguson (1911) for the fine-grained gray shale exposed on the opposite side of Port Barrera at the northernmost tip of Masbate. It unconformably overlies the Buyag Formation. It is overlain by the Masbate Limestone. The Port Barrera Formation is subdivided into two members. The lower member consists of calcareous siltstone with silty limestone nodules and lenses and carbonaceous fragments; the upper member is made up chiefly of coralline limestone, often slightly shaly and locally conglomeratic. Corby and others (1951) assign to this formation a Late Miocene to Pleistocene age. It was considered Early Pliocene by BMG (1981). Porth and others (1989) report the presence of foraminifera and nannoplanktons corresponding to N22 and NN19 to NN20, respectively, equivalent to Pleistocene.

Masbate Limestone

Lithology	Limestone, marl
Stratigraphic relations	Unconformable over the Buyag Formation,
	and the Port Barrera Formation
Distribution	Nabangig; southwestern part of the island;
	hills in the northwest; area around
	Masbate Harbor; southeastern coastal
	areas
Age	Pleistocene
Thickness	50 m
Named by	Corby and others (1951)
Synonymy	Bugui Pt. Limestone (MMAJ-JICA, 1986)

The Masbate Limestone was originally named by Corby and others (1951). Good outcrops are found along the eastern coastal road near Nabangig and in a small creek north of Nabangig. The formation consists mainly of white to buff massive limestone, which is largely coralline, locally marly with large-scale crossbedding. It is well exposed in the southwestern part of the island, in the scattered hills in the northwest, and in the area around Masbate Harbor. This formation unconformably covers thinly both the Buyag Formation and the Port Barrera Formation. Corby and others (1951) assign Late Miocene to Pleistocene age to this formation. Later paleontological dating of samples taken from the type area at Colorado Point near Port Barrera by Muller and others (1981) indicate a Pleistocene age. Paleontological dating reported by Porth and others (1989) also indicates a Pleistocene age (N22, NN19 to NN 20). Benthic foraminifera contained in the samples indicate an outer-neritic to upper bathval environment of deposition. The thickness of the formation has been estimated at 50 m.

Masbate Limestone is equivalent to the **Bugui Pt. Limestone** of MMAJ-JICA (1986), which was named after Bugui Pt. at the northwestern end of the island. It also underlies the southeastern coastal areas of Masbate including Esperanza, P.V. Corpuz, Placer, Palanas and Cawayan. The formation can be correlated to the Carcar Formation of Cebu and Tuktuk Formation of northwest Leyte (Porth and others, 1989) on the basis of the age and physical characteristics of the limestone.

Ticao Island

The basement rocks at Ticao Island consist essentially of greenschists and quartzites as well as igneous extrusive and intrusive rocks, including volcanic breccias and serpentinite.

Talisay Schist

Quartz schist, greenschist
Basement rocks
San Fernando to Danao Point
Cretaceous (?)
MGB (this volume)

BMG (1981) mentioned the presence of basement rocks composed essentially of schists west of San Fernando to Danao Point on the southwestern coast of the island. At Talisay Point, the basement includes quartzites, argillites, and marbles. By virtue of their field occurrence and mineral assemblages similar to those of the Aroroy Schist in mainland Masbate, Aurelio (1992) implies a possible Cretaceous age for the basement in Ticao Island.

Nap Conglomerate

Lithology	Conglomerate, with minor siltstone,
	claystone, coal seams
Stratigraphic relations	Not reported
Distribution	Nap Point, Ticao Island
Age	Late Oligocene – Early Miocene
Named by	Corby and others (1951)

This formation was named by Corby and others (1951) for the exposure at Nap Point, in the northwestern part of Ticao. The Nap Conglomerate is brown to olive green, well-indurated, and massive. The constituent pebbles are mostly volcanic rocks with a scattering of greenschists, serpentinite, and guartz. The clasts are generally less than 5 cm in diameter, but some attain boulder dimensions. Aurelio and others (1991) report that the metamorphic clasts contained in this polymictic conglomerate are obviously derived from the rocks constituting the basement. The upper part of the section consists of siltstones and claystones together with carbonaceous materials. Corby and others (1951) report an age determination of Early Miocene for the Nap Conglomerate. This formation may be correlated with the Animasola Conglomerate (Corby and others, 1951) on Animasola Island north of Ticao and the conglomerate of the Quilla Formation in Burias Island. The Animasola, with exposed thickness of 90 meters, consists of conglomerate with interbeds of siltstones and sandstones. Clasts of the conglomerate are characterized by angular pebbles and boulders (up to 90 cm in diameter) of scoriaceous basalt set in a matrix of highly tuffaceous siltstone and sandstone. The age of the Animasola is Early Miocene.

Pilar Formation

Lithology	Siltstone, limestone, conglomerate
Stratigraphic relations	Not reported
Distribution	Pilar and Togoron bays, northern Ticao;
	Lapos Point;
Age	Middle Miocene
Thickness	500-600 m
Named by	Corby and others (1951)

The Pilar Formation was named by Corby and others (1951) for the rocks underlying the area between Pilar and Togoron bays in the northern part of Ticao. It consists of siltstone, conglomerate, and limestone. The siltstone is massive to well-bedded and slightly carbonaceous. In places, outcrops include calcareous siltstone, limestone, and massive conglomerate. At Lapos Point, outcrops include massive and thinly bedded

fossiliferous limestone and tuffaceous siltstone. Corby and others (1951) report an age of Middle Miocene for the formation and a thickness of 500 - 600 m.

The **San Rafael Formation** in southern Ticao is apparently equivalent to the Pilar Formation in the north. It consists of intercalated, well-bedded, silty limestone, and tuffaceous, carbonaceous siltstone.

Ticao Limestone

Lithology	Limestone
Stratigraphic relations	Overlain by San Jacinto Formation
Distribution	Outcrops throughout most of Ticao
	upland, especially in the northern half and
	central highlands.
Age	Late Miocene
Thickness	365-450 m in the north and 150-300 m in
	the south
Named by	Corby and others (1951)

The Ticao Limestone was designated by Corby and others (1951) for the limestones underlying the highlands of Ticao and several small islands off the northern and northwest coasts. It also forms cliffs along the north and northwest coast. The formation consists mainly of massive white to buff limestone whose upper portion is well-bedded. It is usually hard and crystalline, but locally soft and silty. Corals are present but not abundant. Corby and others (1951) assign a Late Miocene age to the formation. The thickness is estimated at 365-450 m for the north end of Ticao and 150-300 m at the south end.

San Jacinto Formation

Lithology	Siltstone, limestone, conglomerate
Stratigraphic relations	Conformable over the Ticao Limestone
Distribution	San Jacinto vicinity, on the northeastern
	coast
Age	Late Miocene – Early Pliocene
Thickness	Maximum 900 m
Named by	Corby and others (1951)

The San Jacinto Formation was named by Corby and others (1951) for the sequence of siltstones, limestone and conglomerates at San Jacinto and the east coast of the island. The formation consists of intergrading beds and lenses of calcareous siltstone, silty limestone, and conglomerate. Pebbles and boulders (up to 65 cm in diameter) of the conglomerate include basalt, serpentinite, chert, limestone, quartz, and coral heads. Massive conglomerate is widespread in the lower portion, although it is separated from the Ticao Limestone by beds of siltstone and silty limestone. The age of the formation is given by Corby and others (1951) as Late Miocene – Pliocene. More precisely, Aurelio (1992) reports that nannofossil assemblages recovered on the more detrital deposits on top of the sequence belong to NN15 zone, equivalent to Zanclean (Early Pliocene). The maximum thickness is estimated at 900 m.

Matabao Formation

Lithology	Conglomerate, reefal limestone,
Stratigraphic relations	Unconformable over the San Jacinto
Distribution	Formation
DISTINUTION	Island; Matabao and Deagan Islands
Age	Pleistocene
Named by	MGB (this volume)

A widespread thin layer of calcareous sedimentary deposits are found on the eastern third and on the southern tip of the island, as well as Matabao and Deagan Islands, off the southern tip of Ticao Island. The formation is made up essentially of shallow water deposits that include conglomerates, reefal limestones, biocalcarenites, siltstones and mudstones containing numerous reefal bioclasts (Aurelio, 1992). Nannofossil assemblages (NN19) indicate a Pleistocene age for the formation.

Burias and Adjacent Islands

The rocks constituting the basement of Burias and adjacent islands include agglomerates and tuffs, mafic intrusive rocks, and an indurated sequence of conglomerates, sandtones and shales. These rocks occur in scattered outcrops in the northwestern and south central portions of the island and along the eastern coast of Templo Island. Nannofossil zones NP21 to 25 have been identified (Aurelio, 1992) from the conglomeratic sequences at the base of the sedimentary units indicating a Late Eocene to Early Oligocene age.

Makalawang Limestone

Lithology	Limestone
Stratigraphic relations	Disconformable over the basement
Distribution	Makalawang Creek, northwest Burias;
	Templo Island; Red Point; northeast of
	Guinduyanan Point
Age	Oligocene
Named by	Corby and others (1951)

The Makalawang Limestone, disconformably overlying the basement, is exposed along Makalawang Creek in northwest Burias, along the coast of Templo Island, at Red Point, and northeast of Guinduganan Point. The basement consists of Late Eocene – Early Oligocene agglomerates, tuffs, mafic intrusive rocks and an indurated sequence of conglomerate, limestone and mudstone. Exposures of the Makalawang occurring as isolated windows peep through the San Pascual Formation. In the inlier east of Guinduyanan Point, intrusions cut the Makalawang Limestone.

At Red Point, lithologic variations of the formation consist of a lower rust-colored, coarse, crystalline limestone; middle vari-colored limestone with sandstone interbeds; and upper thinly bedded white limestone. The large window east of Alimango Bay also shows various lithologic phases, namely: 1) hard bluish limestone containing small green fragments; 2) flinty cream to pink limestone when fresh but bluish when weathered; 3) flinty limestone with small green fragments; 4) highly brecciated white to cream-colored limestone. In many outcrops, the limestone is yellow, orange or red. Small greenish clasts, probably serpentinite and basalts, are common. Corby and others (1951) assign an Oligocene age to the limestone and estimate the thickness at about 1,200 - 1,300 meters.

Quilla Formation

Claystone, siltstone, sandstone,
conglomerate, coal
Unconformably underlies the San Pascual
Formation
Quilla creek, Mt. Engañosa area; Iriya
Valley near Madanlog Point, southern
Burias
Early Miocene
Corby and others (1951)

The Quilla Formation was named by Corby and others (1951) after Quilla Creek at the Mt. Engañosa area in the south-central part of Burias. It is also well exposed at Iriya Valley near Madanlog Point. The formation consists of brown to black, carbonaceous claystone, siltstone, sandstone, conglomerate and coal. Clasts of the conglomerate include volcanic rocks and serpentinites whose sizes attain boulder proportions. The coal beds measure up to one meter thick. In places, black carbonaceous claystone and siltstone contain nodules and large concretions of limonite. Corby and others (1951) give an age of Early Miocene for this formation. At one place, the exposure measured 90 m thick (Corby and others, 1951).

The Quilla Formation is probably equivalent to the Nap Conglomerate at Ticao Island and Animasola Conglomerate (Corby and others, 1951) at Animasola Island north of Ticao.

San Pascual Formation

Lithology	Siltstone, limestone
Stratigraphic relations	Unconformable over the Quilla Formation
Distribution	San Pascual; the formation caps almost
	the whole island of Burias.
Age	Middle Miocene – Late Miocene
Thickness	100 – 160 m
Named by	Corby and others (1951)
Synonymy	Bagalangit Coal Measures

The San Pascual Formation was named by Corby and others (1951), probably in reference to exposures at San Pascual in northern Burias. It unconformably overlies the Quilla Formation. The formation consists essentially of limestone, which grades laterally and vertically through silty limestones and calcareous siltstones into almost pure clastic siltstone. Corby and others (1951) divide the San Pascual into two members: the lower *Macamote Silt* and the upper *Pasig Silt*. Corby and others (1951) assign a Late Miocene age for the formation. The aggregate thickness of the two members is 90 - 120 m although the Bagalangit Coal Measures, which is probably a facies of the San Pascual, has an estimated thickness of 160 m.

The **Macamote Silt** is typically exposed at the coastal lowland adjacent to Macamote Bay. It consists of massive calcareous siltstone, which has been oxidized to bright yellow, red or orange. In places, it is blue or gray. Limestone occurring as interbedded strata, lenses and nodules and abundant coral heads represent the calcareous portion of the lower member. The thickness of the Macamote is estimated to be 30-60 m. The upper **Pasig Silt** member consists of gray to white massive and bedded limestone with interbeds and lenses of massive calcareous siltstone. The type locality is probably Pasig Point. This upper member is exposed between the northern half of Burias and Mount Engañosa. The thickness of the Pasig is about 60 m.

The Late Miocene **Bagalangit Coal Measures** of Corby and others (1951) is probably a facies of the San Pascual Formation. It is exposed along the northeastern coast of Burias. The Bagalangit is consisted predominantly of siltstone with minor interbeds of claystone, sandstone and coal. The siltstone is dark brown, gray, and blue with white phases. The vertical thickness of the cliff-forming beds along the coast is nearly 160 m (Corby and others, 1951).

Baybay Limestone

Limestone with local silty facies
Unconformable over the Bagalangit Coal
Measures
Maputing Baybay Bay, southern Burias
Pliocene
Corby and others (1951)

The Baybay Limestone was designated by Corby and others (1951) for the limestone at Maputing Baybay Bay in southern Burias. It unconformably overlies the Bagalangit Coal Measures. The Baybay predominantly consists of poorly bedded white and buff limestone with local silty facies. The maximum measured thickness is about 90 meters, but it may be thicker at the south end of the island where the base is not exposed. The age of the limestone is Pliocene.

MINDORO ISLAND (SG 7, 11)

Mindoro Island embodies an arc-continent collision event during the Miocene involving portions of the North Palawan Block (SG 11) and Philippine Mobile Belt (SG 7). For ease of presentation, the discussion of the stratigraphy of Mindoro will be divided into two parts – southwestern
GEOLOGY OF THE PHILIPPINES

				WIINL	JORO
PERIOD	EPOCH	AGE	Ма	SOUTHWEST	NORTHEAST
NEOGENE	HOLOCENE		0.0447		
	PLEISTOCENE	4 Late	0.0117 0.126 0.78 1.81	Oreng Formation	Dumali Volcanic Complex
	PLIOCENE	1 Early 2 Late 1 Early	2.59 3.60 5.33	Balanga Formation	
		3 Late	7.25	Punso Conglomerate	San Teodoro Volcanic Complex
	MIOCENE	2 Middle-	13.65	Pocanil Formation	
		1 Early	20.43	Napisian Formation Tangon Formation	
	011000515	2 Late	00.4	Bugtong Formation	Lumintao Basalt Amnay
	OLIGOCENE	1 Early	20.4	Cargarav Formation	Ophiolite Complex
Щ	EOCENE	4 Late	37.2	Cagaray i cimation	Pagbahan Granodiorite
LEOGEN		3 Middle - 2	40.4	Agbahag Conglomerate	Lasala Formation
PA		1 Early	40.0		
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7		
CEOUS	Upper	Late	99.6		Abra de llog Formation
CRETAC	Lower	Early	445.5		
JURASSIC	Upper	3 Late	145.5		
	Middle	2 Middle	175.6	Mansalay Formation	Halcon Metamorphic Complex
	Lower	1 Early	199.6		

Table 2.13 Stratigraphic column of Mindoro Island

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Mindoro, representing the portion of the North Palawan Block, and northeastern Mindoro representing the southwestern portion of the Southwest Luzon Stratigraphic Grouping.

Southwestern Mindoro

Mansalay Formation

Lithology

Sandstone, shale, siltstone, minor limestone, conglomerate

Stratigraphic relations	Unconformably overlain by the Caguray
	Formation
Distribution	Colasi Pt., Mansalay Bay; Mansalay,
	Amaga, Bongabon, Wasig, Siange,
	Batangan, Caguray and Malan-og rivers
Age	late Middle Jurassic – early Late Jurassic
Thickness	2,500 – 3,500 m
Named by	Corby and others (1951)

According to Teves (1954), Corby and others (1951) named and described this formation ahead of Feliciano and Basco (1947) but the latter published their work earlier. This ammonite-bearing formation consists principally of sandstones, mudstones and shales with minor limestones and pebble conglomerate. Its type locality is near Colasi Point at Mansalay Bay, southeastern Mindoro. It also crops out along the Mansalay, Amaga, Wasig, Bongabon and Siange rivers. Sarewitz and Karig (1986) mentioned other rivers where the Mansalay crops out such as Batangan, Caguray and Malan-og. The formation consists principally of thin- to thick-bedded sandstones, shale and mudstones. In places, the sandstone exhibit crossbedding and cross-lamination. The sandstones include arkosic arenite, lithic arenite and graywacke and some beds contain disarticulated and broken bivalve shells and belemnite fragments. Beds of siltstones and shale are black to dark gray to grayish green to maroon. Localized occurrence of lenses of oolitic and oncolitic carbonates (several meters thick and tens of meters in extent) with significant percentage of clastic detritus, bivalve and coral fragments (dated Late Jurassic) have been noted. The clasts of conglomerate lenses consist of subrounded to subangular pebbles (mostly less than 2 cm in diameter) of chert, sandstone, mudstone, slate and mafic to intermediate volcanic rocks set in a matrix of coarse-grained sandstone. Jurassic ammonites are the predominant fossils. Estimates of the thickness range from at least 2,500 m (Sarewitz and Karig, 1986) to 3,500 m (Andal and others, 1967). The age of the formation is late Callovian to Oxfordian, corresponding to late Middle to early Late Jurassic (Andal and others, 1968). The Mansalay is unconformably overlain by the Late Eocene Caguray Formation and Miocene limestones.

Agbahag Conglomerate

Lithology	Conglomerate
Stratigraphic relations	Overlain by Caguray Formation
Distribution	Agbahag Point, 5 km south of Mansalay
Age	Middle Eocene

Rocks along the shore of Agbahag Point, about five kilometers south of Mansalay, Oriental Mindoro, were named Agbahag Conglomerate by Koike and others (1968). These are poorly sorted and composed of pebbles of limestone, sandstone, mudstone, phyllite, chert, schist, basic volcanic rocks and granitic rocks. The limestone clasts contain fusulinids of Permian age (Andal, 1966). The Conglomerate is conformably overlain by a sequence of green and red siltstones, green to white arkosic sandstones and green conglomerate that was dated Late Eocene (Marchadier and Rangin, 1990). The Agbahag is therefore assigned a Middle Eocene age by Marchadier and Rangin (1990).

Caguray Formation

Lithology	Mudstone, siltstone, shale, sandstone, conclomerate, limestone
Stratigraphic relations	Unconformably overlies the Mansalay
	Formation
Distribution	Caguray River; Lumintao, Bugsanga,
	Kayakian, Tuuyan, Tumalo rivers
Age	Late Eocene to Early Oligoocene
Thickness	1,300 m – 2,048 m
Named by	Miranda (1980)
Synonymy	Talahib Formation (Ocampo, 1971),
	Batangan Formation (BED-WB, 1986)

This formation was named by Miranda (1980) for the clastic exposures along Caguray River, east-northeast of San Jose town, Occidental Mindoro. It consists principally of shale, mudstones and sandstones with minor conglomerates and limestone. In places, the mudstone occurs as areenish aray and reddish thin beds in the sequence. The sandstones occasionally exhibit cross bedding and ripple marks. Conglomerate lenses contain clasts of quartz, chert, sandstones, andesite, phyllite and slate. Limestone with thin interbeds of calcareous siltstones occurs towards the top of the formation. In the northeastern part of the island, the Cagurav is made up of bluish shale, silty or pebbly mudstone, brown, fine- to mediumgrained arkosic sandstone, massive, arenaceous and argillaceous limestone and conglomerate. The formation is also exposed along Lumintao, Bugsanga, Kayakian, Tuuyan, Tumalo and upper Baroc rivers, as well as Tanga and Habang Sapa rivers and Sipatag and Kipalaye creeks, both tributaries of the Cagurav River. Based on the paleontological analyses of foraminifera in samples from different parts of the formation, Zepeda and others (1992) concluded that the formation spans Late Eocene to Early Oligocene time. A partial thickness of at least 1,300 m was estimated for the formation (Zepeda and others, 1992). Ocampo (1971) measures a thickness of 2,046 m for the exposures along Tumalo River and its tributaries - Panaraon and Talahib creeks for his Talahib *Formation*, which is equivalent to the Cagurav Formation.

Sarewitz and Karig (1986) recognize four members in the Caguray – Piatt Mudstone, Kayakian Shale, Lepitan Limestone and Tumalo Member. The *Piatt Mudstone*, which extends for about 30 km from Lumintao River to Caguray River, consists of non-calcareous to slightly calcareous mudstones and siltstone. This unit is considered coeval with the *Kayakian Shale*, composed of dark gray to black shales with subordinate siltstone and mudstone interbeds. The *Lepitan Limestone* is best exposed at a gorge cut by the Batangan River near its confluence with Kayakian River. The limestone consists mostly of packstones and grainstones with abundant large foraminifera and algal debris. The limestone overlies the Piatt Mudstone and Kayakian Shale but all three units are dated Late Eocene. Calcareous mudstones, siltstones and grainstones comprise the *Tumalo Member*, exposed along the Caguray and Tumalo rivers. Calcareous nannofossils and planktonic foraminifera indicate an Early Oligocene age for this member (Sarewitz and Karig, 1986).

The **Batangan Formation** of BED (1986c) may also be considered equivalent to the Caguray Formation. Its type locality is in the Batangan Creek area, a tributary of Busuanga River. It is also reported to be well exposed along the tributaries of the upper Caguray River. The thickness of the formation along Batangan Creek is estimated to reach 4,260 m.

Bugtong Formation

Lithology	Limestone, siltstone, sandstone,
	conglomerate, agglomerate
Stratigraphic relations	Not reported
Distribution	Bugtong Point, Mansalay; Balatasan
	Peninsula; Bulalacao Bay, Mindoro;
	Tambaron Island;
Age	Late Oligocene to Early Miocene
Thickness	500 m
Previous name	Bugtong Limestone (Hashimoto and
	others, 1976)
Renamed by	BMG (1981)

This formation was initially called Bugtong Limestone by Hashimoto and others (1976) but was later changed to Bugtong Formation in BMG (1981) to include clastic rocks and minor agglomerate that are associated with the limestone and calcarenite. The type locality of Bugtong is at Bugtong Point, east of Mansalay. It is also exposed at the southern end of Mansalay Bay, on the isthmus separating Laguna Cove and Pandan Bay at the end of the Balatasan Peninsula and off Bulalacao Bay. Zepeda and others (1992) found it distributed in Tambaron Island and its nearby areas and in Sitios Nasukob and Imbayongan, north of Bulalacao Bay. The Bugtong Formation consists of limestone with associated siltstone, sandstone, conglomerate and agglomerate. The limestone and calcarenites are medium to thick bedded: the sandstone, light grav and coarse. The thickness at Balatasan Peninsula is at least 500 meters as determined by Weller and Vergara (1955).

BMG (1981) reports that the limestone at the south end of Mansalay Bay was dated Early Oligocene; the limestone at Bugtong Point contains *Lepidocyclina (Eulepidina) dilatata* (Michelotti) indicating an Oligocene age and that at Bulalacao Bay, Late Oligocene. The clastic rocks at Balatasan Peninsula, Tambaron Island and Sitio Nasukob were dated Late Oligocene by Zepeda and others (1992) based on the occurrence of *Globigerina binaensis* Koch, which first appears in the Late Oligocene together with the last appearance of *Globigerina sellii* Borsetti also in the Late Oligocene. Limestones in some parts of the Balatasan Peninsula, Tambaron Island and sitios Nasukob and Imbayongan, north of Bulalacao Bay contain Miogypsina and Miogypsinoides, indicative of an Early to Middle Miocene (probably Early Miocene) age. From Bugtong Point, the faunal association of the larger foraminiferal species *Lepidocyclina (Eulepidina) dilatata dilatata* Michelotti, *Miogypsinoides batamensis* Tan and *Spiroclypeus higginsi* Cole points to an early Miocene age. On the basis of all these datings, a Late Oligocene to Early Micoene age is considered for this formation.

The **Ananawin Formation** of PNOC (1979, cited in BED, 1986c) is considered equivalent to the Bugtong Formation. It has an estimated gross thickness of 300 m with an age of Late Oligocene to Middle Miocene as determined from paleontological dating (BED, 1986c).

Tangon Formation

Lithology	Shale, sandstone
Stratigraphic relations	Not reported
Distribution	Tangon River, northwest of Bongabong
Age	Early Miocene
Named by	Teves (1953)

This formation was named by Teves (1953) for the rocks along Tangon River, a tributary of the Manihale River, northwest of Bongabon, Oriental Mindoro. The formation consists of brown to dark gray, partly carbonaceous shale with interbedded sandstone. Teves (1953) dates the Tangon Miocene but it was given a definite age of Early Miocene by Hanzawa and Hashimoto (1970).

Napisian Formation

Lithology	Shale, sandstone, coal beds, conglomerate, limestone.
Stratigraphic relations	Overlain by the Pocanil Formation
Distribution	Napisian Creek, northwest of Bulalacao
	Bay
Age	Early Miocene
Thickness	450 m
Named by	Weller and Vergara (1955)
Synonymy	Mawo Volcanics (Garcia and Mercado, 1981)

The Napisian Formation was named by Weller and Vergara (1955) for the coal measures typically exposed along Napisian Creek northwest of Bulalacao Bay in southern Oriental Mindoro. The formation consists of shale, coal beds, limestone, sandstone and conglomerate. The coal beds, which are classified as low rank sub-bituminous, attain a thickness of three meters. They are black, shiny, breaks conchoidally and often found between shale beds. The limestone is dark, fine-grained and impure. The shale is brown and dark gray or black. The sandstone is poorly bedded and exhibits cross bedding. Small rounded pebbles in the conglomerate, where present, consist of quartz, chert, feldspar and even coal.

Fossils found in the coal measures are mostly long ranging benthic foraminifera, while imperfectly preserved molluscan remains are abundant in the shale and silty shale portions. The mollusks-bearing beds serve as "key markers" or "horizons" to the likely occurrence of coal deposits. Previously, the Napisian was dated Middle Miocene (BMG, 1981). Later studies by Zepeda and Revilla (1990) reveal the presence of *Globigerinoides*, a Neogene genus, which first evolved during the earliest Miocene. Zepeda and others (1992) likewise identify abundant and well preserved *Ammonia* spp. from the shales. The presence of *Ammonia indica*, a benthic species of biostratigraphic significance served as the basis for determining the Early Miocene age of the Napisian. The formation is 450 m thick (Weller and Vergara, 1955).

The **Semirara Formation** on Semirara Island south of Bulalacao Bay is considered equivalent to the Napisian Formation. It is an Early Miocene to Late Miocene coal-bearing sequence previously named Semirara Coal Measures by Melendres (1940, in Vergara, 1956). Three members have been identified by Vergara (1956). The lower member consists principally of light gray to brownish tuffaceous shale with interbeds of sandstones, siltstones, carbonaceous shale, minor conglomerate and at least two coal beds. It has an exposed thickness of 160-223 m. The middle member is mainly gray to brown tuffaceous shale and cross-bedded sandstone and thin coal bed. It is 30-70 m thick. The upper member is a limestone that reaches a maximum thickness of about 100 m. The Semirara Formation is overlain by the Buenavista Limestone of Pliocene age with a maximum thickness of 150 m.

Pocanil Formation

Lithology	Limestone, shale, siltstone, sandstone, conglomerate
Stratigraphic relations	Conformable over the Napisian Formation
Distribution	Pocanil Point, Buyayao Island and
	Peninsula; Bulalacao area; hills north of
	Mananga Valley
Age	Early Miocene – Middle Miocene
Thickness	750 m - 1,000 m (Corby and others, 1951)
Previous name	Pocanil Limestone (De Villa, 1941)
Renamed by	Weller and Vergara (1955)

The Pocanil Formation was originally named Pocanil Limestone by de Villa (1941), for the rocks at Pocanil Point, southeastern Mindoro. Weller and Vergara (1955) call it Pocanil Formation to include the shale, siltstone and sandstone interbedded with the limestone. The Pocanil is also distributed in Buyayao Island and Buyayao Peninsula and covers much of the Bulalacao area between Soguicay Bay and Bulalacao (Cabilian) River, as well as the hills rising north of Mananga Valley. The Pocanil conformably overlies the Napisian Formation. The carbonate rocks constituting the formation consist mainly of coralline limestone and calcarenites that reach up to 35 m in thickness. The shale and siltstone are light to dark gray, calcareous and fossiliferous. The sandstone is light gray and fine-grained to pebbly. At Buyayao Island, the conglomerates are clast-supported and polymictic. The clasts, ranging in size from pebbles to boulders, include subrounded to rounded andesite, shale, chert, schist and quartzite set in a brown sandy matrix.

Paleontological dating by Agadier-Zepeda and others (1992) of foraminiferal assemblages in samples from the formation at Pocanil and

elsewhere indicate an Early Miocene to Middle Miocene age. The Pocanil has a thickness of 750 m - 1,000 m as estimated by Corby and others (1951).

Punso Conglomerate

Lithology	Conglomerate, sandstone, mudstone, shale
Stratigraphic relations Distribution	Unconformably overlies older formations Mt. Punso; Sipainit-Nagbobong area at the headwaters of Lumintao River; western side of Lumintao River; Obelisk Peak; southern part of Kanturoy and Maguyong areas
Age	Late Miocene to Early Pliocene
Thickness Named by	1,500 m Melendres (1953)
Numbu by	

The Punso Conglomerate was named by Melendres (1952) after Punso Mountain, its type locality, east of Labangan River, about 22 km north of San Jose, Occidental Mindoro. The unit is massive with pebbles of gneiss, schist, slate, quartzite, chert, basalt, gabbro, diorite and limestone set in siliceous and limy matrix. The limestone clasts contain fossils ranging in age from Pennsylvanian (Easton and Melendres, 1953) to Late Oligocene-Early Miocene (Marchadier and Rangin, 1990). Easton and Melendres (1953) add that mudstone, shale and sandstone are interbedded with the conglomerate. Fossiliferous basal gray mudstones were also observed at the southeastern and northeastern sides of this synclinally folded conglomerate. Exposures of the Conglomerate are also found at the Sipainit-Nagbobong area at the headwaters of Lumintao River, western side of lower Lumintao River and Obelisk Peak. Scattered pockets in the southern part of Kanturoy area were noted by Tumanda and Agadier-Zepeda (1995). The Punso overlies unconformably older formations. It is also in fault contact with the Caguray Formation at its northern end.

Studies of planktonic foraminifera from the Punso Conglomerate by Agadier-Zepeda and others (1992) and Tumanda and Agadier-Zepeda (1995) indicate a Late Miocene – Early Pliocene age for the formation. Nannofossil assemblage belonging to zone NN11 in siltstones associated with the Punso also indicates a Late Miocene age (Marchadier and Rangin, 1990). At its type locality, the Conglomerate has a maximum thickness of 1,500 m.

Famnoan Formation

Lithology	Conglomerate, sandstone, shale,
	limestone
Stratigraphic relations	Not reported
Distribution	Middle reaches of Bongabon River;
	Balahid in Bongabon Area; Sabang and
	Nawa Rivers
Age	Early Pliocene

Named by	Teves (1953)
Synonymy	Insulman Formation (Agadier-Zepeda and
	others, 1992)

This formation was named by Teves (1953) for the rocks at Famnoan along the middle reaches of Bongabon River. It also crops out at Balahid in the Bongabon area. Agadier and Maac (1987) found exposures of this unit along Sabang River, a tributary of the Pula river in northeastern Oriental Mindoro. The formation consists of a basal conglomerate succeeded by sandstone and shale and topped by limestone. The pebbles of the conglomerate are indurated clastic rocks and occasional serpentine. The limestone is bedded, white and also fossiliferous. Hanzawa and Hashimoto (1970) found rich assemblages of planktonic foraminifera, which indicate an Early Pliocene age, while Agadier and Maac (1987) gave an Early Pliocene age for the rocks in Sabang River based on microfossil content.

The **Insulman Formation**, as redefined by Agadier-Zepeda and others (1992), is probably equivalent to the Famnoan. Their paleontologic dating for this sequence of mudstones, siltstones, sandstones and limestone indicates an age no older than Pliocene for the formation. Marchadier and Rangin (1990) report a dating of Early Pliocene (nannoplankton zone NN14-NN15) for the siltstone sequence at Insulman River.

Balanga Formation

Lithology	Sandstone, limestone; minor mudstone
	and conglomerate
Stratigraphic relations	Not reported
Distribution	Balanga Point; Bongabong River; Colasi
	Bay; Bulalacao
Age	Late Pliocene to Early Pleistocene
Thickness	1,000 m
Named by	Feliciano and Basco (1947) as Balanga
	Conglomerate
Renamed by	Teves (1953)

The name Balanga Conglomerate was introduced by Feliciano and Basco (1947), which included the sequences corresponding to the Barubo Sandstone and Famnoan Formation of Teves (1953). The formation was later redefined by Teves (1953), who treated the Barubo and Famnoan formations as separate units. The type locality is at Balanga Point, along the north coast of Mansalay Bay. To the north, it outcrops along the lower reaches of Bongabong River and to the south, it is exposed along the coast of Colasi Bay and around Bulalacao town. The formation consists principally of sandstone with mudstone and conglomerate interbeds and limestone. The limestone is generally massive but in places it is bedded in such a way that marl rich in foraminifera occupies the spaces between bedding planes.

Samples collected in Balanga Point yielded a Late Pliocene to Pleistocene age. Those taken along the coast of Colasi Bay and Bulalacao Poblacion indicate a Plio-Pleistocene age. In the Bongabon River area, the clastic rocks gave a Late Pliocene to Early Pleistocene age whereas the limestone is Plio-Pleistocene. The rocks distributed along Sabang and Subaan-Singalan rivers were dated Late Pliocene to Early Pleistocene. As a whole, Zepeda and others (1992) give a Late Pliocene to Pleistocene age for this formation.

The Balanga may be correlated in southeastern Oriental Mindoro with the upper sequence of the Bongabon Group of MMAJ-JICA (1984).

Oreng Formation

Limestone, conglomerate
Not reported
Oreng Hill and other hills in the southern
part of Bongabon delta; Pula and Subaan-
Singalan rivers in the northeast
Pleistocene
Teves (1953)
Socorro Group (MMAJ-JICA, 1984)

The Oreng Formation was named by Teves (1953) for the limestone and conglomerate exposed as hills (Oreng, Mamilpil and others) bordering the southern part of the Bongabon delta in southeastern Oriental Mindoro. The limestone, which occupies the lower portion of the formation, is milky white, vuggy, sugary and fossiliferous. The overlying conglomerate consists of loosely cemented pebbles. The reef limestone that comprises llin and Ambulong Islands and the area between Magsaysay and Bulalacao may be considered part of this formation. This is equivalent to the limestone of the Socorro Group of MMAJ-JICA (1984). The Oreng is also encountered along Pula River and Subaan-Singalan River in northeastern Oriental Mindoro (Agadier and Maac, 1987). Based on faunal association and stratigraphic relationships, Agadier and Maac (1987) assigned a Pleistocene, most probably Late Pleistocene, age for these rocks.

Northeastern Mindoro

Halcon Metamorphic Complex

Lithology	Amphibolite, metagabbro, gneiss, greenschist, phyllite, slate, marble
Stratigraphic relations	Constitutes the basement of northeastern Mindoro
Distribution	Northern Mindoro from Mt. Calavite to Puerta Galera and areas around Mt. Halcon; Lubang and Ambil Islands
Age	Late Jurassic (?)
Previous name	Mindoro Metamorphics (Teves, 1953)
Renamed by	MMAJ-JICA (1984) as Halcon Metamorphics

Metamorphic rocks exposed in the upper Bongabon River were named by Teves (1953) as Mindoro Metamorphics. However, the metamorphic rocks of Mindoro are more widely distributed in northern Mindoro from Mt. Calavite to Puerto Galera and in the areas around Mt. Halcon, prompting MMAJ-JICA (1984) to rename it as Halcon Metamorphics. These are also exposed on Lubang Island and other islands off northern Mindoro. The metamorphic complex consists of amphibolites, metagabbro, gneisses, greenschists, phyllites, slates and marble. These rocks represent metamorphosed ophiolitic rocks, quartz diorite or plagiogranite and sedimentary and volcanic rocks.

• Burburungan Amphibolite

Hornblendite and actinolite schist comprise the amphibolites (Caagusan, 1966), Exposures of the hornblendite and metagabbro may be found along the upper reaches of the northerly streams draining Mt. Burburungan such as Matabang, Urilan, Odalo and Nangka rivers as well as the northwestern coast. These rocks are collectively designated here as Burburungan Amphibolite. Actinolite schist occurs in the Binavbav-Inabasan area, along the northern coast of Mindoro and along Odalo River. It is dark green, very fine- to coarse-grained, and occasionally shows thinly banded structure, as at Odalo River. In places, the amphibolite is intimately associated with gneissose metagabbro and appears to be partly contemporaneous with the latter. The metagabbro is made up mainly of albite, uralite and uralitic clinopyroxene or plagioclase-hornblende (Caagusan, 1966). The main components of the actinolite schists are actinolite, albite, oligoclase, epidote and chlorite. Numerous dikes of metadiabase cutting into hornblendite at the upper reaches of Matabang River have also been reported by Caagusan (1966). The amphibolites and metagabbro at Puerto Galera and Ambil Island are regarded by Rangin and others (1985) and Marchadier and Rangin (1990) as parts of a metaophiolite. They correlate these with the meta-ophiolite in Tablas, which had been radiometrically dated 140 Ma. equivalent to Late Jurassic (Marchadier and Rangin, 1989, 1990).

• Camarong Gneiss

The mica-quartz-oligoclase-albite gneiss, designated by Caagusan (1966) as Mindoro Gneiss, is widely exposed in a 150-km² area. It is bounded by Puerto Galera and San Teodoro on the east, Verde Island Passage on the north, Odalo River on the west, and Inabasan-Alag River on the south. Here the gneiss is designated as Camarong Gneiss for the exposures at Camarong River. The rock is white to greenish gray, coarse-grained, with pronounced crystal orientation. Foliation is prominent in varieties rich in muscovite and biotite. Muscovite is commonly dominant over biotite; the latter increases in amount southwestward. The percentages of essential components of the rocks are: oligoclase-albite, 20-60; quartz, 30-60; and micas, 10-50. Farther west, along Odalo River, the quartz-albite-oligoclase gneiss carries actinolite instead of muscovite or biotite.

In Lubang Island, the lower part is made up of coarse-grained quartz feldspar-muscovite-garnet gneiss. The best exposure is in Genting Ridge at the central part of the island where it is intruded by basic dikes metamorphosed into amphibolite schist. The upper part is composed of various types of schists that generally grade into one another. These are quartz-feldspar-muscovite, quartz-feldspar-biotite and chlorite-epidote-actinolite schists.

The protolith of the gneiss is considered by Caagusan (1966) to be an intrusive body, probably quartz diorite or tonalite. The gneiss is adjacent to the Burburungan Amphibolite.

Metasedimentary and meta-volcanic rocks

Sedimentary and volcanic rocks that have undergone metamorphism are represented by quartzofeldspathic schist, semischist, phyllite, slate, marble, metaconglomerate and sericite schist.

The quartzofeldspathic schist is extensively exposed west of Abra de llog up to Mt. Calavite area and Paluan. It crops out thinly and sparsely in Mt. Malasimbo, and along Tabinay and Binaybay rivers. It is fine-grained, green and shows a silvery sheen on cleavage surfaces. The typical mineral assemblage is chlorite, sericite, quartz and albite. Calcite, when present, forms segregation bands or may be admixed with the quartzofeldspathic bands.

The semischists of Caagusan (1966) are extensively exposed along Lapa-ao River, Getaluz Creek, Mamburao River, and in the vicinity of the Lasala Valley. Thick sections underlie the upper Pagbahan, Nangka, Urilan and lower Matabang and Odalo rivers. The semischists are dark gray to black, very fine-grained, massive to thin bedded, well-indurated and with thin laminae of carbonaceous matter. These break easily into slabs with a dull sheen on cleavage surfaces. These are intercalated with thin beds of slates or phyllite near marble horizons. The semischists are metamorphosed graywacke. Relict clastic grains of guartz and plagioclase are scattered in a very fine-grained crystalloblastic groundmass. A semischistose texture is imparted by the orientation of the lepidoblastic sericite flakes. The matrix is made up principally of sericite, chlorite, albite, calcite and carbonaceous matter.

The phyllites occur as thin-bedded exposures below the massive marble in Lagnas Valley. These are very fine-grained, grayish green to green, and break easily along the schistosity with a dull sheen on the surface. These are made up essentially of sericite, xenoblastic albite, quartz crystals and minor chlorite. Sericite phyllite with chloritoid metacrysts were observed in Lagnas Valley.

The slates are exposed along the northern coast in Getaluz Creek, northwest of Lagnas Valley and south of Camangaon. The slates are generally carbonaceous and made up of very fine scales of sericite with chlorite, xenoblastic quartz and albite, sometimes with minor epidote, pyrite and clastic muscovite.

The marbles extensively exposed in northern Mindoro are thickly bedded and are transitional to an older sequence of semischists, phyllite and slates. These are hard, brittle and fine-grained or sugary. The dominant varieties are white and gray; black is rare. Some colors are imparted by carbonaceous matter and chlorite. The texture is granoblastic although a faint schistosity is suggested by the orientation of the long dimension of calcite grains, wavy lines and bands of carbonaceous matter and other impurities. Fine crystalloblastic albite may form thin laminae.

The sericite schist is derived from thin layers of volcanic rock intercalated with the upper horizon of the metasedimentary sequence. Various stages of sericitization are shown by this rock. In Urilan River, it has a mottled appearance because of the presence of relict plagioclase phenocrysts. The inception of alteration is shown much farther north; in the Matabang River where the volcanic rocks intercalated with the semischist is only slightly sericitized. It is intercalated with phyllites in Lagnas Valley.

Abra de llog Formation

Lithology	Graywacke, shale, chert, spilitic basalt
Stratigraphic relations	Overlies the Halcon Metamorphic
	Complex
Distribution	Vicinity of Abra de Ilog; Mamburao River
Age	Cretaceous
Thickness	600 m
Named by	Miranda (1980)
Synonymy	Mamburao Group (MMAJ-JICA, 1984)

The Abra de llog Formation was named by Miranda (1980) for the sequence of sedimentary and volcanic rocks in the vicinity of Abra de Ilog in northern Occidental Mindoro. The formation consists of a graywackechert-shale sequence with intercalated spilitic basalt flows. The formation can be traced for a length of about seven kilometers along a northnortheast direction with a width of three kilometers. It is well exposed in the lower reaches of Mamburao River. The formation is described by Sarewitz and Karig (1986) as a belt consisting mainly of pillow basalts, breccias and tuffs with intercalations of red pelagic limestone between pillows. The formation overlies the Halcon Metamorphic Complex. The spilitic basalt is dark reddish brown, sparsely vesicular and microporphyritic. The matrix is variolitic with very fine grains of pyroxene and chlorite in the intergranular spaces. Some of the flow layers are fragmental and contains green and reddish brown fragments of altered volcanic rocks. The red inter-pillow pelagic limestone yielded Late Cretaceous foraminifera (Karig, 1983). The formation is assigned a Cretaceous age.

The Abra de Ilog Formation is equivalent to the Mamburao Group of MMAJ-JICA (1984). The thickness of the formation is 600 m as estimated by MMAJ-JICA (1984) from the exposures along Mamburao River.

Lasala Formation

Lithology	Sandstone, shale, mudstone,
	conglomerate, limestone, basalt flows and
	dikes
Stratigraphic relations	Unconformable over Halcon Metamorphic
	Complex

Distribution	Lasala River; Patrick, Amnay, Pagbahan and Alitungan, Talusungan, Pagbahan
	Rivers
Age	Late Eocene
Named by	Hashimoto (1981)

The Lasala Formation was named by Hashimoto (1981) for the rocks exposed along Lasala River in northern Mindoro. The formation consists mainly of sandstones and shales with subordinate conglomerate, mudstone and limestone intercalated with basalt flows. Most exposures show rhythmically interbedded gray sandstone and dark gray shale with individual beds varying in thickness from 5-30 cm. Locally, portions of the formation may be sandstone-rich or shale-rich with individual beds reaching up to 2 m thick. Clasts of occasional conglomerates consist mostly of basalt and chert. Basalt flows and dikes occur within the Lasala. At Pagbahan River, pillow basalts are intercalated with sandstones and shales through several hundred meters of section (Sarewitz and Karig, 1986). Coarse crystalline limestone occupies the lower portion of the Lasala. The limestone, which is about 100 m thick, separates the clastic sequence of the Lasala from the underlying Halcon Metamorphic Complex at Pagbahan River. Paleontological analyses of foraminifera indicate a probable Late Eocene age for the formation (Hashimoto and Sato, 1968). Portions of the Sablayan Group of MMAJ-JICA (1984) yielded Halkyardia minima (Liebus) and Biplanispira mirabilis (Umgrove) indicating an Eccene age. Reef limestone in western Lubang Island was reported by Faure and others (1989) to be of Late Eocene age based on the presence of the following foraminifera: Pellatispira mirabilis (Umgrove), Operculina cf. saipanensis, Amphistegina radiata, Rotalidae sp. and Spherogypsina sp. The thickness of the formation has not been determined but it is estimated by Sarewitz and Karig (1986) to reach a few thousand meters.

Pagbahan Granodiorite

Granodiorite, quartz diorite, quartz
monzonite
Intrudes Lasala Formation and older
formations
Pagbahan River; upper reaches of
Mamburao, Pola and Bongabon Rivers
Late Eocene - Early Oligocene
MGB (this volume)
Lubang Granite (Elicano, 1924)

Granodiorite stocks and dikes and dioritic rocks in northern Mindoro are designated here as Pagbahan Granodiorite for the exposures at the upper reaches of Pagbahan River. These intrusive bodies also outcrop in the upper reaches of Mamburao and Pola rivers as well as upper Bongabong River. The granodiorite bodies along Pagbahan River consist chiefly of sodic plagioclase, quartz, microcline, biotite and muscovite. Diorite and quartz diorite bodies at the upper reaches of Mamburao River are associated with the development of iron deposits and skarn in the intruded phyllites (Halcon Metamorphic Complex) and rocks of the Lasala Formation. Hornblende diorite and quartz monzonite stocks and dikes also intrude metasedimentary rocks and gneiss from Abra de Ilog to Puerto Galera. Radiometric K-Ar dating of quartz diorite samples gave a range of values equivalent to 30.4 ± 0.9 Ma to 40.2 ± 6.8 Ma (Late Eocene – Early Oligocene).

In Lubang Island, Occidental Mindoro, a small granodiorite stock previously called **Lubang Granite** by Elicaño (1924), crops out on the isthmus between Looc and Tubahin bays. It is intrusive into the schists and gneisses, is light-colored, coarse-grained, partly gneissose and composed chiefly of quartz and plagioclase with lesser orthoclase, hornblende, muscovite and/or biotite. The Lubang is probably equivalent to the Pagbahan Granodiorite.

Amnay Ophiolite

Lithology	Dunite, peridotite, gabbro, basalt
Distribution	Amnay River; Sitio Igsoso, near
	Mamburao; Lumintao
Age	Early (?) – Middle Oligocene
Named by	Rangin and others (1985)

The Amnay Ophiolite is a northwest trending suite interposed in the suture zone between the North Palawan Block and Mindoro Block. The Amnay was identified by Rangin and others (1985) as distinguished from their Ambil-Puerto Galera metaophiolite, which is here associated with the Burburungan Amphibolite that is part of the Halcon Metamorphic Complex. The ophiolitic rocks are exposed along Amnay River and vicinity, Liwliw area, Sitio Igsoso near Mamburao and Lumintao River. Several distinct ultramafic bodies that belong to the Amnay have been identified by MMAJ-JICA (1984), including the Igsoso, Liwliw and Pintin bodies.

The rock types comprising the ophiolite are serpentinized harzburgite, dunite, websterite and Iherzolite, isotropic and cumulate gabbro, sheeted dike complex, pillow lavas and pelagic mudstones. Small chromitite bodies occur in the peridotites. Transition zone dunite and ultramafic cumulate layers were not encountered (Jumawan and others, 1998). The largest exposure of gabbro can be traced for 7 km in the Amnay River area (MMAJ-JICA, 1984). The dike complex and pillow basalts are well exposed along Lumintao River and these were designated as Lumintao Formation by MMAJ-JICA (1984) and Lumintao Mafic Complex by Sarewitz and Karig (1986). On the basis of Middle Oligocene nannofossils from the pelagic mudstones associated with the Lumintao Basalt, the Amnay is dated Early (?) - Middle Oligocene.

Lumintao Basalt

Lithology	Basalt, tuff, mudstone
Stratigraphic relations	Partly represents the volcanic carapace of
	the Amnay Ophiolitic Complex
Distribution	Lumintao, Bugsanga, Kinarawan, Patrick
	and Amnay Rivers
Age	Middle Oligocene
Thickness	> 2,000 m along Lumintao River

Previous name	Lumintao Formation (MMAJ-JICA, 1984)
Renamed by	MGB (this volume)
Synonymy	Lumintao Mafic Complex (Sarewitz and
	Karig, 1986)

The Lumintao Basalt was previously named Lumintao Formation by MMAJ-JICA (1984) and renamed Lumintao Mafic Complex by Sarewitz and Karig (1986). This formation is widely exposed from the middle to the upper reaches of Lumintao River. It is also exposed in Bugsanga. Kinarawan, Patrick and Amnay rivers (Bondame and others, 1985). The Lumintao consists chiefly of basalt flows with subordinate intercalated tuff and red ferruginous mudstones, siltstones and sandstones. The various facies of basalts identified by MMAJ-JICA (1984) are massive lava, pillow lava, flow breccias, pillow breccias and hyaloclastites. In places, the basalt is heavily criss-crossed by veinlets of zeolite. chlorite-epidote and calcite. Intercalated mudstones reach up to 10 m thick, although these are generally less than a meter thick. The basalts are locally intruded by dikes of basalt, diabase, gabbro and diorite. The dike swarms and pillow basalts apparently represent, respectively, the sheeted dike complex and volcanic carapace of the ophiolite. Ferruginous mudstones that were reported to lie above the basalt in Amnay River could represent the pelagic sedimentary cover of the ophiolitic complex. Nannofossils from the red pelagic mudstone interbeds at Patrick River and red siltstones overlying the basalt at Amnay River indicate a Middle Oligocene age (Sarewitz and Karig, 1986).

San Teodoro Volcanic Complex

Lithology	Basalt, andesite, dacite, agglomerate
Stratigraphic relations	Not reported
Distribution	Binaybay River, near San Teodoro
	poblacion
Age	Late Miocene to Early Pliocene
Previous name	San Teodoro Volcanics (Miranda, 1980)
Renamed by	MGB (this volume)

This volcanic complex was previously named by Miranda (1980) as San Teodoro Volcanics for the exposures of volcanic rocks along Binaybay River, near the poblacion of San Teodoro. The formation consists of basalt flows with minor andesitic and dacitic phases and volcanic agglomerate. Ellipsoidal or pillow structures in the basalt flows indicate submarine conditions during deposition. These volcanic rocks were probably extruded during Late Miocene to Early Pliocene.

Dumali Volcanic Complex

Lithology	Andesite, pyroclastic rocks
Stratigraphic relations	Not reported
Distribution	Mt. Dumali, Macapili, Eplog, Maestre de
	Campo and Simara Islands, Calapan,
	Lake Naujan, Mauhao
Age	Pleistocene
Previous name	Dumali Volcanics (Datuin and Uy, 1979)

Renamed by	MGB (this volume)
Synonymy	Eplog lava flows (Weller and Vergara,
	1955)

Pleistocene volcanism in Mindoro is represented by volcanic centers such as Mt. Dumali and Mt. Macapili and other areas. The volcanism is related to the subduction of the South China Sea Plate along the southern trace of the Manila Trench that impinges on Mindoro. Other areas where such volcanism had taken place are Eplog Hill, Pola, Maestre de Campo and Simara Islands off northern Mindoro, Calapan, Lake Naujan, and Mauhao. The volcanic rocks consist mostly of andesites, except at Mauhao where basalt is also present, together with pyroxene andesite (MMAJ-JICA, 1984). Radiometric K-Ar dating of samples from Mt. Macapili gave values of 1.56 – 1.64 Ma while a sample from Mt. Dumali gave a value of 0.82 Ma (De Boer and others, 1980).

The Dumali is probably equivalent to the **Eplog Lava Flows** of Weller and Vergara (1955) named after Mt. Eplog, the highest hill in Balatasan Peninsula, southeastern Mindoro. The Eplog consists of lava flows with a thickness of at least 35 meters. Similar flows occur near Akihit at the mouth of Naujan Valley. The lava consists of vesicular and glassy hornblende andesite. Some of the vesicles are partly filled with calcite and zeolite.

PALAWAN ISLAND (SG 11, 12)

Palawan is geologically divided into north and south/central parts (SG 11, 12) largely based on the structural and stratigraphic contrast of the two blocks (Wolfart and others, 1986). The stratigraphic grouping to which north Palawan belongs also includes southern Mindoro, northwest Panay and Romblon Island group. Northern Palawan is believed to be part of mainland Asia that was rifted during Paleogene time while the southern and central blocks consist of ophiolitic terrane with superimposed sedimentary formations. The North Palawan Block is considered as a microcontinent by Hamilton (1979) and as Calamian microcontinental block by Taylor and Hayes (1983). Separation is presumed to be along a strikeslip fault (Ulugan Bay Fault) passing the Baheli Isthmus around the vicinity of the Ulugan Bay at the west coast of Palawan and along Honda Bay in the east (Tamesis and others, 1973; Hamilton, 1979). This was refuted by UNDP (1985) and MMAJ-JICA (1988), which placed the boundary separating the continental North Palawan block from the south along the Sabang Thrust, a low to intermediate dipping structural line located a little north of the Ulugan Bay Fault. Later studies, however, disproved the existence of the Ulugan Bay Fault that supposedly divided Palawan Island into two separate terranes (BED, 1986c; Pineda and others, 1992). It is believed that Palawan was rifted eastward as a contiguous block from South China Sea (Hinz and others, 1983; Pineda and others, 1992). It was further explained that the disparity in lithology and structures in the north and south blocks are due to the obligueness of tilting during collision of the North Palawan Block (NPB) and the Philippine Mobile Belt. Other writers contend that Palawan consists of ophiolitic nappe, chaotic clastic sequence (olistostrome), limestones and metamorphic clastics (Wolfart and others, 1986; Isozaki and others, 1988; Faure and Ishida, 1990; Amiscaray and Tumanda, 1990). However, because of the differences in lithologic class-

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	NORTHERN	PALAWAN
	HOLOCENE				
NEOGENE	PLEISTOCENE	4 Late Middle	0.0117 0.126 0.78 1.81	Manou	ao Basalt
	PLIOCENE	1 Early 2 Late 1 Early	2.59 3.60 5.33	mangu	au Dasait
		3 Late	7.25		
	MIOCENE	2 Middle-	13.65	Piedras Andesite	Kapoas Granite
		1 Early	20.43	St. Pau	I Limestone
	OLIGOCENE	2 Late 1 Early	23.03		
PALEOGENE	EOCENE	4 Late 3 Middle - 2	33.9 37.2 40.4 48.6	Maytigu	id Limestone
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7		
ACEOUS	Upper	Late	99.6	Boayan Formation Conception Phyllite	Paly Serpentinite
CRETA	Lower	Early	145.5	Caramay Schist Guinlo Fo	ormation
JURASSIC		3 Late			
		2 Middle			
TRIASSIC		3 Late	205	Coron Formation	Liminangkong Formation
		2 Middle		m	
PERMIAN		1 Early		Minilog Limestone	m
		3 Late	250		~
		2 Middle		Bacuit Fo	ormation
		1 Early			
CARBONIFEROUS			290		

Table 2.14 Stratigraphic column of Northern Palawan

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

ification, relative age values and the lack of consensus among workers, the former lithostratigraphic subdivision is maintained.

Northern Palawan

Recent findings regarding the geologic and tectonic history of the Palawan Group of Islands (Wolfart and others, 1986; Isozaki and others, 1988; Faure and Ishida, 1990; Amiscaray and Tumanda, 1990), indicate that the previously described sequences of Paleozoic and Mesozoic strata in northern Palawan are not representative of normal successions of stratigraphic units but are interpreted as an olistostrome or tectonosuccession of exotic blocks. In accordance with such interpretation, the formations included in the Malampaya Sound Group of Hashimoto and Sato (1973) such as the Bacuit Formation (Middle Permian), Minilog Formation (Middle Permian) and Liminangcong Formation (Middle Triassic) are now regarded as olistoliths set in a sandy pelitic matrix (Guinlo Formation). For stratigraphic clarity, the blocks or formations are still presented in the order of their chronologic ages.

There are notably three formations that have been defined by means of subsurface wells in offshore northern Palawan – the Nido Limestone, Pagasa Formation and Matinloc Formation (BED, 1986c). The Nido Limestone is equivalent to the onshore St. Paul Limestone. The other two offshore formations may also be correlated with the Isugod and Alfonso XIII formations in southern Palawan.

Malampaya Sound Group

This group name was introduced by Hashimoto and Sato (1973) to include the Bacuit, Minilog, Liminangcong and Guinlo formations, exposed in the Malampaya Sound area in northern Palawan. In this volume, the Malampaya Sound Group also embraces the Coron Formation of Wolfart and others (1986).

Bacuit Formation

Lithology	Sandstone, altered tuff, calcareous sandstone, chert and slate
Stratigraphic relations	Unconformable over the Barton
	Metamorphics (Reyes, 1971) and
	conformably overlain by the Minilog
	Limestone.
Distribution	Manmegmeg Bay, south of Bacuit
	(formerly El Nido town);
	Dilumacad Island, Barboring Bay,
	southern part of Natnat Island, north of
	Bacuit, Casian Island and the southern
	coast of Cadlao Island
Age	Middle Permian to Late Permian
Thickness	About 1500-4500 m (BMG, 1972); the
	chert is about 1000 m in the Calamian
	Islands
Named by	Reyes (1971)
Synonymy	Bacuit Chert (Gervasio, 1973)
Correlation	Carabao Sandstone (Vallesteros and
	Argaño, 1965) in Carabao Island,
	Romblon

The name Bacuit was first used by Reyes (1971) for the sequence of shales, sandstones, conglomerate and limestone unconformably overlying the Barton Metamorphics. Its type locality is in the town of Bacuit, the old name of El Nido municipality. It was later termed **Bacuit Chert** by Gervasio (1973) to include the chert dominantly exposed in Busuanga Island. Hashimoto and Sato (1973) subdivide the Bacuit of Reyes (1971) and

(1973) into four formations, namely: Gervasio Bacuit. Miniloa. Liminangcong and Guinlo formations, collectively termed Malampaya Sound Group. The name Bacuit was, however, retained to designate beds in the lower part of the former Bacuit Formation. The Bacuit of present usage is confined to the brecciated sandstone, limestone, chert, altered tuff, calcareous sandstone and contorted alternation of sandstone and slate exposed in Manmegmeg Bay, south of Bacuit and in Dilumacad Island in the Malampava Sound area. It was also found in the beach bordering Barboring Bay, southern part of Natnat Island, north of Bacuit, Casian Island and at the southern coast of Cadlao Island. The rocks are remarkably folded, trending in a northeast direction in southern Bacuit area and gradually shifting to an E-W direction in the southern coast of Cadlao Island (MMAJ-JICA, 1990). Although Middle to Late Permian ranging conodonts Gondolella rosenkrantzi (Benden and Stoppel) and Ozarkodina tortilis Tatge were identified in the chert, a Middle Permian age was assigned to the formation (Hashimoto and Sato, 1973). Wolfart and others (1986) later consider an Early to Middle Permian for the Bacuit based on the additional species identified, which include Spathognathodus sp., Neospathodus sp. and Hindeodella sp.

The Bacuit Formation as presently used is ranked as the basal part of the Malampaya Sound Group. Its thickness is estimated by BMG (1972) to be about 1500-4500 meters. The chert sequence was estimated by Fontaine (1979) to reach a thickness of 1000 m.

Lithology Stratigraphic relations	Limestone One of the exotic blocks in the olistostrome of northern
	Palawan; apparently overlies the Bacuit
Distribution	Minilog Island; west coast of Inabamalaki
	Island, west coast of El Nido town;
	pinnacles in the islands of the Cuyo Group
	of Islands; some islets of the Tara Group
Age	Late Permian to Middle Triassic
Thickness	100-300 meters
Previous name	Minilog Formation (Hashimoto and Sato, 1973)
Renamed by	Wolfart and others (1986)
Correlation	Carabao Limestone (Vallesteros and Argaño, 1965); Pacul Limestone (MGB, 1998) in Carabao Island, Romblon

• Minilog Limestone

The Minilog Limestone was initially classified by Reyes (1971) as the upper Bacuit Formation and later renamed Minilog Formation by Hashimoto and Sato (1973). Due to the predominance of carbonates, the unit was later termed Minilog Limestone by Wolfart and others (1986). It is typically exposed at Minilog Island, off El Nido to the west. The limestone is essentially micritic, massive, partly bedded, dense, white to gray or black,

partly recrystallized and oolitic. Its lower part is oolitic with poorly preserved foraminifera. In places, dolomite is also present.

The limestone contains fusulinids, algae, echinoid plates, crinoid stems and gastropods. Fusulinids identified in the limestone include the following: Neoschwagerina, Verbeekina, Nankinella and Parafusulina (Igo, in Hashimoto, 1981). Other foraminiferal forms identified by Wolfart and others (1986) are: Agathammina, Endothyra and Millerella species (Reves Ordonez, in Gervasio, 1971). Nankinella sp., Globivalvulina and vonderschmidti Reichel, Hemigordius sp. and Pacyphloia sp. Additional species were determined by Amiscaray (1987), which consist of Neoschwagerina megasphaerica Deprat, Neoschwagerina craticulifera Deprat, Yabeina globosa (Schwager), Neoschwagerina margaritae (Yabe). Yabeina sp., Climacammina sp., Kahlerina sp., Verbeekina verbeeki (Geinitz), Vermiporella nipponica Endo, Schwagerina crassa (Deprat) and Schwagerina regularis (Schellwein). Conodont remains were likewise named in the report of Wolfart and others (1986), namely: Acodina sp., Gladiogongolella cf. tethydis (Huckkiede), Parachrognathus sp. and Spathognathodus gondoleloides (Binder). Based on the preponderance of fusulinids and other index foraminifera, a Middle to Late Permian age was assigned to this unit. Wolfart and others (1986) later assign a Late Permian age for the lower horizons of the formation and an Early-Middle Triassic age to the upper portion. The limestone has an estimated thickness of 100-300 m. On the basis of its lithologic composition and fossil contents, the Minilog Limestone is inferred to be deposited in a shallow marine lagoonal setting.

Other exposures of the Minilog Limestone may be found in the west coast of Inabamalaki Island, Cudugman Point on the west coast of Bacuit Bay, Matinloc Island, Dilumacad Island, Tuluran Island and at the west coast of El Nido town. In the Calamianes region, massive limestones presumably of Permian age, determined as Guadalupian in age were identified in Malemeglemeg, Botulan and Pulong Getche Islands of the Tara Group (Fontaine, 1979). The white, massive, highly recrystallized and fractured limestone in Quiminatin and Quiminatin Chicos Islands located southwest of Cuyo Island Group are also believed to be of Permian age, hence equivalent to this unit (Amiscaray and Magbiray, 1983). These carbonates consist chiefly of aggregates of interlocking grains of anhedral calcite, dolomite and minor amounts of clay showing homogenous saccharoidal appearance. A similar Permian limestone exposure in Carabao Island, Romblon is a probable lateral extension of the Minilog.

• Liminangcong Formation

Lithology	Chert/radiolarite, black slate, tuff
Stratigraphic relations	Considered part of an olistostrome but
	noted to underlie the Coron Limestone
	and unconformably rest on the Minilog
	Limestone
Distribution	Liminangcong coast at the northern part of
	Malampaya Sound; widely distributed in
	the northern part of mainland Palawan
	including the Calamian Group of Islands
	-

Age	Late Permian to Late Jurassic
Thickness	500 - 1,000 m
Named by	Hashimoto and Sato (1973)
Synonymy	Liminangcong Chert (Santos, 1989);
	Busuanga Chert (MMAJ-JICA, 1989;
	1990)
Correlation	Gulang-gulang Slates (de Villa, 1941);
	Buruanga Metamorphic Complex
	(Francisco, 1953) in northern Panay;
	Radiolarite (Fontaine and others, 1982) in
	Carabao Island

The term Liminangcong Formation was named by Hashimoto and Sato (1973) for the rocks typically exposed along the coast of Liminangcong in the northern part of Malampaya Sound. It was formerly included in the Linapacan Metamorphic Series and Gulang-gulang Slates of De Villa (1941) and the Bacuit Formation of Reyes (1971). Also, synonymous to the Liminangcong Formation is the Radiolarite of Fontaine (1979) in the Calamian Island Group, the Liminangcong Chert (Santos, 1989; Ringis and others, 1993) and the Busuanga Chert (MMAJ-JICA, 1989; 1990). The formation is considered part of an olistostrome by Wolfart and others (1986), but at Malajon Island, Fontaine (1979) noted that the radiolarite tends to underlie the Coron Limestone. The Liminangcong also apparently rests unconformably on the Minilog. At Maquinit, Coron, it was observed in fault contact with the Liminangcong Formation.

The Liminangcong consists essentially of complexly folded and faulted hematite-bearing chert intercalated with black slate and reddish, bedded tuff. Because of the rich radiolarian tests admixed in these siliceous deposits Fontaine (1979) referred to it as radiolarite. The radiolarite ranges in color from gray to gray green, red, black, light yellow or sometimes white. Interbedded with these siliceous rocks are lenticular and tabular bodies of high grade manganese deposits (braunite, pyroxmangite, alleghanvite, rhodochrosite and haussmannite). The thickness of the manganese ore layers varies from less than a meter to about 2.5 m. These types of deposits were found at several sites in Busuanga Island. Radiolarite or chert, equivalent to the Liminangcong, were also identified in several other places and islands in northern Palawan including Tara. Malacasiao, Linapacan, Culion and Binatican Islands (Fontaine and David, 1982; Isozaki and others, 1988; Samaniego and Nilavan-Tan, 1988). The chert found in islands of the Cuvo Group of Islands that are Middle Triassic in age based on conodonts (Amiscaray and Mabiray, 1983) may be considered as part of the Liminangcong Formation.

Based on stratigraphic position as well as radiolarians, foraminifera, megalodonts, algae, corals and conodonts, the Liminangcong Formation is assigned a Late Permian to Late Jurassic age. Late Early Permian to Late Jurassic radiolarians were identified from the chert by Wolfart and others (1986), Isozaki and others (1988), Tumanda (1991; 1994), Cheng (1989), Faure and Ishida (1990), Tumanda and others (1990) and Yeh (1990). Tumanda (1990; 1992; 1994) recognize 13 radiolarian interval zones from the chert of Busuanga Island, Calamian Island Group indicating an almost continuous deposition from Late Permian to Early Jurassic. These are:

Follicuculus monocanthus, Follicuculus scholasticus, Latentifistula similicutis and Neoalbaillela ornithoformis zone from the Permian interval; *Psuedostylosphaera japonica, Tiassocampe deweveri, Emiluvia* (?) cochleata, Capnuchosphaera, Capnodoce and Livarella zones of the Triassic; and the youngest, the Parahsuum simplum zone from Early Jurassic. Late Jurassic corals, foraminifera and algae were identified by Fontaine and others (1983). The formation is estimated to have a thickness ranging from 500 m to 1,000 m.

Extensive exposures of chert in Tagauayan, Quinluban, Concepcion and Silad Islands in the Sulu Sea region reported by Ramos (1964) are probable extensions of the Liminangcong. In these islands, the chert is intensely fractured and thinly bedded, in varied colors of green, black, yellow, red, white and gray. Quartzites were also encountered in some islands. At Silad and Tagauayan, the quartzite reaches a thickness of about 5 m and 10 m, respectively (Ramos, 1964).

• Coron Formation

Lithology	Dominantly limestone; subordinate shale and sandstone
Stratigraphic relations	Unconformable over the radiolarite of the Liminangcong Formation (Fontaine, 1979)
Distribution	Mabintangin Creek, Coron Municipality, Busuanga Island; limestone hills in several islands of the Calamian Island Group in northern Palawan
Age	Late Triassic to Late Jurassic
Thickness	< 300 m
Named by	Wolfart and others (1986)
Synonymy	King Ranch Formation (MGB, 1984);
	Malajon Limestone (MGB, 1984); Imorigue
	Limestone (MMAJ-JICA, 1989)

The Coron Formation was named by Wolfart and others (1986) for the limestone, shale and sandstone sequences exposed in Coron Island as well as one of the tributaries of Mabintangin Creek in the municipality of Coron, Busuanga Island. The formation consists dominantly of limestone with local interbeds of sandstone and shale or in places, mainly carbonaceous clastic rocks. The limestone is massive, locally bedded, often jointed, light to dark gray, crystalline, reefal and in places oolitic and conglomeratic. It sometimes contains abundant radiolarian tests (Sphaerellaria and Dictyomitra) and few pelagic pelecypods indicating an open marine environment. It usually forms towering pinnacles as in Elet, Kalampisauan and Malajon Islands. Other exposures may be found west of Busuanga Island; Mt. Ili and Sangat Island west of the town of Coron, Seven Brothers, Dibatang and Dilian Islands south and southwest of Coron municipality; Cayatong and Ili Islands east of Linapacan island; and along the coast near Maguinit Hot Spring. The sandstone and shale occurrences were reported from the watershed northeast of Coron town along Mabintangin Creek; in the vicinity of King Ranch in Busuanga Island; and in the eastern side of Coron Island. These clastic deposits were earlier mapped as part of the King Ranch Formation and the Liminangcong Formation (MGB, 1984). The sandstone is thickly bedded and is arkosic to quartzose in composition. The shale is gray to black, apparently of similar composition, and range from silty shale to muddy shale.

The Coron Formation is assigned a Triassic to Late Jurassic age on the basis of stratigraphic position and several paleontological studies. Fontaine and others (1979) and Wolfart and others (1986) report Late Triassic to Early Jurassic foraminifera, chidarians, radiolarians and algae from the limestones of Coron and Seven Brothers Islands. Late Triassic to Early Jurassic condonts were identified by Hashimoto and Sato (1973) from Malajon Island. Later, Epigondelella abneptis (Huckriede), a lower Norian index fossil was reported by Hashimoto and others (1980) from Malajon. Associated fauna, which range from Upper Anisian to Lower Norian are: Enantiognathus ziegleri (Diebel), Cornudina sp. and Neohindeodella sp. The occurrence of pelagic pelecypods and radiolarians were likewise enumerated in these earlier reports. At Malaion and Ili Island. massive and fasciculate corals were also recognized. Tumanda (1991) recognized three radiolarian assemblage zones of Middle to Late Jurassic age from the clastic rocks. Such findings were supported by the studies made by Zamoras and Matsuoka (2000) from samples collected from a creek near Tulbuan Plain in the central part of Busuanga Island. Amiscaray and Tumanda (1990) recover Late Triassic and Middle Jurassic radiolarians from the limestone collected from Coron Island, Likewise, Late Triassic index fossils, from genus Triassina and a Middle Triassic index, genus Involutina were identified from Malajon Island. Other Triassic foraminiferal indicants identified include: Endothyra, Ammobaculites and Duostaminidae species. Algal forms of Thaumatoporella parvosiculifera and Macroporella sp. also indicate Rhaetian age. The limestone at Linapacan is restricted to the Kimmeridgian age (Fontaine, 1979).

The **King Ranch Formation** and **Malajon Limestone** that were mapped by MGB (1984) are considered equivalent to the Coron Formation. The Late Jurassic dark gray karstic limestone of Imorigue Island in Taytay municipality is a probable extension of the Coron Formation. Fossils similar to assemblages identified from Ili Island were recognized by Beauvais (in Fontaine, 1983) from the **Imorigue Limestone** of MMAJ-JICA (1989).

Guinlo Formation

Lithology	Sandstone, conglomerate
Stratigraphic relations	Unconformable over the Coron Formation
	and overlain by the Maytiguid Limestone
Distribution	Guinlo Point, at Malampaya Sound; other
	places in the vicinity of Malampaya Sound;
	Mabin, Maytiguid, Ariara, Cagbatang,
	Inoulay, Imorigue Islands
Age	Late Jurassic to Early Cretaceous
Named by	Hashimoto and Sato (1973)
Correlation	Mansiol Conglomerate (Teves, 1953) at
	Mindoro

The Guinlo Formation was named by Hashimoto and Sato (1973) for the clastic rocks exposed at Guinlo Point in the northwestern coast of Malampaya Sound. It consists mainly of weakly metamorphosed massive, coarse-grained sandstone. The sandstone with few conglomerate interbeds exposed at Ariara, Cagbatang and Inoulay Islands in the southern Calamian Island Group are also considered equivalent to the Guinlo Formation. The conglomerate is usually less than one meter thick, with clasts of quartz and siliceous rocks. The sandstone is white to gray and exhibits cross-stratification. It unconformably overlies the Coron Formation. The conglomerate and quartzite, which underlie the Eocene limestone at Maytiguid Island north of Taytay town, is also considered equivalent to the Guinlo Formation.

The Guinlo is devoid of fossils, but on the basis of stratigraphic position, the formation is assigned a Late Jurassic to Early Cretaceous age.

• Paly Serpentinite

Lithology	Serpentinized peridotite and serpentinite
Distribution	Paly Island, northeast Palawan; Rizal
Age	Cretaceous
Previous name	Paly Ultramafics (MMAJ-JICA, 1990)
Renamed by	MGB (this volume)
Synonymy	Rizal Serpentinites (UNDP, 1985; BMG, 1987)
Correlation	Mt. Beaufort Ultramafics (Delos Santos, 1959)

The Paly Serpentinite was introduced by MMAJ-JICA (1990) as Paly Ultramafics for the dark green serpentinized peridotite and serpentinite at Paly Island, Taytay, northeast Palawan. These rocks were thrusted against the semischist in Turmarbong. Asbestos veinlets were also observed along joints. Such presence of ultrabasic rocks at Paly Island was earlier reported by David and Fontaine (1986). The Paly is equivalent to the Rizal Serpentinites of UNDP (1985), which occur as lenticular bodies exposed in some tributaries of Rizal River in Roxas. In Rizal, the serpentinite bodies appear as diapiric intrusions enclosed within the mudstone beds.

The age of emplacement of these rocks is estimated to be Cretaceous according to the study of BMG (1981).

Barton Group

The Barton Group was previously named Barton Metamorphics by Reyes (1972). It consists of a thick sequence of schists, phyllites, slates, graywackes, sandstones and shales with thin limestone lenses exposed in northern Palawan. The unit was earlier believed to predate the Middle to Late Permian Bacuit Formation, and therefore, could represent the oldest formation in the Philippines, probably dating back to Carboniferous or Early Permian. On the basis of mapping by UNDP (1985) and Wolfart and others (1986), the Barton Group is subdivided into the Caramay Schist, Concepcion Pebbly Phyllite and the Cretaceous Boayan Formation. Hashimoto and Sato (1973) contend that the Barton Metamorphics are unconformably overlain by the Bacuit Formation of the Malampaya Sound Group. In the stratigraphic scheme of Wolfart and others (1986), the Barton Metamorphics was placed below the Malampaya Sound Group, but suggested that it could probably be younger in age. On the basis of structural analyses, Suzuki and others (2001) conclude that the Caramay Schist, Concepcion Phyllite and Babuyan River Turbidites (equivalent to the Boayan) are gradational in terms of degree of metamorphism and that metamorphism accompanied folding, which could have taken place during Eocene or Oligocene. Fold analyses also indicate that the Caramay Schist, Concepcion Phyllite and Babuyan River Turbidites occupy the lower, middle and upper horizons of the stratigraphic succession, respectively.

Caramay Schist

Lithology	Muscovite schist, graphite schist, quartzite
Stratigraphic relations	Stratigraphically below the Concepcion Phyllite
Distribution	Caramay, Roxas; major rivers around
	Roxas; Tinitian Area; San Vicente;
	northwest of Tumarbong
Age	Cretaceous
Named by	UNDP (1985)
Synonymy	Part of the Barton Metamorphics (Reyes,
	1971) Palawan Metamorphics (Hashimoto,
	1981); Crystalline Schist (Hashimoto and
	Sato, 1973); Metasandstone (Faure and
	Ishida, 1990)

The Caramay Schist was named by UNDP (1985) for the schists typically exposed at Caramay, Roxas. The Caramay consists of interlayered and folded mica schist, graphite schist, micaceous quartzite and minor mica-free quartzite. The schists are best exposed along the major rivers around Roxas, namely, Rizal, Caramay and Tulariquien. The formation is also widely distributed in Tinitian area, and other places such as west-northwest of Tumarbong, south of Alemanguhan and San Vicente. Mica schists of the Caramay form layers from a few centimeters up to several meters thick, and locally, may even exceed 10 m. Micaceous guartzites are transitional to guartzose mica schists and characteristically break into rod-like fragments. These are blue gray when fresh, and weather to white and buff. Graphite schists are fine-grained with a submetallic luster when fresh, weathering to silver gray. The graphite schists form layers from less than 1 cm thick to several tens of meters thick, including minor mica schist layers. Pyrite is often present. Thin sections show that some of the rocks consist of biotite schist, biotitemuscovite schist and muscovite-chlorite schist, all with abundant guartz and up to 10% relict feldspar. Semischists interpreted as meta-wackes and micaceous guartzites are also present (UNDP, 1985).

Analysis of the composition and structure of this formation strongly suggests that these metamorphic rocks originated from former sedimentary rocks. At Tinitian, the Caramay has been recumbently folded. Although no fossil was identified from these schistose rocks, a Paleozoic age, probably Carboniferous-Early Permian has been presumed for the formation (UNDP, 1985; MMAJ-JICA, 1990). Wolfart and others (1986) acknowledge a Paleozoic age for the schists, yet they suggest that the Barton Metamorphics was formed by metamorphism of sedimentary rocks of various ages, probably younger than the rocks of the Malampaya Sound Group. Faure and Ishida (1990) note that the Caramay is underlain by the Boayan Formation. Suzuki and others (2001) suggest that the Schist is a facies of the Babuyan River Turbidites, which is equivalent to the Boayan Formation. The structural analyses of Suzuki and others (2001) indicate that it suffered more intense degree of metamorphism due to tectonic deformation in comparison with the Concepcion Phyllite and Babuyan River Turbidites.

The Caramay Schist is partly equivalent to the Barton Metamorphics of Reyes (1971). This is also partly synonymous to the **Palawan Metamorphics** of Hashimoto (1981) and Crystalline Schist of Hashimoto and Sato (1973). It is also referred to as Metasandstone by Faure and Ishida (1990).

• Concepcion Phyllite

Lithology	Phyllite, semischist, slate, quartzite
Stratigraphic relations	Thrusted against the Babuyan Formation;
	Tectonic contact with the Caramay Schist
Distribution	Barrio Concepcion, Roxas; adjacent to
	exposures of the Caramay Schist
Age	Cretaceous
Previous name	Concepcion Pebbly Phyllite (UNDP, 1990)
Renamed by	MMAJ-JICA (1990)
Synonymy	Part of the Barton Metamorphics (Reyes,
	1971)

The Concepcion Phyllite was previously named by UNDP (1985) as Concepcion Pebbly Phyllite in reference to the phyllite exposures adjacent to barrio Concepcion, Roxas, west of the area underlain by the Caramay Schist. The formation consists of phyllite, pelitic semischist, gray to pale brown slate and quartzite between phyllite layers. In some portions of the formation, conglomeratic phyllite occurs as irregular beds within rocks variously described as phyllitic wacke, phyllitic sandstone or semischist. These contain elongate pebbles and flakes of gray to black phyllitic mudstone in a phyllitic matrix. The pebbly unit may reach a thickness of 10 m or more with interbedded thinner and mostly, parallel-bedded quartz sandstone. Quartz veins crossing foliation planes obliquely or perpendicularly are often observed.

Results of fold analysis made by Suzuki and others (2001) indicate that the Concepcion Phyllites lie between the lower Caramay Schist and upper Babuyan Formation. Suzuki and others (2001) further suggest that the Concepcion Phyllite is a facies of the Babuyan River Turbidites (equivalent to the Boayan Formation), which underwent lower degree of metamorphism compared to the Caramay Schist. The Phyllite is therefore presumed to be of Cretaceous age, although metamorphism could have occurred later.

Boayan Formation

Lithology Stratigraphic relations	Sandstone, mudstone Above the Concepcion Phyllite; unconformably overlain by the Eocene Pabellion Limestone (Maytiguid Limestone)
Distribution	Boayan Island; Caruray area; Babuyan River, Ulugan Bay area
Age	Late Cretaceous
Named by	Hashimoto and Sato (1973) as Boayan
	Clastics
Renamed by	MGB (this volume)
Synonymy	UNDP (1985) as Babuyan River
	Turbidites, Boayan-Caruray Clastics
	(Wolfart and others, 1986); Boayan
	Turbidites (Ringis and others, 1993)
	Tinitian Creek Conglomerate (UNDP,
	1985);
Correlation	Panas Formation (Martin, 1972)

The Boavan Formation was previously named by Hashimoto and Sato (1973) as Boayan Clastics for the sequence of sandstones and mudstones at Boavan Island, north of Port Barton. It consists mostly of an alternation of interbedded micaceous feldspathic sandstone and black tuffaceous shale and pillow lavas. The sandstone shows graded bedding and flute casts. At Boayan Island, the clastic rocks are associated with chert, slate, phyllite and schist. Exposures of the clastic rocks in Carurav area prompted Wolfart and others (1986) to rename the unit Boayan-Caruray Clastics. The exposures along Babuyan River around the same area were mapped by UNDP (1985) as Babuyan River Turbidites. As described by UNDP (1985), the formation consists of turbiditic sandstone and mudstone with minor interbedded red and green mudstones. Good exposures of this formation are located west of the Caramay Schist and Concepcion Pebbly Phyllite. The Boayan consists of white to pale gray graywacke, calcareous sandstone and shale. In Sabang Beach, west of St. Paul Limestone, turbiditic sandstones 1-20 cm-thick alternate with dark gray to black mudstones measuring less than 2 cm-thick. The sandstones are mostly fine-grained and guartzose with parallel- and cross-lamination and convolute structures. Outcrops and float of red and green to gray-green mudstones, slates and low-grade phyllites occur in several localities underlain by the turbidites. West of Manlipien Point, red and green slaty siltstones and mudstones are well exposed along the coast for about 200 m. Burrows or worm trails were observed in the sequence. The red and green mudstones and siltstones are in fault contact with the folded turbidite sandstones and mudstones.

As indicated by Suzuki and others (2001), the clastic rocks comprising the Barton Group represent the unmetamorphosed part of the unit that occupies the upper stratigraphic level. According to Hashimoto and Sato (1973), the Boayan is unconformably overlain by the Eocene Pabellion Limestone, which is equivalent to the Maytiguid Limestone. The presence of the coccolith *Prediscophaera cretacea* (Arkhangelsky) on Albaguen Island indicates a Middle Cenomanian to Maastrichtian (Late Cretaceous) age for the formation.

The **Tinitian Creek Conglomerate** of UNDP (1985) is probably a facies of the Boayan that could represent its lateral extension. It is mainly conglomerate with interbedded mudstone and sandstone. The clasts consist of rounded orange to brown chert, quartzose sandstone, quartzite and mudstone set in quartzose sandy matrix. Faure and Ishida (1990) included this formation and the Sagasa Point Tectonic Complex (UNDP, 1985) in their turbidite and slump deposits. The **Boayan Turbidites** of Ringis and others (1993) is also equivalent to the Boayan Formation. Pineda and others (1992) correlate this formation to the Batas Member of the Pagasa Formation in offshore northwest Palawan.

Maytiguid Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Liminangcong
Distribution	Maytiguid Island, Taytay; Pabellion,
	Baraoasen and Apulit Islands; Siracan
	Islet
Age	Eocene
Named by	Gray (1954)
Synonymy	Pabellion Limestone (Reyes, 1971)
Correlation	Bailan Limestone of Tablas Island;
	Sumbiling Limestone in southern Palawan

This Eocene *Nummulites-* and *Discocyclina-*bearing limestone in northeastern Palawan was first recognized by Yabe and Hanzawa (1929). Gray (1954) named it as Maytiguid Limestone after its type occurrence at Panagalan Point at the southern tip of Maytiguid Island, where it unconformably rests over the Liminangcong Formation It also outcrops at Pabellion, Baraoasen, Calabugtong, Apulit and Siracan Islands. The Maytiguid Limestone consists predominantly of light to dark gray limestone interbedded locally with few carbonaceous shale. Eocene foraminifera identified include: *Nummulites, Discocyclina, Pellatispira, Asterocyclina,* and *Fasciolites* species. At Pabellion, the limestone was noted to be dark gray to black, medium to thickly bedded, sandy, fossiliferous and crystalline (David and Fontaine, 1983). It contains foraminifera and algal remains, including *Distichoplax biserialis* (Dietrich) and *Lithothamnium marianae* Johnson.

The name **Pabellion Limestone** established by Reyes (1971) for the exposure at Pabellion Island is equivalent to the Maytiguid. It is probably partly equivalent to the Late Eocene limestones encountered by Galoc No. 1, Malajon No. 1 and Nido No. 1 wells in offshore northwest Palawan (Sales and others, 1997) The Maytiguid Limestone is probably correlative to the Bailan Limestone of Tablas Island and Sumbiling Limestone in Bataraza and northern Brooke's Point, southern Palawan.

St. Paul Limestone

Lithology	Limestone
Stratigraphic relations	Unconformably overlies the Palawan
	Ophiolite and the Maytiguid Limestone
Distribution	St. Paul Bay, adjacent to Ulugan Bay;
	Tugbuan
Age	Late Oligocene - Early Miocene
Previous name	St. Paul's Limestone (De Villa, 1941)
Renamed by	MGB (this volume)
Synonymy	St. Paul Formation (Wolfart and others,
	1986)
Correlation	Coeval to the Ransang Limestone (Martin,
	1972)

The St. Paul Limestone was originally termed St. Paul's Limestone by De Villa (1941) for the massive, dark gray and finely crystalline limestone that crops out along the shore of Saint Paul Bay, northern Palawan. It is also exposed at Ulugan Bay and near Tugbuan in the Babuyan quadrangle. Fine-grained claystone and mudstone flanking the limestone pinnacles are also believed to be coeval to the limestone. Hashimoto and Sato (1973) consider the limestone to unconformably overlie rocks ranging in age from Early Cretaceous to Late Eocene.

On the basis of stratigraphic position and paleontological age determinations, the St. Paul Limestone is assigned a Late Oligocene to Early Miocene age. Although De Villa (1941) assigns a Middle Miocene age to the St. Paul Limestone based on the presence of *Lithothamnion* and *Lepidocyclina* species, an Early Miocene age is indicated by *Lepidocyclina* (*Eulepidina*) formosa (Schlumberger) and *Miogypsina*. Hashimoto and Sato (1973) report a Late Oligocene age for this limestone. Nilayan-Tan (1985) identifies Late Oligocene to Middle Miocene foraminiferal assemblages from several samples and Late Eocene nummulitids from samples collected near the entrance of the underground river. Eocene foraminifera were also identified from the Nido Limestone but no Early Oligocene representative was identified from the limestone. Deposition of the limestone was assumed to be in a lagoonal to reefal setting.

The St. Paul is equivalent to the offshore subsurface Late Oligocene to Early Miocene **Nido Limestone** described by Saldivar-Sali and others (1981). The Nido reportedly rests unconformably on Late Eocene unit and has a thickness of 885 m as determined from Nido -1 well (BED, 1986c). The clastic sequences overlying the Nido, as revealed through offshore subsurface wells, have no equivalent in onshore northern Palawan. The **Pag-asa Formation**, dated Early Miocene to Middle Miocene, lies conformably on the Nido. The **Matinloc Formation**, in turn, rests conformably on the Pag-asa Formation and determined to be Middle Miocene, possibly extending up to Pliocene.

The **Reed Bank Limestone** of Keston (1981) and the **Ransang Limestone** of Martin (1972) in southern Palawan is probably also coeval to the St. Paul Limestone.

Kapoas Granite

Lithology	Granite, quartz monzonite, granodiorite, quartz diorite
Stratigraphic relations	Intrudes the Liminangcong Formation and Barton Group
Distribution	Mt Kapoas, İmuran Island; Cleopatra's Needle, Stripe Peak; central range west of
	Iwahig; northwestern Pancol,
	southwestern Mabini, northwestern
	Silaltan
Age	Middle Miocene
Named by	De Villa (1941)
Synonymy	Tiniguiban Granodiorite (Ringis et al.,
	1993); Stripe Peak Granite (UNDP, 1985;
	BMG, 1987); Stripe Peak Granodiorite
	(MMAJ-JICA, 1990); Kapoas Granitic
	Rocks (MMAJ-JICA, 1990)

The term Kapoas Granite was introduced by de Villa (1941) for the granitic intrusive rocks cropping out in Mt. Kapoas located south of the Malampaya Sound in northwestern Palawan. Two varieties have been distinguished: clear normal biotite granite and a variety with dark patches or schlieren. Both dominantly contain pale gray, finely granular, interlocking, and occasionally staniferous quartz. Other granitic intrusions that are associated with the Kapoas Granite include quartz monzonite, granodiorite and quartz diorite.

Quartz monzonite underlies Cleopatra's Needle chain of peaks in Linapacan east of Bacuit. There are also exposures in the central highland extending southward west of Aborlan; northwest of Pancol; west coast of San Miguel, southwest of Mabini and Darocotan Bay. This also extends northward to Port Barton. The quartz monzonite consists mainly of quartz, sodic plagioclase, orthoclase, perthite and biotite. Xenoliths of schists were noted in boulders of quartz monzonite, which litter the banks and beds of Tarabowan and Babuyan rivers.

Granodiorite at Stripe Peak consists of plagioclase, quartz, biotite and amphibole. It also underlies the areas around the western coast of San Miguel, northwest of Pancol, southwest of Mabini and Darocotan Bay. Quartz diorite at Cagbuli Island is also considered part of the unit.

Different authors have indicated conflicting ages for the intrusive. Earlier authors like De Villa (1941) considers an Early Eocene age for the intrusion of the Kapoas Granite, but BMG (1981) assigns a Late Jurassic age. Radiometric K-Ar age determinations by UNDP (1985) of samples from the project area in central Palawan indicate a probable Early Oligocene age for the intrusion. On the other hand, K-Ar analysis made by MMAJ-JICA (1987, 1989) yielded Late Eocene to Early Oligocene age for this unit.

More recent isotope studies by Encarnacion and Mukasa (1997) indicate an even much younger age of Middle Miocene (13-15 Ma),

suggesting a post-rifting origin of the intrusive rock. On the basis of geochemical and isotopic analysis, these authors believe that the Kapoas has been produced from a calc-alkaline melt related to an old Andean-type arc formed earlier during Mesozoic times. Pre-rifting intrusive rocks within the continental crust of Palawan are considered by Taylor and Hayes (1983) as having formed in an Andean-style north-south trending subduction zone that dipped westerly, subducting beneath eastern Asia during the Mesozoic. For the Mt. Kapoas intrusives, melting is believed to have occurred by underplating of the continental crust beneath North Palawan because of the absence of a subduction zone in this region. These, therefore, do not belong to a truly continental crust as those formed earlier in an Andean-subduction setting.

The older ages determined separately by Mitchell and others (1986 - 37 ± 2 Ma) for the biotite quartz monzonite bodies and MMAJ-JICA (1987 - 36.0 ± 1.8 Ma) for granodiorites would classify the formation of these intrusive rocks in a pre-rifting, pre-collision setting. Following the interpretation of Encarnacion and Mukasa (1997), these older granitic rocks, sampled south of the Mt. Kapoas region, perhaps represent those intrusive events mentioned by Taylor and Hayes (1983) and by later authors and which are unrelated to the Kapoas Granite.

Piedras Andesite

Lithology	Andesite
Stratigraphic relations	Intrudes the surrounding ultramafic rocks.
Distribution	Limited at Piedras Point, Puerto Princesa
	City
Age	Middle Miocene (?)
Previous name	Piedras Point Andesite (De Villa, 1941)
Renamed by	MGB (this volume)

The Piedras Andesite was previously named by De Villa (1941) as Piedras Point Andesite for the intrusive mass at Piedras Point (Punta Diablo) on the west coast, near Puerto Princesa City. The rock is dense hornblende andesite containing some quartz. It is probably Middle Miocene in age.

Manguao Basalt

Lithology	Basalt, subordinate shale, siltstone,
	conglomerate and pyroclastic rocks
Distribution	Around Lake Manguao, Taytay; Islands in
	the Cuyo Island Group
Age	Pliocene-Pleistocene
Previous name	Manguao Volcanics (Reyes, 1971)
Renamed by	MGB (this volume)

This formation was originally named Manguao Volcanics by Reyes (1971). It consists of basalt lava flows exposed around Lake Manguao in Taytay, northern Palawan. The basalt is fine-grained, granular in texture partly vesicular with some vitric components. The phenocrysts are dominantly olivine in association with intergranular pyroxenes. The

Manguao is well exposed along stream valleys and in topographically low areas. A probable Pleistocene age was assigned to the unit.

Equivalent to the Manguao Basalt are the basaltic flows identified in the Cuyo Group of Islands whereby three cones - Mounts Bonbon, Lucban and Aguado - are considered centers of effusion. At Bisucay Island, the basalt flow is dark gray, fine-grained, aphanitic and partly vesicular. In places, it is porphyritic with olivine phenocrysts embedded in a feldspathic groundmass. Other basalt islands that are considered to be equivalent to the Manguao are Lubid. Canipo, Diit, Putik, Guilabog, Imuran, Pagauavan, Agutaya, Cuyo and Caponayan Islands (Amiscaray and Quiel, 1983). Thin beds of tuffaceous shale, siltstone and conglomerate intercalating with pyroclastics that are intermittently exposed in the region could be part of the Manguao. In the northern part of Putic and Lubid Islands, the tuff contains clasts of basalt, diorite and limestone. The limestone boulders are white to buff and fossiliferous. For aminifera identified in the limestone are mostly Pliocene-Pleistocene forms. An undisturbed basaltic flow, which appears to be of Recent age was observed at Limbangan Point, north of Calauag Bay.

The basaltic flows and pyroclastics observed in Cuyo were considered by Fontaine (in Amiscaray and Quiel, 1983) to be Pliocene-Pleistocene in age. The limestone embedded in the volcanics suggests Late Miocene to Pleistocene age (Amiscaray and Quiel, 1983). However, radiometric K-Ar determinations made on samples collected from Manguao area indicate a Pliocene (5 \pm 0.3 Ma) age for the volcanic flows (MMAJ-JICA, 1990).

Central and Southern Palawan and Balabac Island

Due to similarities in lithologic composition and tectonic framework, rocks of central and southern Palawan including Balabac Island are herein grouped into a single stratigraphic grouping (SG-12). The oldest unit in central and southern Palawan is the dismembered Palawan Ophiolite and Paleogene sedimentary rocks. The Paleogene lithologies of southern Palawan are described as a mélange (Hamilton, 1979; Keston, 1981; Wolfart and others, 1986). Obduction of the continental fragment of northern Palawan against southern Palawan was presumed to have started from Middle Eocene time and culminated during Early Miocene time.

Palawan Ophiolite

Lithology	Amphibolite, harzburgite, troctolite, dunite, gabbro, pillow basalt, chert and pelagic mudstone
Stratigraphic relations	Overlain by younger formations
Distribution	Inagauan, Dalrympole Point, Mt. Beaufort,
	Sultan Peak, Stavely Range, Ulugan Bay,
	San Vicente, Espina, Panas and other
	places in central and southern Palawan
Age	Cretaceous
Named by	Gealey (1980)

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	CENTRAL AND SOUTHERN PALAWAN
	HOLOCENE		0.0117	
F NEOGENE	PLEISTOCENE	4 Late 3 - Middle 2	0.126 0.78 1.81	Tagburos Opalite
	PLIOCENE	2 Middle 1 Early	2.59 3.60 5.33	Iwahig Formation
	MIOCENE	3 Late	7.25	Alfonso XII Formation
		2 Middle-	13.65	Isugod Formation
		1 Early	20.43	Ransang Limestone Balabac Formation
	OLIGOCENE	2 Late 1 Early	28.4	Sagasa Melange Pandian Formation
GENE	FOOTNE	4 Late	37.2	Panas Formation
PALEO	EUCENE	2 1 Early	48.6	Sumbiling Limestone
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
CEOUS	Upper	Late	00.6	Palawan Ophiolite Espina Formation
CRETAC	Lower	Early	33.0	Stavely Gabbro Beaufort Ultramafic Complex
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.15 Stratigraphic column for Central and Southern Palawan

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Synonymy

Dalrympole Amphibolite; Ulugan Bay Ultramafic Complex; San Vicente Gabbro of UNDP (1985); Stavely Range Gabbro, Beaufort Ultramafic Rocks, Paraschist and Irahuan Metavolcanics of de los Santos (1959); Inagauan Metamorphics (MMAJ-JICA, 1989)

This ophiolitic terrane stretches from southern to central Palawan for about 300 km along the trend of the island with a maximum width of about 30 km. The complex was termed Palawan Ophiolite by Gealey (1980, in UNDP, 1985). It was described by Rashka and others (1985) to be an almost complete ophiolitic suite composed of ultramafics (Mt. Beaufort Ultramafics), gabbro (Stavely Range Gabbro), pillow basalts with radiolarian chert, and red mudstones (Espina Formation). Sheeted diabase complex is absent. The ophiolite grades downward from pelagic sedimentary rocks and pillow basalt via isotropic and cumulate gabbro towards the troctolite horizon. A basal dunite (transition zone dunite) separates the troctolite horizon from the tectonite sequence of harzburgite with microgabbro and pyroxenite dikes (Santos, in Tumanda and others, 1995). The Dalrympole Amphibolite represents the ophiolitic sole (Pineda and others, 1992). The formation of this complex culminated in Cretaceous time as indicated by paleontologic dating made by Tumanda and others (1995) of radiolarian tests in the chert facies of the sedimentary cover above the pillow lavas. The emplacement of the ophiolites through thrusting apparently occurred during the Eocene.

Beaufort Ultramafic Complex

Lithology Stratigraphic relations	Harzburgite, dunite, pyroxenite; peridotite
	Mayert Desufart Desly Illyree Devisether
Distribution	places in southern and central Palawan
Age	Cretaceous
Previous name	Mt. Beaufort Ultramafic Rocks (De los
	Santos, 1959)
Renamed by	MGB (this volume)
Synonymy	Ulugan Bay Ultramafics (UNDP, 1985);
	Ulugan Bay Ultramafic Complex (MGB,
	1987)
Correlation	Paly Serpentinite in northern Palawan; Smooth Hill Ultramafics in Balabac Island (Basco, 1964)

The Beaufort Ultramafic Complex was originally named Mt. Beaufort Ultramafic Rocks by De los Santos (1959) for the exposures around Mt. Beaufort and the highlands adjoining them to the north and northeast. It is the main constituent of the ophiolitic body. These ultramafic rocks are widely exposed from Puerto Princesa in central Palawan to Bataraza in the south. It also occurs as windows in shallow depressions along the valleys of Tagkuliat and Rapsaan rivers. Similar exposures occur along the toe and slopes of a low hill northwest of the Inagauan Penal Colony. The Beaufort is synonymous to the **Ulugan Bay Ultramafics** of UNDP (1985). The Complex also correlates with the **Smooth Hills Ultramafics** of Basco (1964) in Balabac Island.

The ultramafic rocks consist of unaltered and serpentinized harzburgite, dunite, peridotite and pyroxenite. Harzburgite with accompanying cumulate dunite mainly comprise the complex. Dikes or stocks of dunite also intrude the harzburgite. The pyroxenite usually occurs in stratiform layers that are chiefly composed of well-developed pyroxene crystals. The dunite is stratified and laminated when associated with chromite, as in Narra and Bacungan.

The Paly Serpentinite in Paly Island off Taytay in the north is probably correlative to the Beaufort Ultramafic Complex.

• Stavely Gabbro

Lithology Stratigraphic relations	Gabbro Overlies the Beaufort Ultramafic Complex; thrusted over the Espina Formation; overthrusted by the Beaufort Ultramafic Complex
Distribution	Stavely Range, including Anepahan and Thumb peaks. San Vicente: Sultan Peak
Age	Cretaceous; emplaced during Middle Eocene
Previous name	Stavely Range Gabbro (De los Santos, 1956)
Renamed by	MGB (this volume)
Synonymy	San Vicente Gabbro (UNDP, 1985);
	Sultan Peak Gabbro (MMAJ-JICA, 1990)

The Stavely Gabbro was originally named by De los Santos (1959) as Stavely Range Gabbro for the exposures at Stavely Range, which embraces Stavely, Anepahan and Thumb peaks and other adjacent knobs. Synonymous to the Stavely are the San Vicente Gabbro of UNDP (1985) and the Sultan Peak Gabbro of MMAJ-JICA (1990). The Stavely consists of medium- to coarse-grained gabbro, including olivine gabbro and troctolite. In places, the gabbro is pegmatitic with large crystals of plagioclase, pyroxene and minor amounts of hornblende. The San Vicente Gabbro is described by UNDP (1985) as fine- to medium-grained pyroxene-plagioclase gabbro with banded structures. The Sultan Peak Gabbro consists of both isotropic and lavered gabbros. Cumulate dunite of the Beaufort Ultramafic Complex underlies the gabbro at Sultan Peak. A troctolite layer was also noted to lie between normal gabbro and transition zone dunite in central Palawan (MMAJ-JICA, 1993). In the Bacungan tectonic window, the gabbro is thrusted over the Espina Formation and overthrusted by ultramafic rocks. Gabbro also outcrops near the Inagauan Penal Colony, forming the highlands of the Triple Top and Village ranges. In southern Palawan, it is also well exposed west of Narra in the east of south Palawan; south of Berong and around Long Point in the west coast, as well as Malinao and Balsahan rivers. The Stavely Gabbro is apparently part of the Palawan Ophiolite, which probably formed during the Cretaceous and emplaced through thrusting during the Eocene.

• Espina Formation

Lithology	Spilitic basalt with intercalated sandstone
	and chert
Stratigraphic relations	Unconformably overlain by the Panas
	Formation and the Sumbiling Limestone
Distribution	Espina Point, Pait Hill in Balabac Island;
	Bacungan River; Maranat Creek
Age	Late Cretaceous
Thickness	1000 meters
Named by	Basco (1964)

Synonymy	Bacungan River Group (UNDP, 1985); Chert-Spilite (Reyes, 1971); Chert Basalt
	Series (Martin, 1972)
Correlation	Boayan Formation in northern Palawan;
	Irahuan Metavolcanics (De los Santos,
	1959) in central Palawan

The name Espina Formation was originally used by Basco (1964) to designate the chert, clastic rocks and spilitic basalt at Espina Point in Balabac Island. It is best exposed at Pait Hill, at the south entrance of Calandorang Bay and in the east-central mountainous parts of Balabac Island between Calandorang and Dalawan bays. Wolfart and others (1986) adopted the name for the clastic rocks associated with limestone, chert and spilitic basalt complex in central and southern Palawan. This formation is synonymous to the Chert-Spilite of Reyes (1971) and Chert Basalt Series of Martin (1972). Also included in this unit are: the Espina Basalt of MMAJ-JICA (1990); Bacungan River Group consisting of Maranat pillow lavas, Tagburos Siltstone and Sulu Sea Mine Formation (UNDP, 1985); and the Irahuan Metavolcanics (De los Santos, 1959).

The Espina Formation as originally described consists of basalt with intercalated shale, limestone and chert. The shale is indurated and siliceous. The limestone is brown to gray, dense and fossiliferous. The chert is reddish to brownish gray and manganese-bearing. At the Bacungan tectonic window, along Bacungan River and at Irawan area, pillow lavas and breccias occasionally intercalated with chert form low lying hills.

The pillow lavas and breccias at Maranat Creek, north of Bacungan tectonic window and in Iratag River were designated as **Maranat pillow lavas** by MMAJ-JICA (1990). They were earlier designated as **Irahuan Metavolcanics** by De los Santos (1959), described as altered basaltic flows unconformably overlying paraschists. They are widely distributed in central and southern Palawan as massive basalt and basaltic pillow lavas and breccias. In places, cherty shale and chert were observed intercalated with the basalt.

Overlying the basalt in the Iratag window are pelagic clastic rocks of the Espina Formation, which represent the sedimentary cover of the ophiolite. This sedimentary sequence was subdivided by MMAJ-JICA (1990) into the Tagburos Siltstone and Sulu Sea Mine Formation. The **Tagburos Siltstone** consists of interbedded massive greenish siltstone, minor wacke and conglomerate. This also includes thin turbiditic sandstones and gray mudstones with minor interbedded red mudstones outcropping in Iratag River. Stratigraphically overlying this sequence is the **Sulu Sea Mine Formation** consisting of interbedded red cherts and dark manganiferous cherts, conglomerates and wackes, red and green mudstones, pillow breccias and sparse pillow lavas. This probably includes the "paraschist" mapped by De los Santos (1959) in the Inagauan and Iwahig Penal Colony areas. According to the description, the unit consists of foliated rocks, interstratified with beds of chert, limestone and quartzite. In Bonton River, the limestone reaches a thickness of about 50 cm.
Wolfart and others (1986) recognize the nannofossil *Tetralithus trifidus* assemblage indicating a Late Campanian to Early Maastrichtian age. Chert samples intercalated with the basalt taken in southern Palawan and from the Sulu Sea Mine Formation contain radiolarians of Albian-Campanian age (Tumanda and others, 1995). Radiolarian species identified from the chert spilite series point to pre-Cenomanian and Campanian ages. The age adopted here for the Espina Formation is Late Cretaceous. Its estimated thickness is about 1,000 m.

The Espina Formation is overlain unconformably by the Panas Formation and Sumbiling Limestone and is in thrust contact with gabbro and ultramafic rocks. According to Wolfart and others (1986), deposition of the overlying chert and clastic equivalents was probably coeval to the deposition of the Boayan Formation in northern Palawan.

• Dalrympole Amphibolite

Lithology	Amphibolite, greenschist
Stratigraphic relations	Represents the metamorphic sole of the
	ophiolitic suite
Distribution	Dalrympole Point, west of Nasuedan
	Beach; Bentoan Point; Irawan area
Age	Middle Eocene
Named by	UNDP (1985)
Renamed by	MGB (this volume)
Synonymy	Kabangan Metamorphics (UNDP, 1985);
	Inagauan Metamorphics (MMAJ-JICA,
	1990); Paraschists and Altered Arkose
	(De los Santos, 1959)

The Dalrympole Amphibolite was named by UNDP (1985) as Dalrympole Point Amphibolite for the exposures at Dalrympole Point west of Nasuedan Beach. It also outcrops in a small portion of Bentoan Point. The amphibolite, which attains a thickness of a few tens of meters, is considered as the metamorphic sole of the Palawan Ophiolite (Pineda and others, 1992). It is medium-grained, nematoblastic, and with abundant hornblende needles. Bands of ferromagnesian minerals, including sporadic garnets of up to 3 mm in diameter, alternate with those of plagioclase and/or quartz. Radiometric K-Ar dating of the amphibolite indicates a range of 37-40 Ma corresponding to Middle Eocene (Rashka and others, 1985) to Late Eocene (MMAJ-JICA, 1987).

In Kaydungon Beach and Kabangan Creek, north of the Bacungan window, the metamorphic rocks consist of lenses of amphibolites, greenschist, minor biotite schist, quartzite and marble. These suggest that they were originally basic volcanic rocks, mudstones and cherts metamorphosed to lower amphibolite facies. Tectonic contact shows that it underlies sedimentary and volcanic rocks, welded at the base of the harzburgite. Outcrops of these types of metamorphic rocks are also found in the southern edge of Bacungan window and in some parts of Iratag window.

The **Inagauan Metamorphics** of MMAJ-JICA (1990) in central Palawan is probably partly equivalent to the Dalrympole Amphibolite. The Inagauan is subdivided into greenschist and amphibolite member and quartz-mica schist and quartzose schist member. These rocks are distributed at Inagauan and Malasgao rivers and in the hills and mountains around Berong. The **Kabangan Metamorphics** of UNDP (1985) could also be considered equivalent to the Dalrympole Amphibolite.

Panas Formation

Lithology Stratigraphic relations	Sandstone, siltstone, shale, conglomerate Unconformable over the Espina Formation: partly intertonques with the
	Sumbiling Limestone
Distribution	Panas Creek; Langue, Tagkawayan and Talasag Rivers, all tributaries of Sumbiling
	River
Age	Eocene
Thickness	About 1500 m
Named by	Casasola (1956)

The term Panas Formation was earlier applied by Casasola (1956) to the interbedded, highly indurated and sparsely fossiliferous sandstone and shale exposed in Panas Creek, a tributary of Iwahig River, at Bataraza. The formation is also exposed at the eastern and western base of Bulanjao Range and along the Langue, Tagkawayan and Talasag rivers, which are tributaries of Sumbiling River. The Panas Formation was originally described as a sequence of indurated turbiditic medium to thinly bedded alternations of sandstone, siltstone and shale. Conglomerate beds locally grade to sandstone and shale. The medium to thinly bedded sandstone, siltstone and shale alternations are light to dark gray, quartz-rich, feldspathic, and cemented by carbonate and clayey matrix.

The Panas unconformably overlies the Espina Formation and partly intertongues with the overlying Sumbiling Limestone The sandstone and shale sequence of the Panas yielded small foraminifera that include *Globorotalia velascoensis* (Cushman) and *Globigerina gravelli* Bronnimann, indicative of Paleocene to Early Eocene age (BMG, 1981). It is considered Eocene in age by later studies (MMAJ-JICA, 1989, 1990). The Panas has a maximum thickness of 1,500 m.

Sumbiling Limestone

Lithology	Massive, partly crystalline, dark gray limestone
Stratigraphic relations	Unconformable over the Espina Formation and intertongues with the Panas Formation
Distribution	Tagkawayan Creek, a tributary of the Sumbiling River; Labog, Zambo, Tarusan and Inagauan areas
Age Named by	Eocene Casasola (1956)

Synonymy	Labog Limestone (Martin, 1972);
	Sumbiling Formation (Wolfart and others,
	1986)
Correlation	Maytiguid Limestone (Gray, 1954) in
	northeast Palawan; Pabellion Limestone

The Sumbiling Limestone was established by Casasola (1956) for the carbonate sequence outcropping at the headwaters of Tagkawayan Creek, a tributary of Sumbiling River, in Bataraza. It unconformably overlies the Espina Formation and apparently intertongues with the Panas Formation. The massive, partly crystalline, dark gray limestone comprising the Sumbiling is also exposed in Labog, Zambo and Tarusan areas. In central Palawan, it crops out in the Inagauan Penal Colony and at the base of the St. Paul Limestone in the Underground River, in Sabang, Puerto Princesa.

Maac and Agadier (1988) notice calcisiltite and calcirudite alternating with the clastic rocks of the Panas in Zambo and Marirong areas. Casasola (1956) also notes that a sequence of indurated sandstone and shale was also found conformably underlying and overlying the limestone, indicating that the deposition of both the clastic rocks and the limestone are coeval. However, a similar limestone named by Martin (1972) as Labog **Limestone**, that was found to contain the same foraminiferal and algal assemblages as the Sumbiling Limestone, was observed to overlie a sequence of sandstone and shale identical to the clastic rocks of the Panas Formation.

The Sumbiling Limestone contains the index forms of *Nummulites, Discocyclina, Pellatispira* and *Heterostegina* associated with *Distichoplax biserialis* (Dietrich) and *Archaeolithothamnium* sp. Casasola (1956), de los Santos (1959) and Reyes (1978) assumed an Eocene age for the unit. A Late Paleocene – Early Eocene age was assigned by BMG (1981) to the Sumbiling. The age of the Sumbiling, however, was pegged to the Eocene by Wolfart and others (1986) and Maac and Agadier (1988).

The Sumbiling is equivalent to the Maytiguid Limestone in northern Palawan.

Pandian Formation

Lithology	Massive sandstone, shale, conglomerate
Stratigraphic relations	Unconformable over the Panas Formation
Distribution	Pandian River, Rizal; southern Palawan
Age	Middle Eocene – Early Oligocene
Thickness	1500-2000 m in southern Palawan
	(Casasola, 1956)
Named by	Casasola (1956)
Synonymy	Pulute Formation (Reyes, 1971)

The Pandian Formation was introduced by Casasola (1956) to designate the massive sandstone extensively distributed in southern Palawan with type locality at Pandian River, Rizal in the western side of southern Palawan. The unit is originally described as dominantly made up of massive, coarse-grained, porous arkosic sandstone with indurated dark gray mudstone and silty shale interbeds downsection. Thick beds of conglomerate were recognized near its base. The sandstone is brown to buff, consisting mostly of coarse-grained quartz with few feldspars, serpentine, chert and magnetite. The shale interbeds are light to dark gray and light brown with a thickness of about 6-8 cm.

The Pandian Formation is most prominent in the eastern flank of Mt. Bolanao and is also exposed near Tarusan, in Labog, Marirong-Tagusao, Punang, Lamican, Malinao and Mariquit Island.

The Pandian was originally presumed to be Middle to Late Miocene in age by Casasola (1956). Later, Martin (1972) and BMG (1981) assign an Oligocene age; and MMAJ-JICA (1990), an Early Oligocene age for the formation. However, Gamboa (1977) finds Eocene foraminifera from the shale fraction interbedded with the massive feldspathic sandstone of the original Pandian Formation. Maac and Agadier (1988) likewise recognize Eocene foraminifera and nannofossils from shales interbedded with the thick feldspathic sandstone in Marirong and Bulanao Range. Wolfart and others (1984) report calcareous nannofossils of late Middle Eocene to Early Oligocene age (*Sphenolithus pseudoradians* Zone, NP 20 to *Ericsonia subdisticha* Zone, NP21) from the clastic rocks. A maximum thickness of 1,500 meters is estimated for the Pandian.

Because of their similarities in lithology and age value, Maac and Agadier (1988) suggest that the name Pandian be adopted for the turbidites mapped as Panas Formation. The Pandian is also equivalent to the **Pulute Formation** of Reyes (1971)

Sagasa Mélange

Lithology	Chaotic mixture of turbidite, pillow basalt, chert, guartzite
Stratigraphic relations	Probably formed through tectonism
Distribution	Scattered promontories and islets along
	the east coast of Ulugan Bay.
Age	Possibly Oligocene
Previous name	Sagasa Point Tectonic Complex (UNDP, 1985)
Renamed by	MGB (this volume)

The Sagasa Mélange was previously designated by UNDP (1985) as Sagasa Point Tectonic Complex in reference to the chaotic mixtures of turbidites, pillow basalts, cherts and quartzites outcropping in the Ulugan Bay area especially at Madahon Point, Hill 227, Magispao Reef and Sagasa Point. At the Madahon Point, UNDP (1985) observed successions of gray mudstone and calcareous mudstone. The tectonic activity that gave rise to the formation of the mélange probably occurred during the Oligocene.

Balabac Formation

Members North Bay; Tagkalasa; Catagupan, Sigumay

Lithology	Limestone, sandstone, shale,
	conglomerate
Stratigraphic relations	Unconformable over the Espina Formation
Distribution	North Bay Hill area, Balabac Island
Age	Late Oligocene - Miocene
Thickness	1,100 – 2,300 m
Previous name	Balabac Sandstone (Irving, 1949)
Renamed by	Basco (1964)

The Balabac Formation was previously named by Irving (1949) as Balabac Sandstone for the exposures at Balabac Island. The formation crops out at the North Bay HIII area between the lower Dalawan River and False Balabac Peak west-northwest of Dalawan Bay. The unit was renamed by Basco (1964) in consideration of the presence of shale and limestone in the sedimentary sequence. Interbeds of pebbly conglomerate in the sandstone are also present.

The Balabac Formation has four members, namely: North Bay Hill (here renamed North Bay), Tagkalasa Hill (here renamed Tagkalasa), Catagupan and Sigumay.

• North Bay Member

The North Bay Member consists dominantly of limestone with interbeds of thin sandstone and shale. The limestone is brown to gray, massive, fineto coarse-grained and fossiliferous. The shale and sandstone are gray and fine-grained. The presence of *Lepidocyclina (Eulepidina) monstrosa* Yabe in the limestone delimits the age of these horizons to Late Oligocene.

• Tagkalasa Member

The Tagkalasa Member is composed generally of arkosic, massive, light gray, moderately hard and fine- to medium-grained sandstone with thin layers of shale. The presence of several species of *Spiroclypeus* and *Lepidocyclina* in the member indicates that it was deposited during Early Miocene. Its thickness ranges from 500 to 800 m.

• Catagupan Member

The Catagupan Member consists of 168 to 600 m sequence of shale and sandstone with minor limestone beds. The shale is gray and thick bedded while the sandstone is thin-bedded and arkosic. The limestone is thinly bedded, gray, arenaceous, and crops out mostly in the Catagupan River Valley on western Balabac island. The age is Early-Middle Miocene as indicated by the presence of *Lepidocyclina* and *Miogypsina* assemblages.

• Sigumay Member

The Sigumay Member is composed of gray medium-grained arkosic sandstone that crops out near Sigumay Point on western Balabac Island. It contains small foraminifera of Late Miocene age. The thickness ranges from 450 to 896 m.

Ransang Limestone

Lithology Stratigraphic relations	Limestone, calcarenite and calcisiltite Conformable over the Pandian Formation; conformably overlain by the Isugod Formation
Distribution	Ransang River, Barrio Ransang, Quezon; as patches in Labog, Barangay Underground, Devil's Peak, Malanut Range, Pagoda Hills and along the Ipilan- Kalatagbak route
Age Named by	Early Miocene Martin (1972)

The Ransang Limestone was originally designated by Martin (1972) for the carbonate exposures in Gap Hill near the headwaters of Ransang River in Barrio Ransang, Quezon. Patchy remnants were noted in Labog, Barangay Underground, Devil's Peak, Malanut Range, Pagoda Hills and along the Ipilan-Kalatagbak route. The formation consists of cream to gray, massive to bedded limestone, including calcarenites and calcsiltites. Benthic foraminifera, algae, coral and molluscan fragments were observed in the limestone. Tests of *Spiroclypeus* and *Lepidocyclina* species identified in the Ransang suggest an Early Miocene age for this formation (Maac and Agadier, 1988). Deposition probably occurred in a relatively shallow marine environment from the main reef complex to the lagoonal area.

The Ransang is correlative to the St. Paul Limestone onshore and Nido Limestone in offshore northern Palawan.

Isugod Formation

Lithology	Shale and sandstone; minor limestone; conglomerate
Stratigraphic relations	Unconformable over the Espina
	Formation; underlain by the Alfonso XIII
	Formation
Distribution	Isugod Valley, Quezon; Iwahig Valley,
	Rizal; foothills of the Range from Aboabo
	to Aramawayan
Age	Middle Miocene
Thickness	900 m (maximum)
Named by	Martin (1972)

The Isugod Formation was named by Martin (1972) in reference to the rocks that underlie the coastal plains of Isugod Valley in Quezon. The formation is also widely exposed in Iwahig Valley and the foothills west of the central range from Aboabo to Aramawayan in the southern part of central Palawan. The Isugod consists of a rhythmic sequence of well bedded shale and quartzofeldspathic sandstone with limestone at the base. The limestone is coarse-grained, gray to cream to light brown, massive, hard and coralline. The sandstone is fine- to coarse-grained and medium to thickly bedded. The shale is thinly bedded and silty with parallel

and cross laminations. At the type locality in Isugod, clast-supported conglomerates are occasionally observed alternating with the sandstoneshale interbeds. The conglomerate consists of rounded to subrounded, pebble to cobble sized clasts of volcanic fragments, shale, sandstone, coal lenses, coral fragments and amber set in a sandy matrix.

The formation rests unconformably over the Espina Formation along the slope of the central range and unconformably underlies the Alfonso XIII Formation. Maximum thickness is estimated to be around 900 meters. Middle Miocene planktic foraminifera were identified in the Isugod Formation by Maac and Agadier (1988).

This formation is partly correlative to the **Tumarbong** and **Quezon** Formations of Reyes (1971). Similarly, this formation is partly coeval to the Catagupan Member of the Balabac Formation.

Alfonso XIII Formation

Lithology	Limestone with occasional calcareous shale and sandstone interbeds
Stratigraphic relations Distribution	Unconformable over the Isugod Formation Peaked Island to Moorson Point, Quezon (formerly Alfonso XIII municipality) on the west coast: Separation Point, Aboabo -
	Quezon road; portions of Rizal
Age	Late Miocene
Thickness	About 1000 m
Named by	De Villa (1941)
Synonymy	Quezon Marl and Limestone (Reyes,
	1971); Tabon Formation (Visayan
	Exploration Co. Inc., in Martin, 1972);
	Sayab Formation (Cabrera, 1985);
	Matinloc Formation; Sigumay Member of
	the Balabac Formation
Correlation	Sigumay Member of the Balabac
	Formation

The Alfonso XIII Formation was named by De Villa (1941) for the sequence of limestone, sandstone, claystone, marl and impure calcareous claystone between Moorson Point and Peaked Island on the west coast of southern Palawan. Other exposures may be found along the Aboabo-Quezon (formerly Alfonso XIII) road. The formation is well exposed at Albion Head west of Quezon town. The formation was designated as Quezon Marl and Limestone by Reyes (1971) who described it as a sequence of thinly to thickly bedded limestone with lenses of calcareous shale and sandstone. This is also equivalent to the Tabon Formation named by the Visayan Exploration Co. Inc. geologists (in Martin, 1972). As described by Martin (1972), the formation consists of massive to thick-bedded, cream to light gray limestone representing a facies change from a bioherm to a biostrome. The associated clastic rocks grade from light gray mudstone to almost chalky white marl. The Alfonso XIII unconformably overlies the Isugod at Iwahig as well as Pandian Formation south of

Quezon and the Panas in Tagulango and Wangle. A transgressive contact was observed with the overlying Iwahig Formation.

The Alfonso XIII Formation was dated Pliocene by De Villa (1941) but Hashimoto and Balce (1977) give a Late Miocene age to the basal part on the basis of *Marginopora vertebralis* Quoy and Gaimard and *Alveolinella quoii* d'Orbigny fauna overlying a *Multilepedina luxurians* (Tobler) bearing limestone. Equivalent to the Alfonso XIII Formation is the Early Miocene to early Middle Miocene **Tabon Formation.** The Tabon was later dated Late Miocene age by Martin (1972). Wolfart and others (1986) report Late Miocene nannofossils and foraminifera from the Alfonso XIII Formation. The Alfonso XIII has a thickness of about 1,000 m.

The Alfonso XIII Formation is coeval to the **Matinloc Formation** found in wells offshore of northwest Palawan. This also equates with the **Sigumay Member** of the Balabac Formation. The Alfonso XIII Formation is also equivalent to the **Sayab Formation** of Cabrera (1985) that consist of alternations of Late Miocene sandstone and shale beds exposed in southern Rio Tuba. The sandstone is light gray to reddish brown, fairly cemented and fine- to medium-grained. The shale is silty, reddish brown to mottled and occasionally laminated.

Iwahig Formation

Members	Pusok Conglomerate; Panoyan Limestone
Distribution	Central / southern Palawan
Age	Pliocene
Named by	Casasola (1956)
Synonymy	Clarendon Formation (Basco, 1964)

The Iwahig Formation was named by Casasola (1956) for the Pliocene rocks exposed in the western and eastern parts of southern Palawan and at the eastern part of central Palawan. This formation consists of limestone and conglomerate with siltstone and sandstone interbeds. At the type section in Bataraza, the formation unconformably overlies the Panas and the Pandian formations. It also transgressively overlies the pre-Tertiary rocks. It has two members, the Pusok Conglomerate and the Panoyan Limestone.

The Iwahig Formation is equivalent to the **Clarendon Formation** (Basco, 1964) at Balabac Island. The Clarendon has a clastic and limestone facies. The clastic facies is exposed at Cape Melville and extends to the south. It consists of shale and sandstone with stringers of bitumen. The sandstone is medium to thick bedded, fine- to coarse-grained, micaceous and feldspathic. The limestone facies occurs in Barong-Barong Point and Inanacule Point at Clarendon Bay. The limestone is coralline, reefal and biostromal and conglomeratic in places. It has interbeds of marl and calcareous shale. The thickness ranges from 60 to 90 m.

Pusok Conglomerate Member

Lithology	Conglomerate with interbeds of sandstone
Distribution	Busek and Bainuman hills in Bataraza:
Distribution	portions of Puerto Princesa City; Inagauan
	and Iwahig penal colonies
Age	Pliocene
Thickness	100 m (approx)
Named by	Casasola (1956)

The Pusok Conglomerate crops out at Pusok and Painoman hills at the eastern side of southern Palawan. It also underlies the gently rolling hills north of Puerto Princesa and comprises the terraces within the Iwahig and Inagauan penal colonies in central Palawan (de los Santos, 1959). In central Palawan, the conglomerate consists of pebbles, cobbles and even boulders of ultramafic rocks set in a clayey sandstone matrix. Other clasts include gabbro, schist and occasional megafossils. In the south, the pebbles are composed of chert, limestone and indurated sediments set in a sandy and limy groundmass. The sandstone interbeds are light greenish gray and fine- to medium-grained and the siltstone is light gray. At Tagbarungis and Inagauan, it is massive, poorly bedded, poorly consolidated and poorly sorted, interbedded with thin beds and lenses of sandstone and siltstone. A Pliocene age is assigned to this unit. The thickness is about 100 m.

The Pusok is probably coeval to the clastic facies of the **Clarendon Formation** in Balabac Island.

Panoyan Limestone Member

Lithology	Massive limestone
Stratigraphic relations	Unconformable over the Panas Formation
Distribution	Panoyan Hill, Bataraza; Iwahig River;
	Dalingding Hill; Mt. Gangob
Age	Pliocene to probable Pleistocene
Named by	Casasola (1956)
Synonymy	limestone facies of the Clarendon
	Formation (Basco, 1964) in Balabac Island

The Panoyan Limestone underlies Panoyan Hill and Mt. Gangob and is exposed along the banks of Iwahig River in the eastern part of southern Palawan. It also underlies Dalingding Hill southeast of Canipaan in the western side. The limestone is cream to buff with shades of pink, massive, coralline and usually cliff-forming. The Panoyan is assigned a Pliocene age although it may extend to Pleistocene.

The limestone facies of the **Clarendon Formation** in Balabac Island may be considered as the southern extension of the Panoyan. It is probably also equivalent to other young limestone formations in the Sulu Sea and offshore west Palawan region.

Tagburos Opalite

Lithology	Opalite
Distribution	Tagburos and Bacungan area, Puerto
	Princesa City
Age	Probably Pleistocene
Named by	De los Santos (1959)

The Tagburos Opalite refers to the irregular masses of yellowish to mocha brown siliceous rocks exposed as separate hills in Tagburos, and Bacungan areas, Puerto Princesa City. Such occurrence is believed to have been deposited by hot springs during Pleistocene time. The deposits consist of massive dark gray chalcedony and variegated opaline silica. The chalcedony usually crops out along the peak of ridges while the opalite is commonly found along slopes around the chalcedony peaks.

GEOLOGY OF THE PHILIPPINES



VISAYAS

PANAY ISLAND (SG 11, 13, 14, 16)

Panay Island can be divided into four major tectonostratigraphic terranes. From west to east these are: Buruanga Peninsula, Western Panay Antique Range, Central Panay Iloilo Basin and Eastern Panay Magmatic Arc. Buruanga Peninsula is considered as part of the North Palawan Microblock, along with Mindoro and Romblon Islands. It is located at the northwestern tip of Panay Island and is demarcated by the Tablas Lineament from the Western Panay Antique Range, which is characterized by an ophiolitic-metamorphic terrane.

Buruanga Peninsula

Buruanga Metamorphic Complex

Lithology	Greenschist, quartzite, marble, chert
Stratigraphic relations	Constitutes the basement of Buruanga
	Peninsula
Distribution	Southwest-central section of the peninsula
Age	Late Paleozoic – Early (?) Mesozoic
Named by	Francisco (1956)

The Buruanga Metamorphic Complex (Francisco, 1956) is the oldest formation in Panay Island. This is characterized by thick and highly folded sequence of greenschists, cherts, quartzites, marbles and metavolcanics. Generally, the rocks show evidence of low grade regional metamorphism except those subjected to thermal metamorphism near the contact with quartz diorite intrusive bodies.

The schists are exposed largely in the southwest-central section of the peninsula. The typical schist consists essentially of chlorite, biotite and quartz with minor amounts of muscovite, sericite, epidote, magnetite and feldspar. The quartzites occur as patches or lenses along the road to Libertad, Lindero and in the northern part of the peninsula. The cherts underlie the quartzites south of the road between Union and Lindero and are interbedded with crystalline limestone between Pooc and Habana along the northeastern part of the peninsula. They are essentially composed of cryptocrystalline silica interspersed with limonite and either chlorite or clay, as well as epidote, giving off different colors in shades of buff, red, green and black. Banded marbles form the most rugged and

					PANAT ISLAND		
PERIOD	EPOCH	STAG	EMa	BURUANGA PENINSULA	ANTIQUE RANGE	CENTRAL PANAY- ILOILO BASIN	EASTERN PANAY
	HOLOCENE						
	PLEISTOCENE	4 3 2	0.0117 0.126 0.78 1.81	Libertad Formation	Ando Formation	Cabatuan Formation	Cabatuan Formation Odiongan Andesite
	PLIOCENE	2	2.59		Aportonnaton	Ulian Formation	Ulian Formation
ш		1	3.60 5.33			Iday Formation	
DGEN		3	7.25			Tarao Formation	Dingle Formation
NEG	MIOCENE	2	13.65	Fragante Formation	Lagdo Formation Paniciuan Melange Pacol	Singit Formation	Agudo Basalt
		1-	20.43	Patria Quartz Diorite	Mayos Formation Diorite		Passi Formation
		2	1	~~~~~~	Baloy Formation	Panpanon Formation	Pilar Limestone
	OLIGOCENE	1	28.4				Sara Diorite
ш		4	37.2		Lumbuyan Formation		
GEN	EOCENE	3	40.4				
PALEOC		2	48.6		Gabariohan Limestone		
		1	55.8				
	PALEOCENE	2	58.7				Guimaras Diorite
		1	61.7				h
Story Star	К2		99.6				Sibala Formation
Cherry Cherry	К1				Antique Ophiolite		
JURASSIC			145.5	Buruanga Metamorphic Complex			

 Table 2.16 Stratigraphic column for Panay Island

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

faulted part of the peninsula, overlying, and in places intercalated with, other metamorphic units.

The Buruanga Metamorphic Complex was considered as Late Paleozoic to Early (?) Mesozoic in age (Francisco, 1956; BMG 1981; MMAJ-JICA 1987; David 1988). The metamorphic rocks are similar to those described in the islands of Palawan, Mindoro, Tablas and Romblon (Faure and others, 1989) that are associated with Triassic cherts and Permian carbonates (Fontaine, 1979). The unmetamorphosed rocks associated with the metamorphic units could be part of the Upper Jurassic olistostrome reported in Northern Palawan and Mindoro (Faure and Ishida 1990).

Patria Quartz Diorite

Lithology	Quartz diorite, granodiorite, tonalite,
	gabbro
Stratigraphic relations	Intrudes the Buruanga Metamorphic
	Complex
Distribution	Southeastern coast of the peninsula; Sitio
	Duyong to Barrio San Roque
Age	Early Miocene
Named by	Francisco (1956)

The Patria Quartz Diorite (Francisco, 1956), a circular plug-like mass, underlies relatively low, but deeply dissected, hills fringing the southeastern coast of the peninsula and extends 6 km from Sitio Duyong to Barrio San

Roque. It is in contact with the marble along the northern and northwestern peripheries and with schists on the southwestern rim (Cruz and Lingat, 1966). It intruded the Buruanga Metamorphic Complex forming an intrusive contact metamorphic aureole and skarn deposits along its contact with the marble.

The rock is fine- to medium- grained, hypidiomorphic-granular and in some cases poikilitic. It consists essentially of plagioclase, quartz and biotite with accessory apatite. The quartz diorite also has granodiorite, tonalite and gabbro facies.

This diorite was previously assigned a Mesozoic to Paleogene age and believed to be equivalent to the Pakol Diorite of Jagolino and Jandumon (1973). However, radiometric dating of this diorite yielded ages of 20.8 ± 1 Ma on whole rock sample and 19.5 ± 1 Ma (Early Miocene) on biotite mineral separates (Rangin and others, 1991). Isotropic gabbros exposed to the east of Pandan that had been dated 20.8 ± 1 Ma could belong to this intrusive unit.

Fragante Formation

Lithology	Limestone, basalt, pyroclastic rocks,
	conglomerate, sandstone, shale
Stratigraphic relations	Unconformable over the Buruanga
	Metamorphic Complex and the Patria
	Quartz Diorite
Distribution	Sta. Cruz area at the neck of the
	peninsula; west of Libertad to Malay
Age	Middle Miocene
Named by	Cruz and Lingat (1966)

The Fragante Formation (Cruz and Lingat, 1966) was described by Diegor (1980) as pseudo-reefal limestone intercalated with alkaline basalt flows and pyroclastic rocks associated with conglomerates and sandstones on the western part of Panay Island. The formation unconformably overlies the basement and the Patria Quartz Diorite. The limestone contains large foraminifers such as *Miogypsina*, dated Burdigalian-Langhian (Middle Miocene).

Libertad Formation

Lithology	Conglomerate, mudstone, siltstone, shale,
Our firmed in the firme	reefal limestone
Stratigraphic relations	Unconformable over Fragante Formation and older rocks
Distribution	Sta. Cruz area; west of Libertad to Malay
Age	Pliocene - Pleistocene
Previous name	Sta. Cruz Sediments (Cruz and Lingat,
	1966)
Renamed by	MGB (this volume)

The Libertad Formation was originally designated by Cruz and Lingat (1966) as **Sta. Cruz Sediments** for the rocks that crop out west of Sta.

Cruz along the Pandan-Nabas road at the neck of the peninsula. Exposures are also found at the western side, from west of Libertad to Malay. The formation consists of conglomerate, mudstone, siltstone, shale and Pliocene-Pleistocene reefal limestone. The conglomerate is bedded, poorly sorted, poorly to fairly consolidated with sub-angular to sub-rounded granule- to cobble- size clasts of metamorphic rocks. The sequence unconformably overlies the Fragante Formation and older rocks in the peninsula.

WESTERN PANAY – ANTIQUE RANGE (SG 13)

Antique Ophiolite

Lithology	Serpentinite, harzburgite, dunite, gabbro, sheeted dikes, basalt
Stratigraphic relations	constitutes the basement of the Antique
Diatrikutian	Range Denskensen Dutuen Densei Lembekere
Distribution	Bongbongan, Butuan Range; Lombonero
	Ridge; Libacao; Sibalom River; Aklan
	River
Age	Early Cretaceous (Barremian-Aptian)
Named by	Momongan (1979)

The Antique Ophiolite (Momongan, 1979) corresponds in part to the **Bongbongan Series** of Santos-Yñigo (1949), so named for the exposures at Bongbongan, along Butuan Range, southern Antique. The ophiolite is located mainly in the central part of Antique province and underlies largely the Lombohero Ridge (UNDP 1986). To the north the ophiolite was observed in Libacao above Malinao and Timbalan rivers where they form rugged sharp ridges and peaks along a generally north to northeasterly trend (David 1988). The Antique Ophiolite is characterized by ultramafic rocks such as serpentinite, serpentinized harzburgite and minor dunite, gabbro, sheeted dikes, basalt and associated pelagic sedimentary rocks (Corpuz 1979c, Florendo 1981, Diegor 1980a, UNDP 1986, MMAJ-JICA 1987, David 1988, Rangin and others, 1991). The contacts of the various units of the ophiolite are defined by thrust faults.

The ultramafic rocks of the ophiolite consist mostly of serpentinite and serpentinized harzburgite. It lies within a northeast trending belt with a width of around 7 km in southwestern Panay and occurs as sporadic outcrops to the north of the island.

The gabbros of the ophiolite exhibit different facies, from cumulate gabbro to transitional gabbro and high level gabbro and plagiogranite. In southwestern Panay, these are exposed along Sibalom River, in the vicinity of General Fullon towards Bauang and along Maria Mercedes and the upper portion of the Aklan River to the north of Panay. The gabbro in the upper portion of the Aklan River consists of interlocking granular plates of plagioclase and pyroxene with minor quartz and hornblende.

Diabase dikes and gabbro intrusions in southwestern Panay (UNDP, 1986) to the south of Tabay, San Remigio is considered as the transition

zone between the high level gabbro and the sheeted dike complex. The diabase dikes, with thickness ranging from 20 cm to 1 m, show parallel to sub-parallel orientation with joints developing along the margins. The gabbros are medium grained to pegmatitic with occasional fine-grained facies and are occasionally intruded by diabase dikes.

The sheeted dike complex is exposed along the gorge in Bongbongan creek as a 150-m section of parallel to subparallel sheeted dikes, 15-30 cm thick, showing chilled margins forming dark and fine-grained selvages 0.5 - 1.0 cm thick. The sheeted dike is uralitized porphyritic diabase.

The pillow basalt and associated hyaloclastics are exposed along Sibalom and Igbayo rivers. The sequence along Igbayo River consists of intercalations of pillow lavas, broken pillows, plagiophyric and aphyric pillow breccias and minor chloritized clastic rocks. Some of the pillow basalts are amygdaloidal with calcite or zeolite amygdules. The apparent thickness of the pillow lavas is around 5,000 m along Sibalom and Igbayo rivers.

The pelagic sedimentary rocks consist of red cherts, siliceous red mudstones and reddish calcareous siltstones. Radiolaria in the chert was dated Barremian-Aptian (Rangin and others, 1991) and corresponds partly to the **Igbayo Pelagic Complex** of UNDP (1986) and the **Bongbongan Series** of Santos-Yñigo (1949).

Cabariohan Limestone

Lithology	Limestone, basaltic calcarenite
Stratigraphic relations	Unconformable over the Antique Ophiolite
Distribution	Cabariohan, Antique
Age	Early- Middle Eocene
Named by	Santos-Yñigo (1949)

The Cabariohan Limestone was originally designated by Santos-Yñigo (1949) for the limestone underlying a northeast trending ridge that passes near the village of Cabariohan in Antique. The same limestone was identified by UNDP (1986) on the northeast and northwest flank of the same ridge, forming a small forested hill beside the Patnanongon stream and well exposed in the river gorge.

The basal part of the sequence is coarse calcarenite with basalt fragments and abundant foraminifera where basalt fragments diminish gradually upwards. Poorly bedded white to cream limestone succeeds the basal part of the formation. The limestone is believed to be unconformable over the Antique Ophiolite (UNDP, 1986; Rangin and others, 1991).

Santos-Yñigo (1949) considered this limestone to be Middle Miocene in age. This was dated as Late Eocene by UNDP (1986) and end of Early Eocene by Rangin and others (1991) based on the presence of *Alveolina* with *A. globalveolina sp. (A.(G.).cf telementensis* and *A. lepidula, A. glovalveolina sp. aff. A (G.) levis.* Foraminifera from calcarenites were dated Early to Middle Eocene by UNDP (1986). The calcarenites were considered part of the Igbayo Pelagic Complex, but these could actually be part of the Cabariohan Limestone.

Lumbuyan Formation

Lithology	Mudstone, siltstone, sandstone
Stratigraphic relations	Underlies the Baloy Formation
Distribution	Lumbuyan village
Age	Late Eocene (?)
Named by	UNDP (1986)

The Lumbuyan Formation is named from the succession along Lumbuyan River above its confluence with Dalanas River (UNDP 1986). Along its type locality near Lumbuyan village, the formation is characterized by red to purple mudstones and siltstones with abundant calcite veinlets and thin beds or laminae of greenish to gray tuffaceous siltstones, which define the bedding. The upper part is defined by turbiditic wacke beds interbedded with red to brown siltstone and mudstone. This continues upwards with thicker and coarse-grained dark volcanic turbiditic wackes, which are mostly massive in the lower part and laminated at the top.

The Lumbuyan Formation could be equivalent to the **Tibiao Metasediments** of Corpuz and Florendo (1980) and Florendo (1981). Most of the succession underlies the basalts of the Baloy Formation and is believed to be Late Eocene in age (UNDP 1986).

Baloy Formation

Lithology	Basalt, basaltic breccia, andesite, conglomerate, sandstone, siltstone, mudstone
Stratigraphic relations	Conformable over the Lumbuyan Formation
Distribution	Mt. Baloy, Cangaranan River
Age	Late Oligocene – Early Miocene
Previous name Renamed by	Mt. Baloy Formation (UNDP, 1986) MGB (this volume)

The Baloy Formation was originally named Mt. Baloy Formation by UNDP (1986) with reference to the prominent ridge, Mt. Baloy, underlain by the formation. The Baloy consists dominantly of volcanic rocks with associated graywacke, conglomerates, siltstones and reddish mudstones. The type locality along Cangaranan River exposes basalt breccias overlain by around 1,000 m thick of amygdaloidal, porphyritic pyroxene basalt breccias with minor interbedded aphyric non-amygdaloidal greenish basalt cut by intersecting subparallel chloritic veins or joints. This is overlain by conglomerates and minor turbidites with intercalations of pillow basalts. The clasts of the conglomerates are dominantly volcanic and reach up to boulder sizes.

The basalts of Baloy Formation conformably overlie the Lumbuyan Formation. The lavas intercalated within the volcano-sedimentary sequence were dated 22.8 \pm 1.1 Ma on the basis of radiometric K-Ar determination of whole rock sample (Rangin and others, 1991). The wackes were dated Late Oligocene-Early Miocene by UNDP (1986).

Mayos Formation

Lithology	Calcirudite, calcarenite, calcareous wacke, mudstone, shale, basalt, andesite, tuff,
	limestone, congiomerate
Distribution	Northwestern Antique
Age	late Early Miocene – early Middle Miocene
Named by	UNDP (1986)

The Mayos Formation was named by UNDP (1986) for the exposures along Mayos Creek, a tributary of the Dalanas River. It is largely confined to the northwestern part of Antique province occupying north to northwest trending, low lying areas commonly coinciding with major river courses. The formation consists of interbedded sequence of calcirudites, calcarenites and calcareous wackes, mudstone, green to gray limy shale, massive and brecciated basaltic lava flows. Calcirudites contain basalt and coral-algal limestone clasts and are sometimes interbedded with massive, columnar jointed basalt. Calcarenites and calcareous sandstones show a turbiditic facies with sharp bases, internal lamination and graded bedding.

The Mayos Formation is coeval with the **Maliao Wackes** and **Igsawa Pyroclastics** of UNDP (1986). Northwards the formation is characterized by parareefal limestone intercalated with pillow lavas. The formation was dated late Early Miocene to early Middle Miocene (UNDP 1986). The **Tamayoc Andesite** of Santos-Yñigo (1949), renamed **Tamayoc Volcanics** by Florendo (1981), is equivalent to the Igsawa Pyroclastics of UNDP (1986). Limestone interbeds in the pyroclastic sequence yielded Early Miocene to Middle Miocene foraminifera.

Pakol Diorite

Lithology	Diorite, quartz diorite, granodiorite
Distribution	Pakol-Agutaya; Balilao-Timbahan;
	Madalag, Aklan Province; south-southeast
	of Libacao
Age	Middle Miocene (?)
Named by	Jagolino and Jandumon (1973)

The Pakol Diorite of Jagolino and Jandumon (1973) is bounded by the Pakol Agutaya Fault on the east and the Balilao-Timbahan Fault on the west. These were also observed west of Madalag, Aklan Province and south-southeast of Libacao. The diorite includes biotite hornblende diorite, biotite hornblende quartz diorite, and biotite hornblende granodiorite. It is medium to coarse-grained, equigranular and is principally made up of plagioclase, hornblende, biotite and quartz. East of the serpentinite bodies in Aklan, from Kapatagan to Nabitas, is a series of aligned hypabyssal diorite intrusives, probably part of the Pakol Diorite. The intrusives are medium grained and grades to aplite.

The age of the diorite is presumed pre-Tertiary by Jagolino and Jandumon (1973) and assigned a probable Mesozoic to Paleogene age by BMG (1981). MMAJ-JICA (1987), however, considers the Pakol as

equivalent to the Patria Quartz Diorite and assigned a post Early Miocene age for these intrusives.

Paniciuan Mélange

Tectonic fault breccia in a matrix of silty
mudstone
Unconformable over the Antique Ophiolite
Sibalom Valley
early Middle Miocene
Paniciuan Formation (Santos-Yñigo, 1949)
Florendo (1981)

The Paniciuan Mélange (Florendo, 1981) corresponds to the Paniciuan Formation of Santos-Yñigo (1956), described as a heterogeneous mass of unconsolidated fault breccia exposed between Sibalom and Tipuluan rivers in southwestern Panay, particularly between Sibalom Valley and the highlands bounding the Iloilo Basin to the east. The matrix is characterized by grayish green to bluish silty mudstone with scaly features. Nannofossils in the matrix were dated early Middle Miocene (Zone NN 5). The blocks within the mélange consist of sedimentary rocks such as sandstones, graywackes, conglomerates with granitic clasts, and limestones dated as Late Oligocene-Early Miocene. The Mélange also contains blocks derived from the ophiolite sequence and metamorphic rocks, including metavolcanics, categorized as greenschists and blueschists.

Lagdo Formation

Andesitic lavas and breccias, tuff,
graywacke, mudstone, conglomerate Unconformable over the Paniciuan
Mélange and Antique Ophiolite
Lagdo Creek
late Middle Miocene
Santos-Yñigo (1949)

The Lagdo Formation was named by Santos-Yñigo (1956) for the succession of volcanic and sedimentary rocks along Lagdo Creek. Andesitic breccias and lavas with tuffaceous layers largely constitute the formation. These are often intercalated with coarse graywackes, mudstones and conglomerates with clasts of volcanic rocks, limestone, gabbro and serpentinite.

The Lagdo Formation unconformably overlies the Paniciuan Mélange and the Antique Ophiolite. Fine grained layers within the formation yielded end of Middle Miocene nannofossils (Zone NN 9) supported by several K-Ar radiometric dating on whole rock samples with an age range between 12.4 Ma and 13.8 Ma (Rangin and others, 1991).

The **Makato Formation**, named by Abadilla (1931) for the Interbedded sandstones and shales near Makato, is equivalent to the Lagdo Formation. The Makato is also exposed at Agpa Pt., north of Tangalen, Aklan. Diegor

(1980) considers as part of this formation the conglomerate at Campo Verde and the Maria Cristina Limestone of Jagolino and Jandumon (1973).

Apdo Formation

Lithology	Marl, calcareous clastic rocks
Stratigraphic relations	Unconformable over Lagdo Formation
Distribution	Southern part of southwest Panay
Age	Late Pliocene – Early Pleistocene
Named by	Momongan (1979)

The Apdo Formation occupies the southern part of southwest Panay. It is characterized by gently dipping successions of calcareous sedimentary rocks. The dominant lithology is buff-weathered marl that locally contains thin shell fragments and foraminifera with interbeds of calcilutites and calcisilities. This was dated Late Pliocene-Early Pleistocene and unconformably overlies the Lagdo Formation and older rocks. It is equivalent to the Libertad Formation in Buruanga Peninsula.

Central Panay – Iloilo Basin

Panpanan Formation

Lithology	Basalt, with intercalated sandstone,
	siltstone, mudstone and conglomerate
Stratigraphic relations	Unconformably overlain by Singit
	Formation
Distribution	Dungaroy and Jalaur rivers; headwaters of
	Panay, Aklan, Aliburan and Ulian rivers
Age	Late Oligocene – early Early Miocene
Named by	UNDP (1986) as Panpanan Basalt
Renamed by	MGB (this volume)
•	

The Panpanan Formation was previously designated by UNDP (1986) as Panpanan Basalt in reference to the rocks that are exposed as irregular longitudinal belts along the western flank of the Iloilo Basin. The formation is particularly distributed along the Dungaroy and Jalaur rivers and in the headwaters of Panay, Aklan, Aliburan and Ulian rivers. The Panpanan consists predominantly of basalt with intercalated sandstone, siltstone, mudstone and conglomerate. The basalt is amygdaloidal with conspicuous pyroxene phenocrysts in a black groundmass with amygdules of zeolite, chlorite and quartz. The sandstone is black and basaltic; the siltstone is green and tuffaceous, rarely red and laminated. The conglomerate is made up of basalt clasts. In some places, andesite or basaltic andesite breccia are present. Calcirudites or thin calcarenites were occasionally observed.

The Panpanan Formation is equivalent partly to the Sewaragan Member of the Singit Formation (BMG, 1981). Radiometric dating of basalt and andesite samples indicates an age of Late Oligocene to early Early Miocene for the Panpanan Formation (Bellon and Rangin, 1991).

Singit Formation

Members	Sewaragan, Tanian Limestone, Igtalongon
	Shale, Barasan Sandstone
Lithology	Sandstone, shale, conglomerate,
	calcirudite, calcarenite, calcisiltite
Stratigraphic relations	Unconformable over the Panpanan
	Formation
Distribution	Southwest margin of the Iloilo Basin
Age	Early – Middle Miocene
Thickness	5,750 m – 6,150 m
Named by	Corby and others (1951)

Corby and others (1951) gave the name Singit Formation to the massive sandstone with conglomerate layers that crop out as a continuous belt along the southwest margin of the Iloilo Basin. Santos (1968) divided the formation into four members: Sewaragan Complex, Tanian Limestone, Igtalongon Shale and Barasan Sandstone. The formation unconformably overlies the Panpanan Formation and was dated late Early Miocene-Middle Miocene. The oldest member, named Sewaragan Member (BMG, 1981), is mostly drained by south to southeast flowing streams like the Sewaragan, San Joaquin, Harao, Tomagbok, Bacauan and Oysengan rivers.

• Sewaragan Member

UNDP (1986) considered the Sewaragan Member as a formation and defined it as a succession of thick wackes, shales and conglomerate with minor limestone and volcanic rocks. The most predominant rock types are the volcanic wackes and interbedded mudstone and siltstone. Almost as abundant is the conglomerate whose clasts consist of sandstone, mudstone, pyroxene basalt, pyroxene hornblende andesite and limestone. With the increase of limestone clasts, the conglomerate becomes calcirudite with cobbles and blocks of corals, calcarenite and minor volcanic clasts in a calcareous matrix. Calcarenites and calcisiltites are interbedded with some calcirudite. The calcareous rocks are devoid of bedding or poorly bedded and are mostly bioclastic with numerous coral and algal debris. The volcanic rocks are dark gray to black lavas and breccias. The groundmass is aphyric to plagiophyric with pyroxene or hornblende phenocrysts. The estimated thickness is at least 3,000 m (UNDP, 1986). The presence in the limestone of some foraminiferal species such as Porticulasphaera sp. and Sphaeroidinellopsis disjuncta (Finlay) indicates an age of late Early Miocene to Middle Miocene for the Sewaragan Member.

• Tanian Limestone Member

The *Tanian Limestone Member* of Santos (1968) was originally named **Mountain Limestone** by Corby and others (1951). It crops out in the vicinity of barrios Passes and Igcabugao at the upper reaches of Tanian, Tigmanaba, Igbaras, and Oysoy rivers in Miagao and northwest of Tabuungan, all in Iloilo. It consists of thick bedded, fragmental to detrital limestone with thin and friable layers of sandstone. On the basis of large foraminiferal genera of *Lepidocyclina* and *Miogypsina*, the Tanian Member

was dated Middle Miocene. It has a thickness of 150 m.

• Igtalongon Shale

Santos (1968) gave the name *Igtalongon Shale* to the predominantly fine grained sedimentary rocks at Barrio Igtalongon, Igbaras along Tanian River. According to UNDP (1986), it occupies a kilometer wide northeast trending valley between the Sewaragan to the west and the ridges underlain by the Barasan Sandstone to the east. The member consists largely of turbidites, wackes, conglomerates and shales. The thickness is estimated to be 600 - 1,000 m and was dated Middle Miocene based on the foraminiferal index species *Globorotalia fohsi fohsi* Cushman and Ellisor.

• Barasan Sandstone

The Barasan Sandstone (Santos, 1968) is the uppermost member of the Singit Formation. It was named after Barrio Barasan in Igbaras, Iloilo. It is best expressed topographically in the western flank of the Panay Central Basin as hogbacks and cuestas at 300 - 400 m elevation. The member is composed of thick-bedded, coarse-grained conglomeratic sandstone with thin intercalations of shale. Santos (1968) dated the member as Late Miocene but later workers found fossils, which point to a late Middle Miocene age. The measured thickness is 2,034 m along Ulian River and 1,678 m along Tigum River (Santos, 1968). It was deposited probably within the outer neritic zone.

Tarao Formation

Sandstone, mudstone, minor conglomerate, marl. limestone, calcisiltite
Conformably overlies the Singit Formation
Har-ao River; Tubungan; Guimbal; Tigum
River
Late Miocene
3,380 m maximum
Corby and others (1951)

Corby and others (1951) designated the clastic rocks cropping out along the Har-ao River as Tarao Formation. The formation consists largely of sandstones with interbeds of mudstones. Sandstones are more dominant in the lower part of the formation. Occasional beds of conglomerate and limestone are also present in the lower portion. Santos (1968) divided the formation into lower Tubungan Siltstone Member and upper Guimbal Mudstone Member. The formation was dated Late Miocene based on the presence of *Globoquadrina altispira globosa* Bolli.

• Tubungan Siltstone Member

The *Tubungan Siltstone Member* is best exposed along Har-ao River in Tubungan, Iloilo. It is made up of alternating thin to medium bedded siltstones, claystones and sandstones. Individual beds vary between 0.2 to 6 cm and average 2 cm, although sandstone interbeds may range from 10 to 30 cm thick. In places, the Tubungan is slightly carbonaceous. Tuff intercalations were noted along Sibalom and Tarao rivers (JICA, 1982, cited in BED-WB, 1986b) Maximum measured thickness is 2,214 m along Tigum River, but thins out in the north to 548 m along Ulian River. The thickness along Har-ao River, the type locality, is 1,206 m (Santos, 1968).

• Guimbal Mudstone Member

The type locality of the *Guimbal Mudstone Member* extends from the junction of Har-ao and Tanian rivers going upstream to a point between barrios Napahay and Tagpuan (Santos, 1968). It consists mainly of thick bedded, gray-green, soft, highly calcareous foraminiferal mudstone with highly fossiliferous marl, calcisilitie and minor conglomerate. It attains a maximum thickness of 1,166 m along Har-ao River, while thinner sections of 407 m and 378 m were measured along Ulian and Tigum rivers, respectively (Santos, 1968).

Iday Formation

Lithology	Conglomerate, sandstone, claystone
Stratigraphic relations	Contact with underlying Tarao Formation
	is irregular and locally unconformable
Distribution	Iday Hill, Lambunao, Iloilo; Almodian,
	Iloilo; Tapaz, Capiz, Maasin, Iloilo
Age	Late Miocene – Early Pliocene
Thickness	242-681 m
Named by	Corby and others (1951)

The Iday Formation was named by Corby and others (1951) after Iday Hill, a conglomerate hogback that is cut by the Magapa River some 8 km southwest of Lambunao, Iloilo. It occurs as a narrow strip from Alimodian, Iloilo to Tapaz, Capiz. Its contact with the overlying Ulian Formation is gradational, while the contact with the underlying Tarao Formation is irregular and locally unconformable (BED, 1986b). The Iday is a sequence of conglomerate, sandstone and claystone (commonly carbonaceous) of various thicknesses and grading into each other. The conglomerate is matrix-supported, containing pebbles, cobbles and boulders of volcanic rocks, limestone and diorite. Boulder clasts may reach maximum dimensions of a meter or more. The conglomerate sometimes consists of masses of intermingled volcanic debris set in a tuffaceous matrix. The sandstone and claystone also contain scattered diorite and volcanic pebbles. It is calcareous and contains abundant fossils, both planktonic and benthonic foraminifera as well as mollusks. The fossils indicate a Pliocene age for the formation. In the vicinity of Maasin, the formation reaches a thickness of 450 m and west of Lambunao it is approximately 425 m. The thickness is 681 m along the Ulian River section and 242 m along the Tigum River section, as reported by Santos (1968).

Ulian Formation

Lithology	Claystone, mudstone, minor sandstone, siltstone, limestone
Stratigraphic relations	Conformable over the Dingle and Iday formations
Distribution	Lambunao and Cabatuan region; Panay Central Plain, from Maasin, Iloilo to Dumalag, Capiz
Age	Late Pliocene
Thickness	123 m – 536 m
Named by	Corby and others (1951)

The Ulian Formation was named by Corby and others (1951) for the sedimentary sequence along Ulian River. It covers the western and northeastern margins of the Panay Central Plain forming low hills and depressions from Maasin, Iloilo to Dumalag, Capiz. It consists for the most part of massive, greenish gray, highly calcareous and fossiliferous claystone or mudstone with irregular sandy or silty portions. At the western margin, volcanic conglomerates characterize the base of the Ulian as it grades into the Iday Formation. In the northeastern part, calcareous mudstones grade downward to impure limestone with interbeds of silty mudstone. Abundant and well preserved foraminifera and molluscan fossils point to a Late Pliocene age for the Ulian. Santos (1968) reports a minimum thickness of 123 m along Ulian River and a maximum composite thickness of 536 m in the Maasin area

Cabatuan Formation

Lithology	Mudstone, sandstone, siltstone,
Distribution	Cabatuan and Sta. Barbara, Iloilo
Age	Pleistocene
Thickness	> 390 m
Named by	Corby and others (1951)

The Cabatuan Formation was designated by Corby and others (1951) for the nearly flat-lying rocks in the central part of the Iloilo Basin. These rocks are largely exposed between Cabatuan and Sta. Barbara, Iloilo along the Tigum River. They divided the formation into three members - Balic Clay (renamed here as Balic Mudstone Member), Maraget Sandstone and Sta. Barbara Silt. The formation was dated Plio-Pleistocene by Santos (1968) but BED (1986b) considers its age as Pleistocene.

Balic Mudstone Member

Since Corby and others (1951) did not designate a type locality for the lowermost *Balic Mudstone Member*, Santos (1968) selected Barrio Turing, Cabatuan along the northern bank of Tigum River as its type locality. The member is limited to the south-central part of the plain and is composed essentially of thick bedded, dark gray, soft and highly fossiliferous mudstone. At the type locality, the mudstone is interbedded with fine-grained sandstone. In both the mudstone and sandstone, cobbles of volcanic rocks are scattered. Well-preserved molluscan fossils are present,

especially along bedding planes.

• Maraget Sandstone

The type locality of the middle member – *Maraget Sandstone* – is at Barrio Maraget in Cabatuan, Iloilo. It also crops out as far as Calinog in the north and San Miguel in the south. The lower beds are principally siltstone with occasional coarse-grained sandstone and mudstone layers. Cross-bedded, ferruginous, loosely consolidated, porous, light and permeable sandstone with white tuffaceous clay partings make up the uppermost beds. In some localities, lenses of conglomerate have been encountered. The sandstones are largely cross-bedded and contain megafossils, but no microfossils. The thickness varies but west of Calinog, it is about 150 m, while Santos (1968) measured a thickness of 392 m along the Dayanduyan-Maasin road section.

• Sta. Barbara Member

The uppermost *Sta. Barbara Member* consists principally of massive or poorly bedded coarse-grained and silty sandstone and siltstone with minor claystone. The type locality is Santa Barbara, Iloilo. It is also exposed south of Lucena, north of Sta. Barbara and west of Jalicoun, Cabatuan. The member contains abundant well-preserved large mollusks. Carbonized wood fragments have also been noted.

Eastern Panay Magmatic Arc

Sibala Formation

Lithology	Andesite, basalt, pyroclastic rocks, tuff,
o	Sanusione
Stratigraphic relations	Intruded by Sara Diorite
Distribution	Sibala Hills, eastern lloilo
Age	Cretaceous (?)
Named by	Capistrano and Magpantay (1958)

The Sibala Formation was named by Capistrano and Magpantay (1958) for the volcanic and sedimentary rocks that crop out at the Sibala Hills, eastern Iloilo. David (1988) added that the formation is a sequence of basaltic to andesitic lava flows with interbeds of coarse pyroclastic rocks and fine tuff and sandstone. The basalt is dark gray and amygdaloidal. The andesite shows plagioclase laths and octagonal augite crystals occuring as phenocrysts in a quartzofeldspathic groundmass. The **Mt. Pandan Volcanics** of Javelosa (1989) in Guimaras Island could be correlated to the Sibala Formation. The **Bayuso Volcanics** is also considered by BED (1986b) as equivalent to the Sibala. The age of the formation could be Cretaceous or younger.

Guimaras Diorite

Lithology	Diorite, quartz diorite
Stratigraphic relations	Intrudes the Sibala Formation
Distribution	Guimaras Island

Age	Paleocene
Named by	Culp and Madrid (1967)

The Guimaras Diorite was named by Culp and Madrid (1967) for the diorite stock measuring roughly 9 km by 4 km in Guimaras Island. It intruded sandstones that could be part of the Sibala Formation. The Guimaras is massive, leucocratic to mesocratic, fine- to medium- grained, consisting of feldspar, quartz, hornblende and pyroxene. Previously it was believed to be coeval with the Sara Diorite but radiometric K-Ar dating revealed an age of 59 ± 2 Ma, equivalent to Paleocene (Wolfe, 1981).

Sara Diorite

Lithology	Tonalite, quartz diorite, andesite
Stratigraphic relations	Intrudes the Sibala Formation
Distribution	Pilar, Capiz to Barotac Viejo, Iloilo
Age	Early Oligocene
Named by	Capistrano and Magpantay (1958)

The Sara Diorite was named by Capistrano and Magpantay (1958) in reference to a dioritic batholith in the Eastern Cordillera mountains of Panay. The Sara intrudes the Sibala Formation, resulting in propylitic alteration in the latter. It covers an area of about 600 km² from Pilar, Capiz in the north to Barotac Viejo, Iloilo in the south. According to David (1988), the intrusive body has varying phases identified as tonalite, quartz diorite and andesite. The tonalite has large crystals of plagioclase, quartz and hornblende in a hypidiomorphic granular groundmass. The quartz diorite is made up of interlocking coarse plagioclase, green hornblende and anhedral quartz. The andesitic phase is observed at the periphery of the intrusive mass. It is fine- to medium- grained, porphyritic with hornblende and plagioclase phenocrysts and few quartz set in a matrix of plagioclase, chlorite and epidote.

Radiometric K-Ar dating of the diorite as reported by MMAJ-JICA (1988) indicates an age of 25.1-28.0 Ma (Late Oligocene) but later radiometric K-Ar determination gave a value of 30.1 ± 1.5 Ma (MMAJ-JICA, 1993). Isotopic dating of Bellon and Rangin (1991) gave an age of 29.7 Ma or Early Oligocene for the Sara Diorite.

The Sara was also designated as Sara Granodiorite by MMAJ-JICA (1993). The **Yating Monzonite** (MMAJ-JICA, 1987) and **Pilar Monzonite** (MMAJ-JICA, 1988) could also be equivalent to the Sara Diorite.

Pilar Formation

Lithology	Calcarenite, calcirudite, biocalcarenite,
	calcisiltite
Stratigraphic relations	Not observed
Distribution	Pilar-Balasan Road, northeastern Panay
Age	Late Oligocene
Named by	Capistrano (1953)
Synonymy	Salvacion Limestone (Culp and Madrid,
	1967)

The carbonate knobs that crop out along the Pilar-Balasan road were designated by Capistrano (1953) as Pilar Limestone. According to David (1988) the carbonate rock is composed of recrystallized calcarenite and calcirudite grading into biocalcarenite and calcisilitie. The calcarenite is bluish gray and contains abundant foraminifera and coral heads. The calcirudite is massive with interspersed sub-angular pebbles of andesite and chloritized pyroxene crystals. Corpuz (in David, 1988) mentioned that the Pilar Limestone was dated Late Oligocene based on nannofossils.

The **Salvacion Limestone** of Culp and Madrid (1967) is equivalent to the Pilar Limestone. It is the oldest sedimentary unit in Guimaras Island. The limestone occurs in Barrio Salvacion and Panobolon Island south of Guimaras. It was dated Late Oligocene on the basis of orbitoidal foraminifera and has an estimated thickness of 700 m (Culp and Madrid, 1967). The **Panablan Limestone** of Javelosa (1989) in Guimaras Island is probably the same as the Salvacion Limestone.

Mention was made by BED (1986b) of an unnamed Oligocene clastic unit with a thickness of 200 m that was encountered in PODCO's Lucena-1 well. It consists of silty shale with thin limestone intercalations and could be equivalent to the Pilar Limestone.

Passi Formation

Members	Salugan Member, Assisig Member
Lithology	Conglomerate, sandstone, mudstone
Stratigraphic relations	Unconformably overlain by the Agudo
	Basalt and Dingle Formation
Distribution	Passi, Iloilo
Age	Early – Middle Miocene
Thickness	843 - 888 m
Named by	Corby and others (1951)

The Passi Formation was named by Corby and others (1951) to designate the dark-colored and very fine to coarse-grained clastic sedimentary rocks cropping out at Passi, Iloilo. It underlies a narrow north-south belt covering about 55 sq km in the northeast. The formation consists of a basal conglomerate reaching up to 10 m in thickness and sandstones and mudstones. Volcanic material largely comprises the clasts of the conglomerate. The clasts attain diameters of 0.5 m locally. On the other hand, claystones in the upper portion of the formation contain limestone nodules reaching 0.5-0.7 m in diameter. Along the Assisig River the Passi is 888 m thick, and along Lamuran and Ginayan rivers the aggregate thickness is 843 m. It was dated Early to Middle Miocene. Santos (1968) divided it into two members, namely, Salngan and Asisig. The agglomerates, breccias and basaltic to andesitic flows of the Bayuso Volcanics of BED (1986b) could be part of the lower member.

• Salngan Member

The Salngan Member was named after Barrio Salngan about 10 km north-northeast of Passi. It occurs at the edges of the volcanic rocks in the eastern border from Badbaran River east of Damarco, Capiz to Barrio

Cubay, San Enrique, Iloilo. The member is made up of massive homogenous mudstone and indurated sandstone. The boundary between the two members is marked by boulder to cobble conglomerate. The thickness is 373 m along Guinayan River.

• Assisig Member

The Assisig Member was named after Barrio Assisig about 3 km northeast of Passi, Iloilo. It consists of uniformly stratified thin bedded, light greenish brown, fine grained sandstone and shale. Conglomerate or pebbly sandstone occurs locally. It has a thickness of 543 m along the Assisig River.

Agudo Basalt

Basaltic breccia and flows Unconformable over the Passi Formation Agudo, northeastern Iloilo, Panobolon
Island and offshore to the south
Middle Miocene
50 m
Agudo Volcanics (Capistrano and
Magpantay, 1958)
MGB (this volume)

The name Agudo was named by Capistrano and Magpantay (1958) for the volcanic formation in eastern Iloilo Basin. The Agudo rests on the Passi Formation, with the latter showing contact metamorphic effects. The formation was named Bayuso Volcanics by Santos (1968), which was described as consisting principally of basaltic breccias and flows. The diameters of the breccia fragments vary in size from 1 cm to 30 cm. The Agudo extends down south to Panobolon Island and its offshore equivalent in Ilog-1 well in Panay Gulf (BED, 1986b). Radiometric K-Ar dating of the basalt in the Ilog-1 well indicated an age of 11.1 ± 0.8 Ma (late Middle Miocene), and the thickness of the formation as encountered in the well is 50 m.

The **Bayuso Volcanics** of Santos (1968) could be considered equivalent to the Agudo. The Bayuso is well exposed below Arigwis Bridge along the Passi-San Rafael Road and at the foot of Mt. Bayuso. The basalt is in contact with the Salngan Member of the Passi Formation, about 1 km west of Arigwis Bridge. Basalt breccias on the eastern rim of the Panay Central Plain contain boulder size chunks of altered and indurated sandstones and shales that could have been derived from the Passi Formation.

Dingle Formation

Lithology	Limestone, marl, sandstone, mudstone
Stratigraphic relations	Unconformable over the Passi Formation
Distribution	Dingle, Iloilo; eastern and northern
	margins of Iloilo Basin; northwest coast of
	Guimaras

Age	Late Miocene
Thickness	2,200 m (maximum)
Named by	Corby and others (1951)

Corby and others (1951) named the formation after Dingle town, 45 km north of Iloilo City. As described by them the Dingle consists of reefal limestone occurring as lenses and interbedded marls, sandstones and mudstones. The formation rests unconformably over the Passi Formation. The Dingle occupies the eastern and northern margins of the Iloilo Basin and reappears as a belt of reefs along the northwest coast of Guimaras. Its age is pegged at Late Miocene. The maximum aggregate thickness of the formation reaches 2,200 m. The Dingle could be equivalent to the Tarao Formation in the west.

Corby and others (1951) subdivided the Dingle into two informal members - carbonate and clastic. Santos (1968) subdivided the formation into a lower Aglalana Limestone; middle Summit Clastics and upper Sto. Thomas Limestone.

• Aglalana Limestone Member

The lower *Aglalana Limestone* was named after Barrio Aglalana, Passi, Iloilo. The cliffs northeast of Duran, Dumalag, south of San Enrique and north of Dingle, the pinnacles west of Dumalag and the limestone mounds northwest of Barotac Viejo, belong to the Aglalana Limestone Member. It consists mainly of well bedded limestone with mudstone and sandstone beds at the base. At the type locality, the upper and lower parts are made up of thin bedded coralline limestone, highly calcareous and fossiliferous mudstone and sandstone. The middle part is composed of massive and homogenous limestone. The Aglalana is 590 m thick. In Guimaras Island, the **Sta. Teresa Marl** of Culp and Madrid (1967) could be a facies of the Aglalana.

• Summit Clastic Member

The middle *Summit Clastic Member* was named after Barrio Summit, Passi, Iloilo. It extends north to Barrio Tumalulud, Dumalag, Capiz and thins out south of Passi, Iloilo. The Summit Clastic Member consists of massive, gray, medium to coarse-grained sandstone, fossiliferous shale and thin lenses of limestone. It is 483 m thick along Lamunan River.

• Sto. Thomas Limestone Member

The upper *Sto. Thomas Limestone Member* was named after Mt. Sto. Thomas along a tributary of the Bitaogan Creek, 10 km north of Passi. Northwards it could be traced to Dumarao, Capiz and southwards to about 4 km north of Passi where it grades into the Ulian Formation. It is cream to gray, hard, fragmental and thin-bedded. Coarse-grained highly calcareous sandstone and mudstone are interbedded with the limestone. The Sto. Thomas is 750 m thick.

Ulian Formation

Lithology	Claystone, mudstone, minor sandstone, siltstone, limestone
Stratigraphic relations	Conformable over the Dingle and Iday Formations
Distribution	Lambunao and Cabatuan region; Panay Central Plain, from Maasin, Iloilo to Dumalag, Capiz
Age	Late Pliocene
Thickness	123 m – 536 m
Named by	Corby and others (1951)

The Ulian Formation is described in the section under Central Panaylloilo Basin. In the northeastern part, calcareous mudstones grade downward to impure limestone with interbeds of silty mudstone.

Odiongan Andesite

Hornblende andesite
Not reported
eastern coast of Panay and
Calagnaan Island
Pleistocene
Odiongan Volcanics (MMAJ-JICA, 1992)
MGB (this volume)

The Odiongan Andesite was previously named by MMAJ-JICA (1992) as Odiongan Volcanics and is distributed along the hilly regions of the east coast and at Calagnaan Island. The Odiongan consists of pale-grayish brown porphyritic hornblende andesite. Certain andesites that were previously lumped with the Odiongan were determined by MMAJ-JICA (1993) as altered hematite-stained facies of the Sibala Formation.

Cabatuan Formation

Lithology	Mudstone, sandstone, siltstone
Distribution	Cabatuan and Sta. Barbara, Iloilo
Age	Pleistocene
Thickness	390 m
Named by	Corby and others (1951)

The Cabatuan Formation is described in the section under Central Panay-Iloilo Basin. Among the three members of the formation, only the middle *Maraget Sandstone Member* crops out in Eastern Panay, particularly from Calinog to Duenas, Lambunao to Dingle, Janiuay to south of Lucena and south of Pototan. The Maraget is reddish-brown, cross - bedded and loosely consolidated.

ROMBLON ISLAND GROUP (SG 11)

Romblon Metamorphic Complex

Lithology	Schist, slate, quartzite and marble
Stratigraphic relations	Unconformably overlain by the Tablas
	Volcanic Complex in northern Tablas
	Island; in fault contact with the Sibuyan
	Ultramafic Complex; intruded by gabbro at
	San Agustin and Culaton Hill, Tablas
	Island; overlain by basaltic flows in Tablas
	Island from Alcantara to Canguyo, Sta. Fe
Distribution	Lunas River, Romblon (type locality);
	Romblon, Tablas, Sibuyan, Cobrador and
	Alad Islands
Age	Paleozoic
Previous name	Rombion Marble (Adams, 1910)
Renamed by	Vallesteros and Argaño (1965)
Stratigraphic correlation	Mindoro Metamorphics in Mindoro Island
Synonymy	Rombion Marble (Adams, 1910);
	Rombion Formation (Smith, 1924);
	Sibuyan Formation (Hashimoto, 1939);
	Basement Rocks (Corby and others,
	1951); Rombion Metamorphics (BMG, 1981)

The Romblon Metamorphic Complex of Vallesteros and Argaño (1965) refers to the schists and marbles that serve as the basement rocks of the Romblon Island Group. It was originally designated as Romblon Marble by Adams (1910), typically exposed in the middle course of Lunas River, Romblon Island. Subsequent workers renamed this unit as the Sibuyan Formation (Hashimoto, 1939), basement rocks (Corby and others, 1951); Romblon Metamorphic Rocks (Liggavu, 1964): and Romblon Metamorphics (BMG, 1981). The metamorphosed clastic rocks identified by Fontaine and others (1983) outcropping north of Looc, Tablas Island are also presumed part of the Romblon Metamorphic Complex. Extensive outcrops were observed in Romblon, Tablas, Sibuyan, Cobrador and Alad Islands. In northern Tablas Island, it was found unconformably overlain by the Tablas Volcanics and in fault contact with the Sibuvan Ultramafics. Similarly, it was also found in contact with the ultramafics at Sibuyan Island. In San Agustin and Culaton Hill, Tablas Island, gabbro intruded these metamorphic rocks. Likewise, in the same island from Alcantara to Canguyo, Sta. Fe, basaltic flows overlie the metamorphics.

The unit basically consists of foliated rocks intercalated with slate, marble and quartzite. The foliated rocks are composed of amphibolite, biotite-muscovite-quartz schist, phyllite and quartzofeldspathic schist. They are usually brownish to greenish gray and massive. The marble is irregularly bedded, either intercalating or overlying the schist. It is described as laminated and varicoloured - white, gray, yellowish-brown, pinkish and black (Angeles, 1980). The schists in Tablas could be equi-

PERIOD	EPOCH	AGE	Ма	ROMBLON ISLAND GROUP
	HOLOCENE			
		4 Late	0.0117	
	PLEISTOCENE	3 Middle	0.78	Looc Limestone
		1 Early	1.81	
Щ	PLIOCENE	2 Late	2.59	Peliw Formation
OGE		1 Early	5.33	Banton Volcanic Complex
Ř		3 Late	7.25	Anahao Formation
			11.61	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
	MIOCENE	2 Middle-	13.65	
			15.97	Binoog Formation
		1 Early	20.43	
		2 Late	23.03	
	OLIGOCENE	1 Early	28.4	
Щ	EOCENE	4 Late	33.9	Bailan Limestone
GEN		3 Middle -	40.4	Calatrava Quartz Diorite
LEC		2	40.0	
PA		1 Early	48.6	
	PALEOCENE	3 Late	55.8	
		2 Middle	- 61.7	
(0		1 Edity	65.5	Tablas Volcanic Complex
EOUS	Upper	Late		
TACE			99.6	Sibuyan Ophiolitic Complex
CRE	Lower	Early		
JURASSIC		3 Late	145.5	
		2 Middle	1	
		1 Early	1	
TRIASSIC		3 Late	205	
		2 Middle		
PERMIAN		1 Early	250	
		3 Late		
	_	2 Middle		Pacul Limestone Carabao Sandstone
		1 Early		Rombion Metamorphic Complex
CARBONIF	EROUS		290	

 Table 2.17 Stratigraphic column for Romblon Island Group

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

valent to the metamorphosed and strongly folded gray to black shale and sandy shale described by Fontaine and others (1983).

Petrographic analysis indicates that the amphibolite consists mainly of hornblende needles, plagioclase and quartz. The biotite-muscovite-quartz schist is greenish to brownish gray with granoblastic quartz grains admixed with biotite and muscovite flakes. The quartzofeldspathic schist is composed of interlocking grains of twinned plagioclases and quartz grains.

No fossil was identified from the Romblon Metamorphic Complex but a Paleozoic age was assigned by BMG (1981). This is correlated with the metamorphic rocks of Mindoro and Buruanga. According to Fontaine and others (1983), the metamorphosed shale and sandy shale exposed north of Looc, Tablas Island are apparently older than Permian.

Carabao Sandstone

Lithology	Dominantly sandstone with shale
	interbeds.
Stratigraphic relations	Unconformably overlain by the Pacul
	Limestone
Distribution	Limited outcrops in Carabao and Sibuyan
	Islands
Age	Permian (?)
Named by	Vallesteros and Argaño (1965)

In Carabao and Sibuyan Islands are isolated outcrops of sandstone unit designated as Carabao Sandstone (Vallesteros and Argano, 1965). It is dominantly composed of well bedded, greenish to grayish brown, finegrained indurated sandstone with shale interbeds. According to Fontaine and others (1983) the shale and sandstone underlie the Middle Permian Pacul Limestone. The sandstone, however, did not yield any fossil. Based on its stratigraphic position, a Late Paleozoic age, probably Lower-Middle Permian may be assigned to this formation.

Pacul Limestone

Lithology	Recrystallized fusulinacean-bearing limestone
Stratigraphic relations	Overlies the Carabao Sandstone and apparently underlies a radiolarite unit of probable Triassic age
Distribution	Restricted to its type area in Carabao Island
Age	Murghabian (upper part of Middle Permian)
Thickness	40-100 m
Previous name	Carabao Limestone (Vallesteros and Argaño, 1965)
Renamed by	MGB (this volume)

The limestone unit in southern Carabao Island overlying the Carabao Sandstone was designated by Vallesteros and Argano (1965) as Carabao Limestone and later adopted by BMG (1981). However, pursuant to the provisions of the Philippine Stratigraphic Guide (2001), it is hereby renamed Pacul Limestone to avoid repetition of the geographic name carried by Carabao Sandstone. The name is derived from a barrio (southwestern Carabao Island) where Fontaine and others (1983) collected their Permian limestone. At Pacul, the limestone forms prominent

elongated hills about 40-100 m thick. It is light gray, massive but fractured and recrystallized. This unconformably overlies the Carabao Sandstone. At the type locality, the limestone apparently dips under the adjacent thinlybedded chert, which is probably equivalent to the radiolarite facies of the Buruanga Metamorphic Complex of Francisco (1953). Fontaine and others (1982) equate this radiolarite facies to the conodont-bearing radiolarite of northern Palawan dated Early-Middle Triassic.

Based on the contained fusulinacean species Andal (1966) assigned a Permian age to the unit. Fusulinid genera identified include *Neoschwagerina, Paleotextularia* and *Endothyra*. Fontaine and others (1982) also identified some Murghabian (upper part of Middle Permian) foraminiferal and algal species from Carabao Island. The foraminifers are; *Tuberitina collosa* Reitlinger, *Calcitornella heathi* Cushman and Waters, *Pachyploia* sp., *Climacammina* sp., *Pseudoendothyra* sp., and *Neoschwagerina haydeni* Doutkevitch and Khabakov. *Mizzia velebitana* Schubert, an algae from Family Dacycladaceae was also noted.

This limestone probably also correlates with the fusulinacean-bearing Minilog Formation of northern Palawan.

Sibuyan Ophiolitic Complex

Lithology	Dunite, harzburgite, lherzolite, gabbro,
	diabase, serpentinite, pillow lavas
Stratigraphic relations	Intruded by quartz diorites
Distribution	Sibuyan Island; Tablas Island
Age	Cretaceous
Previous Name	Sibuyan Ultramafics (Vallesteros and
	Argano, 1965)
Renamed by	Dimalanta and others (2004)

The ultramafic rocks at Sibuyan Island were designated as Sibuyan Ultramafics by Vallesteros and Argano (1965), which they considered to have been emplaced in Late Cretaceous to Early Eocene time. It was earlier included in the Mangyan Igneous Rocks of Hashimoto (1961) and later termed Sibuyan Ultramafic Rocks by Liggayu (1964). Recently, the ultramafic rocks were recognized as part of a suite that includes gabbros, diabasic dike complex and pillow lavas designated by Dimalanta and others (2004) as Sibuyan Ophiolitic Complex. The ultramafic rocks, consisting chiefly of harzburgites and subordinate lherzolite and dunite, constitute the central core of Mt. Guiting-guiting, Sibuyan Island. These ultramafic rocks. which have undergone varving degrees of serpentinization, were observed to be thrusted over gabbro in Magdiwang and the western coast of Sibuyan island.

Gabbros consist mainly of massive or isotropic variety. Layered gabbro has been noted in Bulabog Creek, Sibuyan Island and in Tablas Island, south of Calatrava. On Sibuyan Island, the gabbro occurs as a tectonic slice thrusted above peridotites and underthrusted below peridotite and volcanic rocks (Dimalanta and others, 2004). Volcanic rocks representing the upper levels of the ophiolitic complex consist of dikes/sills of varying density and pillow lavas. The volcanic rocks are exposed mainly on Tablas Island and, to a lesser extent, on Sibuyan Island. The Sibuyan Ophiolitic Complex was probably emplaced during Cretaceous time.

Tablas Volcanic Complex

Lithology	Andesite, tuff, volcanic breccia and flows; microgabbro
Stratigraphic relations	Unconformably overlies the Romblon
	Metamorphic Complex; intruded by quartz
	diorite; intrudes gabbro
Distribution	Central Tablas and northern Sibuyan
	Islands
Age	Late Cretaceous
Synonymy	Tablas Metamorphic Rocks (Liggayu,
	1964); Tablas Altered Volcanic Rocks
	(Vallesteros and Argano, 1965)
Previous name	Tablas Volcanics (BMG, 1981)
Renamed by	MGB (this volume)
	· · · · · · · · · · · · · · · · · · ·

Unconformably overlying the metamorphic rocks constituting the basement is the Tablas Volcanic Complex, formerly referred to as the Tablas Metavolcanic Rocks (Liggayu, 1964) and Tablas Altered Volcanic Rocks (Vallesteros and Argano, 1965). BMG (1981) renamed it as the Tablas Volcanics, which is here modified to Tablas Volcanic Complex. These effusive basic rocks, which have undergone varying degrees of alteration or thermal metamorphism, are exposed in Central Tablas and northern Sibuyan. The rocks include chloritized hornblende andesite and tuff with microgabbro intrusive facies. Volcanic breccias and flows are closely associated varieties. These rocks are fine- to medium-grained, dark, greenish gray with reddish brown patches. They are largely made up of argillized plagioclases and hornblende with fibrous green chlorite as alteration product of hornblende. Fine grains of calcite and epidote are distributed in minor amounts. The age is probably Late Cretaceous.

In Naabang and Caburan points, pegmatitic and diabase dikes cut the metavolcanic rocks and are in turn dissected by later andesite dikes (Liggayu, 1964). In central Tablas and northern Sibuyan Islands this unit unconformably overlies the Romblon Metamorphic Complex. In northern Tablas this was intruded by quartz diorite. A probable Late Cretaceous age is assigned to this formation.

The Tablas Volcanic Complex could be part of the ophiolitic complex representing the sheeted dike complex and, partly, the volcanic carapace of the ophiolitic suite.

Calatrava Quartz Diorite

Lithology	Quartz diorite, tonalite, diorite
Stratigraphic relations	Intrudes schist, ultramafic rocks and
0	Tablas Volcanic Complex

Distribution	Tablas and Sibuyan Islands
Age	Eocene
Named by	Liggayu (1964) as Calatrava Intrusives
Renamed by	MGB (this volume)

Intrusive rocks of different shapes and sizes in Tablas Island and northern Sibuyan Island were named Calatrava Intrusives by Liggayu (1964) and Vallesteros and Argaño (1965). This was mapped by MMAJ-JICA (1990) as Romblon Quartz Diorite Group. Along the Calatrava to Carmen-San Agustin road, the unit is represented by elongated bodies of quartz diorite and tonalite. The quartz diorite is composed of interlocking grains of bladed plagioclases and anhedral quartz with associated secondary chlorite and epidote. Tonalites consist of anhedral quartz, plagioclase crystals and hornblende prisms. Relict pyroxenes and biotite flakes are present as interstitial materials. At Saupiton, Sibuyan Island, the rocks are mostly hornblende tonalite, which exhibit holocrystalline equigranular texture. In southern Tablas, the intrusive rocks are dominantly diorite.

The quartz-diorite apparently intruded the schists and the altered rocks of the Tablas Volcanic Complex and Sibuyan Ultramafic Complex during the Eocene.

Bailan Limestone

Lithology	Nummulite-bearing limestone
Stratigraphic relations	Rests on Calatrava Quartz Diorite
Distribution	Bailan Point, San Agustin; Barangays
	Mahabang Baybay and Sogod, San
	Agustin
Age	Eocene
Thickness	15 m
Named by	Maac and Ylade (1988)

The Bailan Limestone was referred to by Fontaine and others (1983) as the *Nummulite*-bearing limestone that crops out north of Bailan Point in San Agustin. It is essentially composed of fossiliferous, massive, buff to gray and sandy limestone. The unit is a biomicrite made up of anhedral calcite grains, sparite, bioclast and quartz chips set in a micritic matrix. Specks of clay and limonite stains are also present as infilling materials. Uninterrupted exposures of the limestone body were observed in Barangays Mahabang Baybay and Bailan, San Agustin. In Barangay Sogod, San Agustin, rubbly limestone boulders rich in *Nummulites* species were also observed associated with the Binoog Limestone blocks.

At the type locality at Bailan, the limestone is 15 m thick. The presence of *Nummulites in* most of the studied samples of Maac and Ylade (1988) indicates an Eocene age. Among the foraminifers present, *Nummulites pengaronensis* Verbeek is the only abundant form. Species of *Gypsina* and miliolids also occur as minor components. The Bailan was probably deposited in a lagoonal or open platform to a reefal environment as shown by the presence of species of Nummulites, abundant corals, algae echinoid stems and sponge spicules.
Stratigraphically, it appears that the underlying Calatrava Quartz Diorite is older than the Bailan. No signs of alteration, shearing, or baking are observed along the contact, suggesting a nonconformable contact.

Binoog Formation

Lithology	Limestone, mudstone, sandstone, conglomerate, volcanic preccia
Stratigraphic relations	In central Tablas, Tuguis limestone rests upon the Tablas Volcanic Complex; unconformably overlies the Bailan
	Limestone in San Agustin
Distribution	Tuguis, Odiongan, San Agustin, Tablas
Age	Early – Middle Miocene
Thickness	400 m (Tuguis Limestone)
Named by	Vallesteros and Argaño (1965), Maac and
-	Ylade (1988) for the Tuguis Limestone
	Member and Cogon Member

The Binoog Formation of Vallesteros and Argaño (1965) are Early to Middle Miocene rocks exposed over a wide area in Tablas and Carabao Islands. Maac and Ylade (1988) divided the formation into two members, namely, the lower Tuguis Limestone and the upper Cogon Clastics. Here, the Cogon Clastics is renamed as Cogon Member.

• Tuguis Limestone

The Tuguis Limestone was designated by Maac and Ylade (1988) for the massive to bedded, sandy to fine-grained, gray to cream fossiliferous limestone that forms the lower part of the Binoog Formation. It consists mainly of fine carbonate materials and fossil clasts. Quartz, feldspar and specks of clay occur as interstitial materials. At its type locality in Tuguis, Odiongan, the limestone occurs as towering pinnacles that can be followed northward into Canayong Forest. In the western extremity, the Tuguis Limestone is represented by the Macatol and Colasi Hills, which generally dips eastward forming a synclinorium. Good exposures of the limestone were also observed in the eastern periphery of San Agustin and Concepcion and the white cliffs in the northeastern tip of Tablas. In central Tablas, the limestone generally rests over the Tablas Volcanic Complex whereas in San Agustin, it unconformably overlies the Bailan Limestone. Its maximum thickness at the type locality is estimated to be 400 m. Based on the Miogypsina and Lepidocyclina species present the age is Early to Middle Miocene.

• Cogon Member

The Cogon Member represents the upper member of the Binoog Formation. The exposure at Cogon River consists of successions of thin calcareous and tuffaceous mudstone beds with wacke interbeds and intercalations of volcanic breccias (Maac and Ylade, 1988). The mudstone varies from brown to cream to bluish gray. The interbedded wacke is essentially composed of quartz, volcanic clasts, serpentine, schist and ferromagnesian minerals. The intercalated volcanic breccia is basaltic in composition, consisting essentially of plagioclase, augite and labradorite with minor amounts of bowlingite and glass shards.

Typical exposures of the Cogon Member may be found along Carolina River and Barangay Manlilico in Odiongan. Intercalations of volcanic breccia and sedimentary rocks were observed in the northeast-southwest trending trough north of Alcantara and in Barrio Canguyo, Sta. Fe (Liggayu, 1964). These also crop out in Rizal, Sicop, Lutod Bukid, Cogon and Carolina rivers. Planktic foraminiferal species in the clastic sequences indicate a Middle Miocene age.

Anahao Formation

Lithology	Interbedded limestone, sandstone, mudstone and shale
Stratigraphic relations	Unconformable over Binoog Formation
Distribution	Odiongan-Looc, Tablas; Carabao Island
Age	Late Miocene – Early Pliocene (?)
Thickness	450 m
Previous name	Anahao conglomerate and silts (Corby and others (1951)
Renamed by	Liggayu (1964)

The formation was originally designated by Corby and others (1951) as Anahao conglomerate and silts. Liggayu (1964) later renamed it as Anahao Formation. It is well developed in Tablas Island, where it represents a broad synclinorium extending from Odiongan to Looc Bay. Outcrops of the formation were found unconformably resting over the Binoog Formation. At Carabao Island, this largely covers the Pre-Paleogene rocks.

The unit consists of interbedded limestone, sandstone, mudstone and shale. The basal limestone is thinly-bedded, bioclastic with rounded to subrounded particles of limestone, quartz schist, volcanic rocks and diorite. The sandstone is light gray, cross bedded, feldspathic with hornblende, quartz and minor amounts of fine particles of volcanic rocks, shale and schist in a tuffaceous matrix. The shale is thin bedded, tuffaceous and calcareous. Fine conglomerate lenses are interbedded with the shale. The Anahao has a maximum thickness of 450 m.

Samples collected by Maac and Ylade (1984) yielded planktic foraminifers as well as benthic foraminifers in lesser amounts. Associated fauna includes radiolarians and nannoplanktons. However, in the interbedded calcarenites and calcirudites, a probable Late Miocene *Vicarya* species associated with other mollusks, corals and algae was noted. Rich foraminiferal assemblage in the mudstone supports a Late Miocene to probable Early Pliocene age.

Banton Volcanic Complex

Lithology	Volcanic flows and pyroclastic rocks
Stratigraphic relations	Overlain by Pliocene – Pleistocene reefal
	limestone
Distribution	Banton Island

Age	Pliocene
Previous name	Banton Volcanics (Vallesteros and
	Argaño, 1965)
Renamed by	MGB (this volume)

This unit was previously designated as Banton Volcanics by Vallesteros and Argano (1965). It consists of volcanic flows and pyroclastic rocks, which mainly underlie Banton and Simara Islands. The rocks are generally well banded, vesicular and porphyritic. The pyroclastic rocks consist of vesicular and porphyritic hornblende andesite fragments set in a tuffaceous matrix. In western Simara Island, the Banton is partly overlain by Pliocene to Pleistocene reefal limestone.

Peliw Formation

Lithology	Calcareous sandstone, mudstone and
	conglomerate; limestone
Stratigraphic relations	Unconformably overlies Anahao
	Formation
Distribution	Peliw, Odiongan, Tablas Island
Age	Late Pliocene
Previous name	Peli Formation (Liggayu, 1964)
Renamed by	Maac and Ylade (1988)

Appearing as outlier on, and unconformably overlying the Anahao Formation, is the Peliw Formation as renamed by Maac and Ylade (1988). The formation was originally designated as Peli Formation by Liggayu (1964), which was mistakenly attributed to Vallesteros and Argaño (1965) in BMG (1981). The name was derived from a small village of Peliw in the municipality of Odiongan. Maac and Ylade (1988) recognized two divisions in the Peliw Formation, the Mayha Clastics and Looc Limestone.

• Mayha Clastic Member

Lithology	Calcareous sandstone, mudstone and
	conglomerate
Stratigraphic relations	Overlaps Anahao Formation in western
	Tablas; discordant to the Banton Volcanic
	Complex
Distribution	Odiongan-Looc area, western Tablas
Age	Late Pliocene
Named by	Maac and Ylade (1988)

This member was proposed for the gently dipping sandstone and mudstone beds with occasional conglomerates distributed over Odiongan and Looc municipalities (Maac and Ylade, 1988) with type locality at Barangay Mayha, Odiongan.

At barangays Mayha and Rizal, Odiongan, these clastic rocks typically occur as thick alternations of mudstone, sandstone and conglomerate. These rocks are grayish to cream, bedded, fossiliferous and calcareous. Towards Peliw and Lupog areas, they laterally grade into gray silty- to coarse-grained sandstone. Conglomerates with interbeds of coarsegrained sandstones were, however, observed in Progresso Oeste. Other prominent exposures are in Tolay, Tubigon and in Capid and Pasilagan points. The conglomerates are poorly sorted, matrix- to clast-supported, the clasts being composed mostly of angular to sub-rounded cobble- to boulder-sized fragments of schists, altered volcanic rocks, limestone, quartz and occasional diorite loosely embedded in a tuffaceous silty matrix. The maximum thickness of the conglomerate measures approximately 30 m. Planktic foraminifers and nannofossil assemblages contained in the mudstone points to a Late Pliocene age. Based on planktic foraminifers, the Mayha Member is dated Late Pliocene to probable Early Pleistocene. However, the presence of nannoplankton *Discoaster* species restricts the age of the unit to Late Pliocene, probably above the base of Stainforth's (1975) *Pulleniatina obliquiloculata* Zone.

Looc Limestone

Lithology	Coralline limestone
Stratigraphic relations	Conformable over Mayha Clastic Member
Distribution	limited at its type locality in Looc
Age	Late Pliocene to probable Pleistocene
Named by	Maac and Ylade (1988)

This coralline limestone at the upper part of the Peliw Formation is typically exposed in Looc, northwest of the Poblacion (town proper). It is white to buff, obscurely bedded and made up of poorly consolidated corals and other calcareous debris. It conformably overlies the Mayha Clastic Member. It is dated Late Pliocene to probable Pleistocene. The limestone member denotes deposition in a shallow reefal environment. Dominant fossils are colonial corals and encrusting algae.

NEGROS ISLAND (SG 15, 16, 17)

Negros Island may be divided into three tectono-stratigraphic terranes, namely, Recent Negros Arc (15), Ancient Negros Arc (16) and Visayan Sea Basin (17). The Recent Negros Arc and the portion of the Visayan Sea Basin occupies, respectively, only the eastern and western fringes and the central portion constitute the Ancient Negros Arc.

Basak Formation

Lithology	Basalt, sandstone, siltstone, shale
Stratigraphic relations	Constitutes the basement rocks of Negros;
	Intruded by the Pangatban Diorite
Distribution	Basak, Cauayan, Negros Occidental
Age	Cretaceous (?)
Previous name	Basak Volcanic Rocks (Vallesteros and
	Balce, 1965)
Renamed by	MGB (1981)
Synonymy	llog Formation (Santos-Yñigo and Oca,
	1946)

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	NEGROS
	HOLOCENE		0.0117	
	PLEISTOCENE	4 Late 	0.126 0.78 1.81	Malindig Volcanic Complex Caliling Formation
BN	PLIOCENE	2 Late	2.59 3.60	Amlan Conglomerate Magsinulo
NEOGE		1 Early	5.33 7.25	Andesite Talave Formation
	MIOCENE	2 Middle-	13.65 15.97	Macasilao Formation Malabago Formation
		1 Early	20.43	Escalante Formation
	OLIGOCENE	2 Late 1 Early	28.4	Pangatban Diorite
Щ		4 Late	37.2	Isio Limestone
	EOCENE	3 Middle - 2	40.4 48.6	
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
CEOUS	Upper	Late	99.6	Basak Formation
CRETA	Lower	Early	145 F	
JURASSIC	Upper	3 Late	161.2	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.18 Stratigraphic column for Negros Island

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

The Basak Formation was previously designated as Basak Volcanics by Vallesteros and Balce (1965, in Castillo and Escalada, 1979) in reference to the rocks at Basak, south of Cauayan, Negros Occidental. This formation consists of massive chloritized volcanic flows and fragmental pyroclastic rocks of andesitic and basaltic composition (Burton, 1982) with intercalated tuffs and thin beds of conglomerate, sandstone, siltstone and shale. The Basak is intruded by the Pangatban Diorite. The formation includes the *llog Formation* of Santos-Yñigo and Oca (1946) consisting of sandstone, shale and quartzite. The age of the Basak Formation is probably Cretaceous.

Isio Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Basak Formation
Distribution	Basak, Cauayan, Negros Occidental
Age	Late Eocene
Named by	Vallesteros and Balce (1965)

This formation was named by Vallesteros and Balce (1965, in Castillo and Escalada, 1979) for the limestone at Isio River at Isio, Cauayan, Negros Occidental. It is buff yellow to brown, well bedded silty and fossiliferous. The unit lies unconformably over the Basak Formation. On the basis of the foraminiferal assemblage (including *Discocyclina* and Nummulites) contained in the limestone, David (1982) dated the formation Late Eocene.

Pangatban Diorite

Lithology	Diorite, quartz diorite, minor gabbro
Stratigraphic relations	Intrudes the Basak Formation
Distribution	Pangtaban River; extends northwest-
	southeast from Panay Gulf to Talong Bay;
	underlies most of the western part of
	southwestern Negros including Damutan
	Valley
Age	Oligocene
Previous name	Pangatban Intrusive (Castillo and
	Escalada, 1979)
Renamed by	Burton (1982)
,	

The Pangatban Diorite was previously named Pangatban Intrusive by Castillo and Escalada (1979) for the extensive osures of diorite along the length of Pangatban River. The diorite stitutes a batholithic mass stretching northwest- southeast for some 62 km from Panay Gulf to Talong Bay in southwestern Negros. In terms of lithology, it consists mainly of diorite and quartz diorite with textures that vary from medium grained to coarsegrained, hypidiomorphic-granular to porphyritic. The **Manlawaan Gabbro** of Castillo and Escalada (1979) and other gabbro bodies, occurring in limited exposures, are probably facies of the diorite body. Minor tonalites and granodiorite have also been noted. Likewise, occurrences of andesite and dacite porphyry are probably associated with the emplacement of the diorite. Biotite in porphyritic tonalite from Sipalay gave a radiometric K/Ar dating of 30.2 ± 4 Ma, equivalent to late Early Oligocene (Burton, 1982). Radiometric K-Ar dating of diorite samples reported by MMAJ-JICA (1988) ranges from 25.1 Ma to 28 Ma, which is equivalent to early Late Oligocene.

Escalante Formation

Lithology	Sandstone, siltstone, shale; limestone;
Stratigraphic relations	Unconformably overlain by Malabago
	Formation
Distribution	Escalante, Negros Occidental; Trankalan

	Range; Danao River
Age	Late Oligocene-Early Miocene
Thickness	1,730 m
Named by	Caguiat (1967)

The Escalante Formation was named by Caguiat (1967) for the rocks exposed in the vicinity of Barrio Libertad, Escalante in northeastern Negros Occidental. It is well exposed around Trankalan Range. The formation may be divided into the lower Paitan Member and upper Trankalan Limestone member (Yap, 1972). The **Paitan Member** consists of an alternation of sandstone, siltstone, mudstone and marl. White to cream dense micritic limestone occurs in the middle. Intercalations of turbiditic layers and limestone breccias that reach a thickness of 500 m have been described by Jurgan (1980). The **Trankalan Limestone** is pinkish, cream to white, generally thick bedded, partly brecciated, with fragments of head and branching corals, algae and locally with abundant orbitoids. Patch reefs are also locally developed. Porth and others (1989) consider the Trankalan as time equivalent of the lower part of the clastic Escalante Formation.

Porth and others (1989) also describe a sequence in Danao River of tuffaceous sandstones and siltstones with intercalations of volcanic pebble to boulder conglomerate, which could be part of the Escalante Formation. The foraminiferal assemblage of the clastic facies of the Escalante Formation, as reported by Muller and others (1989), consists of *Globorotalia kugleri, Globoquadrina binaiensis, Globigerinoides primordius* and *Globigerina ciperoensis* typical of zones N3–N4 (Late Oligocene – Early Miocene). The nannoplankton assemblage with *Helicosphaera recta, Ericsonia fenestrata* and *Sphenolithus ciperoensis* belong to NP 25 (Muller and others, 1989), corresponding to Late Oligocene. According to Gramann (1982), the upper part of the Escalante Formation extends into the Early Miocene. On the other hand, Hashimoto and others (1977) found an assemblage of *Eulepidina* and *Spiroclypeus* without *Miogypsina* in the upper part of the Trankalan indicating a Late Oligocene age. The total thickness of the formation, including the Trankalan Limestone, is 1730 m.

Tabu Formation

Lithology	Sandstone, siltstone, shale, minor
Stratigraphic relations	Unconformable over the Basak Formation
	and Pangatban Diorite
Distribution	Barangay Labu, Gulinungan, Salog and Dacongcogon rivers, southwest Negros
Age	Early Miocene
Named by	Castillo and Escalada (1979)

Tabu Formation was named by Castillo and Escalada (1979) for the exposures of sedimentary rocks along a roadcut in Brgy. Tabu in southwestern Negros Island. At its type locality, the formation consists of highly indurated sandstone, siltstone and shale. A limited exposure of basal conglomerate is present at Tablas River. Other exposures are mainly in the upper reaches of Guilhungan and Dacongcogon rivers. Along Salog and Guilhungan rivers, tuffaceous sandstone and siltstones are

intercalated with pyroclastic rocks, including pyroclastic breccia (MMAJ-JICA, 1990). The Tabu is unconformable over the Basak Formation and Pangatban Diorite. It was dated Early Miocene by Santos and Velasquez (1988). It may be considered partly equivalent to the Escalante Formation in northern Negros.

Malabago Formation

Lithology	Conglomerate, tuffaceous sandstone and siltstone; tuff; volcanic breccia, pillow lava; mudstone marl: limestone
Stratigraphic relations	Unconformable over the Escalante Formation
Distribution	Malabago, San Carlos; east of Macasilao, north of Tigbao; West of Toboso; Paghumayan area
Age	early Middle Miocene (Langhian)
Thickness	500 m (Corby and others, 1951); maximum 1,500 m (Melendres and Barnes, 1957)
Previous name	Malabago Shale and Conglomerate (Corby and others, 1951)
Renamed by	MGB (this volume)
Synonymy	Odeong and Tigbao formations (Melendres and Barnes, 1957); Fuentes Green Tuff (Caguiat, 1967)

The Malabago Formation was previously named Malabago Shale and Conglomerate by Corby and others (1951) in reference to the clastic sequence at Malabago, north of San Carlos, Negros Occidental. The formation is widely exposed in the areas east of Macasilao, north of Tigbao, west of Toboso and around Paghumayan. The Malabago consists of tuffaceous conglomerates, sandstones, siltstones and mudstones as well as pillow lavas, volcanic breccias, and tuffs. Few thin layers of marls and marly limestone are also present. Paleontological studies by Muller and others (1989) indicate that the foraminiferal and nannoplankton assemblages in the formation belong to biozones N9 and NN5, respectively, corresponding to early Middle Miocene (Langhian).

Melendres and Barnes (1957) raised Malabago to group rank, which they subdivided into Odeong Formation and Tigbao Formation. The Malabago Formation, as defined in this volume, is equivalent to the Odeong and Tigbao formations combined. The Odeong and Tigbao may thus be considered as members of the Malabago Formation. As described by Melendres and Barnes (1957) the **Odeong** consists predominantly of volcanic conglomerate with subordinate mudstone and little interbedded limestone. On the other hand, the **Tigbao** is composed mainly of tuffaceous mudstone with interbedded conglomerate and sandy limestone. The **Fuentes Green Tuff** of Caguiat (1967) may also be regarded as equivalent to the Malabago Formation.

The thickness of the formation is 500 m as estimated by Corby and others, (1951). According to Melendres and Barnes (1957) the thickness of

Tigbao varies from 50 m to 600 m, and therefore the range of the aggregate thickness of Odeong and Tigbao is 950 m - 1500 m.

Vista Alegre Dacite Porphyry

Lithology	Dacite	porphyry,	rhyodacite	porphyry;
	dacitic I	oreccia		
Stratigraphic relations	Intrudes	s Basak For	mation and F	Pangatban
	Diorite			
Distribution	Bulawa	n, Vista Aleg	gre, Nagtalay	΄,
	southw	est Negros		
Age	Middle	Miocene		
Named by	MGB (t	his volume)		

The Vista Alegre Dacite Porphyry was named by MGB (2005) for the stocks and dikes of dacite porphyry at Vista Alegre, southwest Negros. The Dacite Porphyry, which intrudes the Basak Formation and Pangatban Diorite, is mostly confined along a 1 km x 5 km northeast trending belt that defines the "Vista Alegre Gold zone". The biggest stock of the dacite porphyry measures 1.3 km x 0.40 km (Bobis and Comia, 1987). The dacite porphyry consists of large oligoclase and quartz phenocrysts (up to 5 and 3.5 cm, respectively) set in a microgranular groundmass of plaguioclase, K-feldspar, quartz and apatite (Rollan and others, 1997). K-feldspar constitutes as much as 40% of the groundmass, which could make the rock fall in the category of rhyodacite. Dacitic hydrothermal breccias associated with the Dacite Porphyry occur as a pipe-like body at Bulawan and as dikes at Nagtalay. Multilithic breccias in, which fragments of andesite, dacite, basalt, tuff and even diorite, float in a dacitic groundmass, are also associated with the Dacite Porphyry.

Radiometric K-Ar dating of sericite in dacite drill cores from Bulawan gave values of 14.4 ± 0.7 Ma and 13.2 ± 0.6 Ma, corresponding to Middle Miocene (Bobis and Comia, 1987).

Dacongcogon Formation

Lithology Stratigraphic relations	Limestone, sa	andstone, cor de over the T	nglomerate abu Format	ion
Distribution	Dacongcogor	n, Cabilokan I	River, uppe	r
	reaches of lia	ig and Tablas	s rivers;	
	Candoni, Cali	iling, Dong-I,	southwest	
	Negros			
Age	Middle Mioce	ne		
Previous Name	Dongcogon	Limestone	(Castillo	and
	Escalada, 19	79)		
Renamed by	MMAJ-JICA (1990)		

The Dacongcogon Formation was originally named Dacongcogon Limestone by Castillo and Escalada (1979) and subsequently renamed by MMAJ-JICA as Dacongcogon Formation to include the clastic units associated with the limestone. As described by Castillo and Escalada (1979), the limestone of Dacongcogon unconformably overlies the Tabu Formation. Other limestone bodies associated with the Dacongcogon may be found in Candoni, Caliling, Dong-I and Dancalan. Clastic rocks considered part of the Dacongcogon are sandstone, and conglomerate, which are well bedded in the lower section and massive in the upper section (MMAJ-JICA, 1990). Paleontological dating reported by Santos and Velasquez (1988) indicates a Middle Miocene age for the Formation.

Macasilao Formation

Sandstone, siltstone, claystone, condomerate, limestone, coal
Overlies the Malabago Formation
Macasilao, Negros Occidental; extends
from Malabago in the north to as far south
as upper Talave River
late Middle Miocene
300 m (Corby and others, 1951); 1,400 –
3,200 m (Melendres and Barnes, 1957)
Macasilao Conglomerate and Shale
(Corby and others, 1951)
Melendres and Barnes (1957)

The Macasilao Formation was originally named Macasilao Conglomerate and Shale by Corby and others (1951), with type locality at Barrio Macasilao, 10 km southwest of Toboso, Negros Occidental. Melendres and Barnes (1957) renamed it Macasilao Formation, which they described as a thick sequence of sandstone and shale containing lenticular beds of conglomerate, coal and limestone. The Ania Conglomerate and Paghumayan Shale of Melendres and Barnes (1957) constitute the lower portion of the Macasilao Conglomerate and Shale of Corby and others (1951). In addition, Melendres and Barnes (1957) describe a Magbanco Conglomerate member. The conglomerate consists of sub-angular to angular clasts of lithic tuff, basalt and andesite in a matrix of tuffaceous mudstone and sandstone. These clasts attain a maximum dimension of 2 m. According to Porth and others (1989), the lower part of the Macasilao consists of dark gray claystones, fine to coarse-grained tuffaceous sandstones, thin conglomeratic layers and lignitic coal seams. The upper portion of the formation consists mainly of siltstones and claystones. Intercalations of limestone breccias with fragments of corals and larger foraminifera have been observed within the fine clastic sequence.

The formation covers a fairly large area north of San Carlos. It extends from Malabago in the north to as far south as the upper course of the Talave River. The Macasilao is late Middle Miocene in age, based on nannoplankton assemblage. The nannoplanktons of the formation, as reported by Muller and others (1989), include Coccolithus pelagicus, Reticulofenestra pseudoumbilica, Cyclicargolithus abisectus. Cyclococcolithus rotula, Discoaster exilis and Rhabdosphaera poculi, indicating zone NN6. Discoaster kugleri, indicative of NN 7, though rare, has been noted and zone NN 8 has been determined by the presence of Catinaster coalitus. The presence of abundant pelecypods and gastropods and rare ostracodes, otoliths and fish teeth suggest a near shore, inner to middle neritic depositional environment (Muller and others, 1989). The thickness of Macasilao is estimated by Corby and others (1951) to be 300 m. Melendres and Barnes (1957) estimate a total thickness of 1,400 – 3,200 m for the Macasilao.

Canturay Formation

Lithology	Sandstone, siltstone, shale
Stratigraphic relations	Unconformably overlain by the
	Kalumbuyan Formation
Distribution	Canturay and vicinity; Calat-an River,
	southwest Negros
Age	Late Miocene
Previous Name	Canturay clastic sedimentary rocks (Kinkel and others, 1956)
Renamed by	Castillo and Escalada (1979)

Exposures of well-bedded sedimentary rocks at Canturay were named by Kinkel and others (1956) as Canturay clastic sedimentary rocks. This was later renamed Canturay Formation by Castillo and Escalada (1979). The formation consists of a thick sequence interbedded sandstone, siltstone and shale. These clastic beds are carbonaceous at the lower section, and calcareous towards the top. Thin coquinal layers were also observed at the upper reaches of Calat-an River. It was assigned a Late Miocene age by MMAJ-JICA (1990) and is partly equivalent to the Talave Formation.

Talave Formation

Lithology Stratigraphic relations Distribution	Limestone, conglomerate, mudstone Overlies the Macasilao Formation Talaye River and vicinity: Macasilao: east
Distribution	central Negros; south-central Negros (Bais
	City-Mabinay-Bayawan area)
Age	Late Miocene – Early
Thickness	960 m (Melendres and Barnes, 1957)
Previous name	Talave Limestone and Conglomerate
	(Corby and others, 1951)
Renamed by	Caguiat (1967)
Synonymy	Paton-an Formation (Melendres and
	Barnes, 1957)

This formation was previously named by Corby and others (1951) as Talave Limestone and Conglomerate in reference to the exposures along Talave River. The **Nalikban Conglomerate** of Melendres and Barnes (1957) is probably equivalent to the conglomerate portion of the Talave Limestone and Conglomerate of Corby and others (1951). Caguiat (1967) renamed the unit Talave Formation and divided it into three members, namely; lower *Talave Limestone*, middle *Tigbao Clastics* and upper *Bairan Agglomerate*. Porth and others (1989) divide the formation into a clastic member and a limestone member. As described by Porth and others (1989), well-bedded, partly marly, limestones at Razor Back Mountain are overlain by massive limestone containing coral heads and bivalves. The clastic member consists of laminated to thin-bedded tuffaceous mudstone interbedded with conglomerate and thin-bedded, gray, sandy limestone. The Talave is widely exposed in east-central Negros (San Jose and Libertad rivers; Razor Back Mountain) and south-central Negros (Bais City-Mabinay-Bayawan area). As reported by Muller and others (1989), foraminiferal and nannoplankton assemblages are indicative of zones N16 to N19 and NN11 to NN15? respectively, corresponding to Late Miocene – Early Pliocene (Tortonian – Zanclean).

The **Paton-an Formation** of Melendres and Barnes (1957) is probably equivalent to the clastic member of the Talave Formation. It consists of calcareous clastic rocks with thin lenses of coal and conglomerate, which reportedly overlies and intertongues with the Talave Formation (Melendres and Barnes, 1957). The combined maximum thickness of the conglomerate (70 m), limestone (400 m) and clastic member (490 m) is 960 m.

Magsinulo Andesite

Lithology	Andesite
Stratigraphic relations	Unconformably overlain by the Amlan
	Conglomerate
Distribution	Magsinulo, southeastern Negros
Age	Early – Late Pliocene
Previous name	Magsinulo Andesite Flow Breccia (Ayson,
	1987)
Renamed by	MGB (this volume)

The Magsinulo Andesite was previously named by Ayson (1987) as Magsinulo Andesite Flow Breccia for the exposures in southeastern Negros. As described by Ayson (1987), this formation consists of andesite flow breccia and blocky andesite flows. The breccia shows angular clasts of hornblende andesite in a yellowish vitric matrix with phenocrysts of feldspars and ferromagnesian minerals. Ayson (1987) assigns an age of Early-Late Pliocene to this unit.

Kalumbuyan Formation

Lithology	Sandstone, siltstone, shale, limestone
Stratigraphic relations	Unconformable over the Canturay
	Formation
Distribution	Barangay Kalumbuyan; Magballo and
	Candoni; Pangatban and Bayawan rivers,
	southwest Negros
Age	Pliocene
Named by	Castillo and Escalada (1979)

The Kalumbuyan Formation was named by Castillo and Escalada (1979) for the exposures of thickly bedded sedimentary rocks underlying the ridge overlooking Brgy. Kalumbuyan. It consists of sandstone, siltstone, shale and limestone containing both megafossils and microfossils. Occasional thin lenses of lignitic coals were observed in the sandstone (Castillo and Escalada, 1979). The limestone is porous, poorly bedded to massive and marly. The Kalumbuyan rests unconformably over the Canturay Formation. The Formation is exposed mainly around Kalumbuyan. Isolated patches of the Kalumbuyan also occur near

Magballo and Candoni as well as the lower reaches of Bayawan and Pangatban rivers. MMAJ-JICA (1990) reports a Pliocene age for the formation.

Amlan Conglomerate

Lithology	Conglomerate, sandstone, mudstone,
	pyroclastic rocks, andesite flows
Stratigraphic relations	Unconformable over the Magsinulo
	Andesite; unconformably overlain by
	Balinsasayao Formation
Distribution	Amlan, Cambuelao, Palaypay, Badjang
	and Bicos rivers; southeastern Negros
Age	Late Pliocene
Previous name	Amlan River Conglomerate (Ayson, 1987)
Renamed by	MGB (this volume)

The Amlan Conglomerate was named by Ayson (1987) for the conglomerate at Amlan River. It is also well exposed along the channels of Cambuelo, Palaypay, Badjang and Bicos rivers in southeastern Negros. The Amlan consists mainly of conglomerate with minor sandstones, mudstones, andesitic flows and pyroclastic rocks, including tuffs. The Amlan unconformably overlies the Magsinulo andesite and is in turn overlain by the Balinsasayao Formation (Ayson, 1987). The clasts of the conglomerate are principally hornblende andesite and subordinate pyritized and silicified rocks. The Amlan Conglomerate is well bedded and exhibits local cross-bedding. It was probably deposited during Late Pliocene.

Caliling Formation

Lithology Stratigraphic relations	Limestone, sandstone, siltstone, shale Overlaps older formations
Distribution	Mabinay, Negros Oriental; eastern coast of Negros
Age	Late Pliocene – Late Pleistocene
Thickness	500 m (Melendres and Barnes, 1957)
Previous name	Caliling Limestone (Vallesteros and Balce, 1965)
Renamed by	MGB (this volume)
Synonymy	Carcar Formation

This formation was previously named Caliling Limestone by Vallesteros and Balce (1965, in Castillo and Escalada, 1979) for the limestone along Caliling River, east of Sojoton Point in southwestern Negros Occidental. The limestone is massive to thin bedded, coralline, white to pink to yellowish, dense to conglomeratic, locally friable, marly and argillaceous. In places it contains pelecypods, gastropods, coral heads and coral fingers. Other workers (Corby and others, 1951; Melendres and Barnes, 1957; Caguiat, 1967; Yap, 1972; Porth and others, 1989) refer to the limestone extending along the length of the eastern coast as the Carcar Formation, which is its equivalent in Cebu. It is also widely exposed at Mabinay, Negros Oriental where it extends more than 25 km with a maximum width of 15 km (Amiscaray and Quiel, 1987). The Caliling unconformably overlaps the older Neogene formations. The formation is subdivided into two members: a lower limestone member and upper clastic member named Mahaba Sandstone. The upper **Mahaba Sandstone** consists of a succession of grit to pebbly sandstone with coral fragments and mollusks. The Mahaba Sandstone apparently represents the back-reef zone of a reef build-up (Amiscaray & Quiel, 1987). Foraminiferal and nannoplankton assemblages reported by Muller and others (1989) correspond to N20 -N23 and NN19 – NN 20/21, respectively, indicating Late Pliocene to Pleistocene age (Piacenzian – Late Pleistocene). The thickness of the formation as estimated by Melendres and Barnes (1957) is at least 500 m along Talave River.

Calaogao Pyroclastics

Lithology	Pyroclastic breccia, tuff, andesite
Stratigraphic relations	Unconformable over the Kalumbuyan
	Formation
Distribution	Calaogao and vicinity; Tinabanan River,
	southwestern Negros
Age	Pleistocene
Named by	Miranda and others (in Castillo and
-	Escalada, 1979)

The Calaogao Pyroclastics was named by Miranda and others (in Castillo and Escalada, 1979) for the exposures at the coastal plain near Calaogao. Outcrops are also present at the upper reaches of Tinabanan River. It lies unconformably over the Kalumbuyan Formation (MMAJ-JICA, 1990). The Calaogao consists mainly of pyroclastic breccia, tuff and associated volcanic flows. The breccia consists of pebble to cobble sizes of andesite and dacite fragments in a matrix of lithic tuff. BMG (1984) assigns a Pleistocene age for the formation. It is probably partly coeval with the eruptive products of Mt. Canlaon, Balinsasayao Formation and the Sagay Volcanics in other parts of Negros Island.

Canlaon Volcanic Complex

Lithology	Basalt, andesite, dacite
Stratigraphic relations	Occurs as volcanic edifice
Distribution	Mt. Canlaon, Mt. Mandalagon, Mt. Silay, in
	northern Negros; Cuernos de Negros in
	southern Negros
Age	Pleistocene - Recent
Named by	MGB (this volume)
Synonymy	Balinsasayao Formation (Ayson, 1987)
	Sagay Volcanics (Yap, 1972)

Canlaon Volcano, together with other volcanoes in Negros, form part of the Negros volcanic arc associated with the eastward subduction of the Sulu Basin along the Negros Trench. The volcanic edifice that forms Canlaon Volcano was built up through several episodes of pyroclastic and lava flow eruptions and at least one debris avalanche deposit (Martinez-Villegas and others, 2001). The pyroclastic flow deposits are classified by Martinez-Villegas and others (2001) as block-rich, pumice-rich, and scoriarich. Martinez-Villegas and others (2001) also identified four main types of lava flow units, namely: pyroxene andesite, hornblende-pyroxene andesite, pyroxene basaltic andesite, and olivine-bearing basalt-basaltic andesite. The earliest eruption of Canlaon, as determined by radiometric K/Ar dating. is 0.86 Ma (Sajona and others, 2000). The earliest recorded eruption of Canlaon was in 1866 (PHIVOLCS, 1997). As of 1997, Canlaon has erupted 27 times (PHIVOLCS, 1997). The other volcanoes associated with the Negros volcanic arc are Mt. Mandalagon and Mt. Silay, also in northern Negros and Cuernos de Negros in southern Negros. Mandalagon is underlain by basaltic rock while Silay is andesitic (Comvol, 1981). Radiometric K-Ar dating for andesites of Mt. Mandalagon and Cuernos de Negros ranges from 0.45 to 5.2 Ma and 0.31 to 1.97 Ma, respectively (Sajona and others, 2000). The Balinsasayao Formation of Ayson (1987) apparently corresponds to the Pleistocene eruptive products of Cuernos de Negros. The pile of andesite flows and pyroclastic rocks comprising the Balinsasayao are estimated to total at least 950 m thick (Tebar, 1984 in Ayson, 1987)

The **Sagay Volcanics** of Yap (1972), named for the Pleistocene basaltic and andesitic volcanic rocks at Sagay, is probably equivalent to the eruptive products of the Canlaon Volcanic Complex. The same may be said for the pyroclastic rocks in Kabiluhan River and Kasoy Creek reported by Domingo (1977) and those on the southeastern part of Cabanbanan area, Cauayan, Negros Occidental.

CEBU ISLAND (SG 17)

In the first edition of the Geology of the Philippines (BMG, 1981), the stratigraphy of Cebu Island was discussed under two separate headings: northern to central Cebu and southern Cebu. Stratigraphic schemes previously established for the island followed a natural chronologic succession of stratigraphic events. However, in recent years, new ideas have been forwarded regarding the origin and nature of the depositional and tectonic history of the island. Santos-Yñigo (1999) emphatically postulates that previously established formations (Tunlob Schists, Tuburan Formation, Cansi Volcanics, Pandan Formation, Baye Formation) represent allochthonous blocks distributed around the island serving as the basement rocks. Emplacement of such slabs is speculated to have occurred only after the deposition of the Baye Formation, probably during Late Eocene or Oligocene time. Likewise, Florendo (1989) believed that the older formations in Cebu were thrusted as separate blocks and not deposited in natural chronological fashion, with each being juxtaposed in a youngerover-the-older relationship. He hypothesized that the Pandan, Unnamed Paleocene and the Baye formations form a separate block (Consolacion Succession); the ultramafic rocks as a distinct slab; and the Cansi Volcanics and Tuburan Limestone (Danao Succession) as another block. These were believed to have been emplaced as thrusts or folded thrusts each representing fault-bounded bodies. Further investigations might have to be undertaken to substantiate such ideas. Hence, in this edition, discussions will still follow the normal succession of stratigraphic units.

PERIOD	EPOCH	STAGE	Ma	NORTH	CFBU	SOUTHERN CEBU	SIQUIJOR ISLAN
	HOLOCENE				0200		
	PLEISTOCENE	4 Late 3 Middle - 2 Late	0.0117 0.126 0.78 1.81	Ca	rcar Formation		Siguijor Limestone
GENE	PLIOCENE	2 Late 1 Early	2.59 3.60 5.33	~	Barili Formation		
NEG	MIOCENE	— 3 Late — — 2 Middle— — 1 Early —	7.25 11.61 13.65 15.97 20.43	Talamban Diorite Luka Fm Malub	Bulacao Andesite Uling Limestone	Linut-od Formation	Basac Formation
		o late	23.03	Cab	Envertion	Butong Limestone	
	OLIGOCENE	1 Early	28.4	Luta	k Limestone	Calagasan Formation	
PALEOGENE	EOCENE	4 Late 3 Middle 2 1 Early	33.9 37.2 40.4 48.6	Ba	ye Limestone		
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	Lutopan	Bantoon Peridotite		
EOUS	Upper	Late	65.5	Diorite	Pandan Formation	Pandan Formation	Kanglasog Volcanic Comp
CRETAC	Lower	Early	99.6	Tuburan Limestone	Cansi Basalt		
GIC	Upper	3 Late	145.5	Tur	lob Schist		
RASS	Middle	2 Middle	161.2				
5	Lower	1 Early	1/5.6				

Table 2.19 Stratigraphic column for Cebu and Siquijor Islands

Northern and Central Cebu

Tunlob Schist

Lithology	Chloritic orthoschist and micaceous paraschist
Stratigraphic relations	Unconformably overlain by the Pandan Formation and the Cansi Volcanics; overlapped on the north by Carcar Limestone
Distribution Age Named by	Restricted to the central highlands Jurassic to Early Cretaceous Santos-Yñigo (1951)

Santos-Ynigo (1951) named the metamorphic rocks underlying the central highlands of Cebu as Tunlob Schist. The rock is essentially chloritic orthoschist and micaceous paraschist belonging to the albite-epidote-amphibolite facies. The orthoschist is well exposed to the west of the Calangahan Fault and north of the Cabagdalan Fault. In these areas, particularly along Tunlob Creek, one orthoschist body extends about 10 km long and 1 km wide, mostly bounded by the younger Cansi Volcanics. In the same locality, another large outcrop covers an area measuring 7.5 km long by 2 km wide and in fault contact with the Pandan Formation. Other good exposures are in Panoypoy area, Consolacion, and along the northern section of the Lutac-Jaclupan Fault. Moreover, Porth and others

(1989) found a huge float of quartz-amphibolite schist in Sanggol Creek near Cebu City and siliceous metasedimentary rocks in Guinabasan River in northern Cebu. Likewise, micaceous paraschist was recognized upstream of Guinabasan River and along the Lutac-Jaclupan fault, 15 km west-northwest of Old Carmen (MMAJ-JICA, 1990).

The Tunlob Schist is strongly foliated, folded and faulted. The faults apparently controlled the subsequent intrusion of serpentinite. In northern Cebu, it is unconformably overlain by the Carcar Limestone. It is uniform in mineralogic composition both laterally and vertically across the foliation. The Tunlob consists of chlorite, fibrous tremolite or hornblende, albite and variable amounts of epidote, calcite, quartz and actinolite. Bull quartz occurs as lenses along and across the foliation planes. The light and darkcolored constituents generally tend to segregate into crude layers. Due to its uniformity in composition and distribution of crude layers, the protolith of the Tunlob is postulated to be of igneous origin (Santos-Yñigo, 1951).

Along principal fault zones, coarse-grained chlorite and hornblende schists are closely associated with serpentinite, especially near diorite intrusions. These schists are of local occurrence and inferred to have developed much later than the Tunlob and Panoypoy schists.

Previous workers (Santos-Yñigo, 1951; BMG, 1981; Kerntke, 1991 in Diegor and others, 1996) believe that the Tunlob formed during pre-Cretaceous time, probably Jurassic, or Early Cretaceous.

Mananga Group

The Mananga Group was designated by Balce (1970) for the sequence of formations exposed at Mananga Valley. The Group is composed of the Tuburan Limestone, Cansi Basalt and Pandan Formation. These units were found to have intertonguing, gradational or conformable relation to each other. The Group occurs mainly in the central highlands, either in fault contact or unconformable to the younger formations.

Tuburan Limestone

Lithology	Orbitolina- rich limestone
Stratigraphic relations	Underlies or intertongues with the Cansi Volcanics.
Distribution	Cansi-Tuburan area, in Mananga Valley; western Tuburan-Asturias area; Mago locality; Duangan locality near Balamban; along Maypay ridges; southwestern range of the southeastern highlands between Campo 2 and 7: between Bulageo and
	Dita; Pulangbatu River and at Camp 5 near Tabunoc.
Age	Early Cretaceous
Thickness	Limestone patches seldom exceed 20 meters
Named by	Santos-Yñigo (1951)

This limestone unit refers to the Orbitolina-bearing small ridge-top remnants exposed in Tuburan, northern Cebu. Its designated type locality is in Langoven River gorge near Barrio Marmol, Tuburan. Based on the original description of Santos-Yñigo (1951), the unit was recognized as a distinct formation. Limestone patches are found in the western Tuburan-Asturias area; west of Calangahan Fault; Mago locality in the central northern highlands; Duangan locality near Balamban; along Maypay ridges in the central highlands: southwestern range of the southeastern highlands between Camps 3 and 7; in the northeastern range between Bulacao and Dita; and north of Cabagdalan Fault. These were also observed in the Cansi-Tuburan area, in Mananga Valley, Pulangbatu River and at Camp 5 near Tabunoc. Thin orbitoid-rich limestone has been observed to lie directly on the volcanic rocks of the Cansi while elsewhere clasts of the limestone were found admixed in the volcaniclastic facies, which probably indicates an intertonguing relationship between the volcanic rocks and the limestone. Pebbles of the limestone were likewise identified in the Maingit Formation at Maingit River (Porth and others, 1989).

The limestone is light to dark gray with shades of buff or brown. It is usually orbitolinid-bearing, micritic, pelletoidal, with debris of pelecypods, algae and foraminifera. It is conglomeratic at the base, consisting of angular fragments of basalt and crystallized limestone. In places, patches whose longer dimension measure 450-100 m were found resting over the Tunlob Schist. In northeastern Maypay area, the limestone was found intruded by the Maypay Diorite.

Samples from Tuburan were found to contain abundant orbitolinids. These were identified by Amiscaray and Tan (1984) as *Orbitolina (Mesorbitolina) texana* (Roemer) and *Orbitolina kurdica* Henson. This assemblage points to an Early Cretaceous age. An age range of probable Aptian to Albian was given by Gramann (1983, in Porth and others, 1989). Masse and others (1996) also reported caprinid rudists, corals, sponges, stromatoporoid, red algae and foraminifers from limestones collected along Pulangbatu River, an area close to Cebu City and at Camp 5 near Tabunoc. The rudists were initially ascribed to the Genus *Amphitriscoelus*, a Lower Albian indicator (Wolcke and Scholz, 1988). Further examination of the rudists however, revealed that the species belong to a genus related to *Pachytraga* Paquier (1905), which indicates a Late Aptian age. Corroborative foraminiferal species *Orbitolina (Mesorbitolina) texana* group and *Neorbitolinopsis conulus* supports a Late Aptian age for the Tuburan Limestone.

Cansi Basalt

Lithology	Andesite and basaltic flows; agglomerate
Stratigraphic relations	Blankets the basement rocks of Cebu;
	overlies or intertongues with the Tuburan
	Limestone
Distribution	Cebu central highlands
Age	Early-Late Cretaceous boundary
Thickness	300-500 m
Previous name	Cansi Volcanics (Santos – Yñigo, 1951)
Renamed by	BMG (1981)

In the central highlands, pillow lava, flow breccia and agglomerates roughly blanket the basement rocks. These rocks were collectively termed Cansi Volcanics by Santos-Yñigo (1951). The unit is typically exposed in the Tuburan area. Patches of the volcanic rocks also crop out in the Cantabaco-Tabunoc road, Cabalawan plateau and along Mananga River. Balce (in Hashimoto, 1977) renamed it as Cansi Formation to include the adjacent Tuburan Limestone. Such classification was followed by BMG (1981). However, subsequent workers still regard it as a separate formation (Porth and others, 1989; Muller and others, 1989; Buchsel and others, 1991). The thickness of the Cansi ranges from 300 m to 500 m.

Petrologically, the Cansi ranges from typical basalt to pyroxene andesite. Thin layers of chert were also observed intercalating with the basalt. The rocks are generally gray, fine-grained occasionally with porphyritic and amygdaloidal textures. Observed effects of alteration are silicification, pyritization, sericitization, kaolinization and chloritization with minor degree of epidotization.

Though no fossil was recognized in the Cansi, Cretaceous age was inferred for the unit, probably near the Early-Late Cretaceous boundary (Buchsel and others, 1991). This assumption was based on the close affinity of the volcanics with the Tuburan Limestone. The thickness of the unit ranges from 300 m to 500 m.

Pandan Formation

Lithology	Limestone, shale and conglomerate
Stratigraphic relations	Unconformable over the Cansi Basalt
Distribution	Pandan Valley, Naga; Manipis Road
Age	Late Cretaceous
Thickness	2,000 m
Named by	Corby and others (1951)
Age Thickness Named by	Late Cretaceous 2,000 m Corby and others (1951)

The Pandan Formation was originally described as a wide assortment of metamorphosed limestone, shale and conglomerate, with occasional coal stringers named by Corby and others (1951) after the type locality at Pandan River, Barrio Pandan, Naga, near the Naga-Uling road. It is also exposed along Manipis Road between Toledo and Tabunoc in central Cebu and in Sanggol River near Cebu City. The beds are greenish gray, highly contorted and steeply dipping. Aside from the limestone and clastic sequences, thick layers of thin bedded chert and pillow basalt intercalations were also mapped as part of the Pandan (Santos-Yñigo, 1951). The limestones are usually *Globotruncana*- bearing, silty and sometimes siliceous. The intercalated shales are black, laminated to thinly-bedded, with calcareous concretions. The thickest section is found in the northern highland between Tuburan and Catmon where the shale and other slightly metamorphosed sediments are recrystallized into dark hornfels (MMAJ-JICA, 1990). In places, the basalt flows are chloritized or epidotized.

BMG (1981) also included the unnamed Paleocene formation of Balce (in Hashimoto and others, 1977) in the Pandan Formation. These Paleocene sections consist of subgraywackes, chocolate brown to gray shale and argillaceous limestone. The rocks crop out on the eastern and western flanks of the Pandan anticline. Porth and others (1989), however, did not find any Paleocene rocks in the Pandan area.

Globotruncana species recovered from the limestone and clastic rocks indicate a Late Cretaceous age for the Pandan. The estimated thickness of the Pandan is 2000 m.

Bantoon Serpentinite

Lithology	Serpentinized peridotite
Stratigraphic relations	Intrudes the Tunlob Schist and Pandan
	Formation; in fault contact with the Cansi
	Volcanics and Tuburan Limestone
Distribution	Tunlob, Calangahan, Toledo-Tabunoc
	road and Mago areas
Age	Late Cretaceous to Paleocene
Previous name	Serpentinized Peridotite (informal)
Renamed by	MGB (this volume)

This unit was informally designated by Santos-Yñigo (1951) as serpentinized peridotite in reference to the lenticular bodies of serpentinite widely occurring in the principal fault zones of central Cebu. The largest mapped exposure is along the Toledo-Tabunoc road where it crosses the ridge at Camp 7. It measures about 3.5 km long and 0.4 km wide. It also outcrops west of Bantoon Valley; in the Tunlob, Calangahan and Mago areas; along the Cabagdalan, Cueva, Maypay and Malubog faults; and along Lutac-Jaclupan, Cagahoan and Cambaog faults in the southeastern range. The rock consists of clinopyroxene and olivine, which have been altered to serpentine minerals with small amount of anhedral plagioclase and hornblende. Surface exposures suggest that they intrude the Pandan Formation, Tunlob Schists and the Cansi Volcanics. Sections of the Pandan may sometimes be found enclosed within these serpentinite bodies as observed in one exposure along Bairan Creek in Naga (Santos-Yñigo, 1951).

Serpentinite subjected to recurrent shearing movements resulted in the development of wide breccia and/or foliated zones accompanied by gouge materials. Intrusion was inferred during Late Cretaceous to Paleocene time probably after the emplacement of the Tunlob Schist, Cansi Volcanics and the Pandan Formation.

Lutopan Diorite

Diorite, quartz diorite; andesite, dacite,
gabbro
Intrudes Cretaceous sedimentary and
volcanic rocks
Lutopan, Barot-Udlom, Sibakan, and
Kuanos-Mangilamon areas; Calangahan
and Guadalupe districts
late Early Cretaceous – Early Eocene
Santos-Yñigo (1956)

Synonymy	Lutopan Porphyry (Santos-Yñigo, 1956);
	Barot diorite (Santos-Yñigo, 1951)

The Lutopan Diorite refers to northeast trending elongated masses of diorite and related intrusive rocks that occur as stocks and dikes intruding the Cretaceous sedimentary and volcanic rocks of the Cebu central highlands. They are exposed in the Lutopan, Barot-Udlom, Sibakan and Kuanos-Mangilamon areas. Small diorite bodies also crop out in the Calangahan and Guadalupe districts.

The best known intrusive stock is the Lutopan Porphyry (Santos Yñigo, in Kinkel and others, 1956) consisting of hornblende diorite and hornblende quartz diorite. The diorite is pale gray, medium- to coarse-grained and composed of 50-70% andesine, 10-20% hornblende and biotite set in a matrix of feldspar and mafic minerals. The unit intrudes the Pandan Formation at Lutopan area.

Another diorite body, which is equivalent to the Lutopan is the **Barot Diorite** of Santos Yñigo (1951). The diorite is generally porphyritic, grading into hornblende andesite or dacite, which appear to be its border facies. It contains 40-50% andesine, 30-35% quartz, 5-20% chlorite and less than 5% biotite. Secondary sericite and kaolin from plagioclase vary widely in concentration from place to place. Common accessory minerals include magnetite, apatite and zircon. The Barot stock is occasionally cut near the immediate contact zone by quartz veinlets containing base metal sulfides and iron ore minerals.

Coarsely crystalline mafic and alkaline differentiates of the diorite magma range from dark, coarse-grained or pegmatitic gabbros to almost pure plagioclase pegmatites (Santos-Yñigo, 1951). Gervasio (1971) reports a radiometric K-Ar dating of 59.5 Ma for the Lutopan Diorite. Subsequent radiometric K-Ar dating by MMAJ-JICA (1989) indicates an Eocene age (50.7 \pm 2.5 Ma). Radiometric K-Ar dating by Walther and others (1981) of three samples from Biga and Frank deposits in Atlas mine indicates an age of 101-108 Ma. A radiometric Rb-Sr dating of the sample from Frank deposit indicates an age of 107 Ma, which conforms to the K-Ar dating of a sample from the site. Multiple phases of intrusion are therefore suggested for the diorite bodies in Lutopan.

In hydrothermally altered zones the major components are sericite, quartz, kaolin and epidote. Contact zones with the Cansi Volcanics are marked by strong shear and intense epidotization.

Baye Limestone

Lithology	Nummulitid- bearing limestone
Stratigraphic relations	Overlies the formations of the Mananga
	Group
Distribution	Pandan River
Age	Middle to Late Eocene
Thickness	20 m
Previous Name	Baye Formation (Balce, 1974)
Renamed by	MGB (this volume)

The Baye Limestone is a 20-meter thick fossiliferous limestone that was first termed Unnamed Limestone by the Bureau of Mines Petroleum Division (1966). Balce (1974) named it Baye Formation. This unit crops out on the eastern flank of the Pandan anticline along Pandan River. It was given an Eocene age on the basis of *Nummulites*. This is apparently the same as the *Flosculina*- bearing limestone described by Santos-Ynigo (1951) and *Distichoplax*-bearing limestone from the Asturias area (Villavicencio and Andal, 1964). Paleontological age determination of a sample by Weiss and Gramann (1985, in Porth and others, 1989) indicate an age of Middle to Late Eocene for the formation. The Baye directly overlies the formations of the Mananga Group.

Lutak Limestone

Articulated nummulitid-bearing limestone
Unconformable over the Pandan
Formation
Restricted in the Lutak Hill area
Middle Oligocene
80 m
Balce (1974)

Lutak Limestone was named from its typical occurrence in the southern slope of Lutak Hill, in the middle part of Pandan Valley, central Cebu (Balce, 1974). Another outcrop is exposed at Sitio Inamuan, south of Lutak where it unconformably overlies siltstones of the Pandan Formation (Foronda, 1994). The exposure at Inamuan has a thickness of about 80 m. It consists mainly of bedded packstone and floatstone with bioclasts of corals, large benthic foraminifers and some corallinacean algae (Foronda, 1994). It is generally massive, light gray, sandy and fossiliferous. Fossils indicative of an Oligocene age include Nummulites fichteli (Michelotti), Lepidocyclina (Eulepidina) dilatata (Michelotti), Lepidocyclina (Nephrolepidina) isolepidionoides (Van der Vlerk) and Nummulites intermedius (d' Archaic). The formation was, however, dated Early Oligocene based on the presence of Nummulites fichteli. The extinction of this species extends to Middle Oligocene. Middle Oligocene nannofossil assemblages were reported by Muller and others (1989) from the clastic equivalent of the limestone facies outcropping at the western side of Mt. Lantauan, Danao. These are: Dictyococcites dictyodus, Sphenolithus predistentus and Sphenolithus distentus typical of zone NP 23; Helicosphaera recta, Sphenolithus distentus, Sphenolithus ciperoensis and Cyclicargolithus abisectus typical of NP 24.

Talamban Diorite

Lithology	Diorite, quartz monzonite
Stratigraphic relations	In fault contact with Tunlob Schist
Distribution	Talamban area
Age	late Middle Miocene
Named by	MMAJ-JICA (1990)

Small stocks of diorite and quartz monzonite in the western part of central eastern Talamban in fault contact with the Tunlob Schist were designated by MMAJ-JICA (1990) as Talamban Diorite. It is mainly coarsearained quartz monzonite containing euhedral to subhedral plagioclase. euhedral guartz, potash feldspar and hornblende. This unit probably includes the diorite bodies exposed in Maypay, Talamban and Matugan areas as described by Santos-Yñigo (1951). In these localities, the medium to coarse-grained diorites consist essentially of 60-70% anhedral to subhedral aggregates of plagioclases (oligoclase-albite), 5-10% quartz, 12-30% hornblende and biotite and 5% accessory minerals (magnetite, apatite, titanite and zircon). In hydrothermally altered zones the plagioclases are pervasively replaced by sericite, quartz, kaolin, chlorite and epidote. Its contact with the Cansi Volcanics is marked by strong shears and intense epidotization. Similar to the Maypay and Matugan diorites are the diorites at Mangilamon and Sibakan, except for the pink coloration of the plagioclases. Radiometric K-Ar dating (10.2 to 12.5 Ma ± 0.5-0.6 Ma) obtained by MMAJ-JICA (1990) indicates a late Middle Miocene age.

Naga Group

Santos-Yñigo (1956) introduced the name Naga Group for the intertonguing formations exposed along the Naga-Uling Road in central Cebu, consisting of the Cebu Formation and Malubog Formation. The Guindaruhan Conglomerate served as the base of the unit, which signalled the initial transgression and start of basin formation in Cebu. Paleontological and sedimentological studies confirmed that the deposition of these formations is interrelated and hence should be ranked under one group.

• Cebu Formation

Members	Lower Coal Measures, Ilag Limestone
Age	Late Oligocene
Named by	Corby and others (1951)

The Cebu Formation, as defined by Corby and others (1951), consists of two members: Cebu Coal Measures and Cebu Orbitoid Limestone. In conformity with the Philippine Stratigraphic Guide (2001), the Cebu Coal Measures and Cebu Orbitoid Limestone are hereby renamed Lower Coal Measures and Ilag Limestone, respectively. In this way, we avoid the use of the same locality name applied to both the unit of a higher rank and to any of its part.

Lower Coal Measures

Lithology	Basal conglomerate grading to successions of sandstone, siltstone and mudstone occasionally with coal and conglomerate interbeds
Stratigraphic relations	Unconformable over Lutak Limestone and other older rocks
Distribution	Naga-Uling, Danao and adjacent areas

Age	Probably Late Oligocene
Thickness	15 - 58 m
Previous name	Cebu Coal Measures (Corby and others,
	1951)
Renamed by	MGB (this volume)
Synonymy	Guinibasan Conglomerate (Santos-Ynigo,
	1956)
	Guindaruhan Conglomerate (Balce, 1974)

The Lower Coal Measures was originally designated as Cebu Coal Measures by Corby and others (1951) and represents the lower member of the Cebu Formation. This also includes the **Guindaruhan Conglomerate** of Balce (1974, in Hashimoto, 1977) and **Guinibasan Conglomerate** of Santos-Ynigo (1956).

The base of the section is dominated by clast- to matrix-supported conglomerate with coarse sandstone interbeds that grades into alternations of sandstone, siltstone and mudstone and minor coal seams and conglomerate. The conglomerate is 10 - 15 m thick. It is well compacted, cobbly to pebbly, composed of sub-angular to sub-rounded clasts of volcanic rocks, quartz, pyroclastic fragments and chert. The basal conglomerate is well exposed in the Guindaruhan and Guinibasan areas. The middle portion represents alternations of loosely compacted, thin to moderately thick beds of sandstone and shale with occasional lenses of conglomerate and coal. Coal seams found in the lower part of the unit appear to be extremely lenticular, averaging less than 2 m in thickness. The coal measures are relatively thin, ranging in thickness from 15 m to a maximum of 58 m (Balce, 1964; Foronda, 1994).

The coal measures are exposed in a narrow belt in the Uling area northwest of Naga, west of Compostela and in the Toledo area west of central Cebu. They are also exposed between Moalboal on the west coast, and Argao on the east coast, Butong and Mantalongon, Dalaguete.

• Ilag Limestone

Lithology	Orbitoid-rich limestone
Age	Late Oligocene
Thickness	Quite variable and often lenticular (≤ 60 m)
Named by	Santos-Yñigo (1956)
Synonymy	Cebu Orbitoid Limestone (Corby and
	others, 1951);
	Cebu Limestone (Smith, 1924)

This unit was originally introduced by Smith (1924) as Cebu Limestone for the well bedded orbitoid-rich limestone typically exposed along the Naga-Uling road in central Cebu. The same locality name was applied by Corby and others (1951) for a similar limestone unit but was designated as the "Cebu Orbitoid Limestone" due to the ubiquity and prevalence of platelike *Lepidocyclina (Eulepidina) richthofeni* Smith in the limestone. Aside from orbitoids, other foraminifers, algae and molluscan fragments were also identified. Santos-Yñigo (1951) later referred to this unit as Ilag Limestone. The limestone is white to buff, dense, crystalline, thickly to thinly-bedded, sometimes marly. At the type area, thin alternations of sandstone and shale were also observed. The unit conformably overlies and occasionally intertongues with the Uling Coal Measures. The thickness is quite variable but rarely exceeds 60 m.

• Malubog Formation

Lithology	Mudstone, shale, limestone, minor
Stratigraphic relations	Conformable over the Cebu Formation
Distribution	Malubog, northeast of Toledo; exposed
	from Catmon to Naga, including Toledo
	area; between Butong and Mantalongon;
	east of Alegria; west of Boljoon
Age	Late Oligocene – Early Miocene
Thickness	500m – 1,200 m
Named by	Corby and others (1951)

The name Malubog Formation was designated by Corby and others (1951) for the exposures near Barrio Malubog, northeast of Toledo. However, the type section was defined at Sapang Daku River, Media Once area (Huth, 1962). In the Uling region, the Malubog was originally divided into a lower Cantabaco Mudstone Member and an upper Alpaco Member. The Alpaco was further subdivided into a lower Binabac Limestone, a lower coal measure, an upper Binabac Limestone and upper coal measure. Santos-Yñigo (1951) later divided the Malubog into three members, a lower Cantabaco; a middle Binabac Limestone and an upper Alpaco Coal Measures, Here, the Malubog is divided into a lower Cantabaco Mudstone Member and an upper Alpaco Member. The Cantabaco Mudstone consists dominantly of shales and mudstones with local lenticular limestone beds at the base and minor thin sandstone interbeds and coal stringers toward the upper part. The term Alpaco Member was named by Smith (1924) after its type locality in Barrio Alpaco, Naga. It includes the lower Binabac Limestone, a lower coal measure, an upper Binabac Limestone and an upper coal measure. East of Alegria the unit was noted to yield mega- and microfossils. The sandstone and siltstone are usually carbonaceous in association with some coal seams.

In the type area at Malubog, the unit consists of a lower, dark-colored, pyrite-bearing, slightly indurated, mudstone overlain by somewhat coarser, coal-bearing horizons intercalated with limestone beds, and in turn overlain by a lighter colored, softer, ferruginous, impure mudstone (Huth, 1962). Coal seams are intercalated with the clastic beds, particularly in the upper sections.

The Malubog is almost continuously exposed from Catmon to Naga, including Toledo. It occurs in a broad belt in the Uling area. To the south, large exposures of the formation are found between Butong and Mantalongon as well as east of Alegria and west of Boljoon, near barrio Lunop.

The Malubog conformably rests over the Cebu Formation. Porth and others (1989) considered this as the deeper clastic facies of the Cebu

Limestone because both units belong to the NP25 biozone (Late Oligocene). Foronda (1994), however, extended the age date of lower Malubog Formation to NN1 zone (earliest Miocene). The lower Malubog is about 460 m thick in the Naga-Toledo city area (Foronda, 1994). The thickness, as estimated by Corby and others (1951), ranges from 500 m near southern Cebu to 1,200 m near Uling.

Uling Limestone

Lithology	Biocalcarenite, biomicrite
Stratigraphic relations	Conformable over the Malubog formation;
	in places interfingers with the Toledo
	Formation
Distribution	Exposed in a continuous belt from Mount
	Uling, southward and westward towards
	Toledo; also from Liloa to Catmon
Age	Middle Miocene
Thickness	200 - 250 m
Previous name	Mount Uling Limestone (Corby and others,
	1951)
Renamed by	Balce (1974)

Uling Limestone was originally designated as Mount Uling Limestone by Corby and others (1951). This was later renamed by Balce (1974) as Uling Limestone. It consists of dense biocalcarenites and biomicrites, frequently with abundant head corals admixed with red algae and some benthic foraminifers. The unit was described as a transgressive limestone conformably overlying the Malubog Formation. In places, it interfingers with the Toledo Formation (ESCAP, 1978; Porth and others, 1989). The Uling Limestone occurs in the northern and eastern parts of the central highlands. Porth and others (1989) consider the Uling Limestone as the shallow water equivalent of the Toledo Formation. The Uling is conformable to the Luka Formation and appears to be deposited in a coral shoal / back-reef / lagoonal environment (Porth and others, 1989). The Uling is assigned a Middle Miocene age. It is estimated to be 200 -250 m thick.

Luka Formation

Lithology	Sandstone, conglomerate and mudstone
	with limestone lenses
Stratigraphic relations	Unconformable over the Malubog
	Formation
Distribution	Luka area northeast of Balamban
Age	Middle Miocene
Named by	Santos-Yñigo (1951)

The Luka Formation was introduced by Santos-Yñigo (1951) for the alternating beds of sandstone, conglomerate and mudstone with limestone lenses exposed in the west coast, about 15 km east-northeast of Balamban. It is unconformable over the lower Malubog Formation. The age of the formation is Middle Miocene.

Bulacao Andesite

Lithology	Andesite flows and pyroclastic rocks
Stratigraphic relations	Not reported
Geographic distribution	southwestern range of central Cebu
Age	Middle – Late Miocene
Named by	Santos-Yñigo (1951)

The Bulacao Andesite of Santos-Yñigo (1951) is essentially a porphyritic and brecciated andesite made up of phenocrysts of andesine, hornblende, augite and hypersthene in a glassy microlitic groundmass. Magnetite and apatite are the common accessory minerals. The unit is well exposed in the southwestern range of central Cebu. Exposures in the Central Highlands consist of massive volcanic flows and pyroclastic rocks (MMAJ-JICA, 1990). Outcrops of the andesite are fairly fresh but are usually cut by stringers of barren chalcedony and quartz. Alteration of the andesite is confined in parts around the Talamban Diorite and manifests as products of pyritization, silicification and epidotization with minor argillization. It is associated with the lead-silver-quartz carbonate veins in the Mabini area. The Bulacao Andesite is considered Middle to Late Miocene in age.

Talavera Group

The Talavera Group was introduced by Huth (1962) for the exposures cropping out in the hills bordering western Cebu east of Talavera Bay and the municipality of Talavera located in central Cebu. These consist of Toledo and Maingit formations that were earlier described by Corby and others (1951).

• Toledo Formation

Litholog	Shale, sandstone, conglomeratic limestone
Stratigraphic relations	Conformable over Uling Limestone and grades upward into the Maingit Formation
Distribution	Toledo area, Talisay, Tabunoc - Toledo road, Cebu Central Highlands, vicinity of Pinamungahan, in Asturias and from Danao to Daan-Catmon on the west
Age	Middle Miocene
Thickness	620 m - 1,860 m
Named by	Corby and others (1951)

The Toledo formation was named by Corby and others (1951) for the rocks exposed south of the Toledo-Tabunoc road approximately 4 km northeast of Toledo. At Toledo, the formation lies conformably over the Uling Limestone, but Porth (1984) noted intertonguing between the two units along the nearby Media Once – San Miguel Road and Buga Valley. At its type locality, the basal part consists of 15 m of fossiliferous conglomeratic limestone. This is overlain by a thick, calcareous, tuffaceous and locally bentonitic white shale and sandstone with occasional beds of sandy to conglomeratic limestone and gray brown shale. The sandstone is essentially carbonaceous, calcareous and tuffaceous. Outcrops of the unit

have been observed in the outer margins of Cebu Central Highlands, in the vicinity of Pinamungahan, in Asturias and from Danao to Daan Catmon on the west. The Toledo rests unconformably over the Malubog Formation. The boundary between the Toledo and the underlying Malubog Formation is marked by an angular unconformity.

Large foraminifers that have been noted in samples from the formation include *Cycloclypeus*, *Lepidocyclina* (B-form), *L. (Nephrolepidina), L. (Nephrolepidina - Trybliolepidina), Miogypsina* (A-form), indicating a Middle Miocene age.

The thickness of the formation ranges from 620 m to 1,860 m.

• Maingit Formation

Lithology	Limestone, conglomerate, sandstone, mudstone, shale
Stratigraphic relations	Unconformably overlain by the Barili Formation.
Distribution	Maingit River south of Balamban; exposures extend southward to Pinamungahan
Age	late Middle Miocene – early Late Miocene
Thickness	1,175 m
Named by	Corby and others (1951)

The Maingit Formation was designated by Corby and others (1951) for the exposures at Maingit River south of Balamban. The exposures extend southward to Pinamungahan, about 4 km northeast of Barili. The Maingit may be divided into three members: a lower limestone, a middle conglomerate, and an upper sandstone and shale sequence. The lower limestone is coralline but contains few microfossils. It is a lenticular member, which attains a thickness of only 50 m. The conglomerate member has interbeds of poorly sorted sandstone. The middle member is about 575 m thick. The clasts of the conglomerate range from pebbles to boulders of basement rocks and limestone that measure up to 15 cm in diameter. The upper member of the Maingit consists of sandstone and shale with stringers of coal and occasional thin beds of limestone. The thickness of the upper member is about 550 m. The formation has an aggregate thickness of 1,175 m.

Some of the large foraminifers identified in samples from the Maingit include *Alveolinella, Lepidocyclina (Nephrolepidina), L.* (B-form) and *Miogypsina* (A-form), indicating a probable late Middle Miocene age. Porth and others (1989) however, report an age of Late Miocene based on nannoplanktons (NN11) and therefore, consider the Maingit as a facies of the Barili Formation. Here, the age of the Maingit is regarded as spanning late Middle Miocene to early Late Miocene time (Serravallian-Tortonian).

Barili Formation

Lithology	Limestone, calcareous mudstone,
Stratigraphic relations	Unconformable over the Maingit
	Carcar Limestone
Distribution	Barili; Pinamungahan-Naga area; Danao-
	Carmen area; Alegria-Malabuyoc area;
	along Sibonga-Dumanjug and
	Mantalongon-Aloguinsan roads; Boundary-
	Sanggi area
Age	Late Miocene – Early Pliocene
Named by	Corby and others (1951)

Corby and others (1951) originally named the rock unit after the town of Barili in southern Cebu. The designated type locality is along the Carcar-Barili road between Sibonga anticline in central Cebu and the town of Barili. Exposures have been observed near the center of the island and persist south to Ginatilan. Outcrops can also be found north of Barili, in a small area between Pinamungahan and Naga, at the Danao-Carmen area, southwest of Bogo, in the Alegria-Malabuyoc area, along the Sibonga-Dumanjug and Mantalongon-Aloguinsan roads, as well as in the Boundary-Sanggi area. The Barili is unconformable over the Maingit and Toledo formations. Corby and others (1951) subdivided the Barili into lower Barili Limestone and upper Barili Marl. In line with the provisions of the Philippine Stratigraphic Guide (2001), the members of the formation are here renamed **Lower Limestone Member** and **Bolok-bolok Member**.

• Lower Limestone Member

Lithology	Coralline limestone, basal conglomerate
Stratigraphic relations	Unconformable over the Maingit Formation
	and conformably overlain and partly
	intertongues with the Bolok Bolok Member
Age	Late Miocene
Thickness	200-350 m
Previous name	Barili Limestone (Corby and others, 1951)
Renamed by	MGB (this volume)

The lower limestone member of the Barili is predominantly cream to buff, hard, coralline, locally porous or sandy and richly fossiliferous with a thickness ranging from 200 to 350 meters.

Large foraminifers contained in the limestone belong to the following genera: *Cycloclypeus, Lepidocyclina (Trybliolepidina) and Miogypsina sp.* The age of the limestone is Late Miocene. Deposition is inferred to be in a lagoonal to reefal setting

Bolok-bolok Member

Lithology	Light-colored, calcareous, highly foraminiferous mudstone; Minor
	sandstone, conglomerate, limestone, shale
Stratigraphic relations	Unconformably overlain by the Carcar
	Limestone
Distribution	Bolok bolok Hot Springs, east of the town
	of Barili; Barili area; Bago-Medellin area;
	Malabuyoc area
Age	Late Miocene to early Early Pliocene
Thickness	500 m
Previous name	Bolok Formation (Huth, 1962)
Renamed by	Maac (1983)
Synonymy	Barili Marl (Corby and others, 1951)

The term Barili Marl was originally introduced by Corby and others (1951) for the clastic portion of the Barili Formation. Huth (1962) however, raised it to the rank of formation and assigned the name Bolok Formation for this clastic member. Its designated type locality is in Bolok-bolok Hot Springs east of the town of Barili. Maac (1983) however, considered it as a member and designated it as Bolok-bolok Member.

The typical Bolok-bolok Member is cream to light gray, calcareous, highly foraminiferous, dominantly silty, mudstone with interbeds of siltstone and sandstone. In places basal carbonaceous shale is present and in other places, the basal portion is characterized by poorly bedded, lenticular sandstones and conglomerates. The Bolok-bolok attains a thickness of 500 m. Deposition probably took place in a deep basinal environment during Late Miocene to early Early Pliocene time.

Carcar Limestone

Coralline, porous, dolomitic limestone
Boundary with underlying Barili Formation
is characterized by angular discordance
Practically fringes most of the coastal
areas of Cebu except in a narrow strip
between Ginatilan and Malabuyoc in the
south
Probable Late Pliocene to Pleistocene
300 m (average); 375 maximum
Corby and others (1951)
Carcar Formation (BMG, 1981)
Cortes Limestone in Bohol, Caliling
Limestone in Negros and Hubay
Limestone in northwest Leyte

The name Carcar Limestone was introduced by Corby and others (1951) for the young coralline limestone fringing most of the coastal areas of Cebu Island. The type locality is located in the municipality of Carcar, between the coastal areas east of the town proper of Carcar up to a point approximately 3 km west of the poblacion. The Carcar is porous, coralline,

bedded to massive and fossiliferous, in places dolomitic. Intercalations of marls and gradation into rubbly to conglomeratic limestone have been observed. It is usually hard but generally cavernous. Muller and others (1989) confirm a Pleistocene age for the Carcar on the basis of nannoplankton and foraminifers identified in a few marly samples. However, it is believed that the age of the Carcar may extend down to Late Pliocene (Porth and others, 1989). Abundant mollusks, corals, algae and foraminifers suggest shallow marine deposition for the unit. The average thickness is about 300 m. The thickest section was encountered in northern Cebu, which measured to about 275-375 m (Porth and others, 1989).

Southern Cebu and Siquijor Island

The basement rocks and the coal bearing formations of southern Cebu crop out as erosional windows in the central highlands. They generally strike north-northeast and dip southwest. In this edition, the stratigraphic subdivisions recognized in Siquijor Island are likewise equated with stratigraphic units identified in southern Cebu.

Pandan Formation

Lithology	Limestone, shale and conglomerate
Stratigraphic relations	Unconformable over the Cansi Volcanics
Distribution	Pandan Valley, Naga; Manipis Road
Age	Late Cretaceous
Thickness	2,000 m
Named by	Corby and others (1951)

The Pandan Formation was originally described as a wide assortment of metamorphosed limestone, shale and conglomerate, with occasional coal stringers (Corby and others, 1951). Its name is derived from its type locality at Pandan River, Barrio Pandan, Naga near the Naga-Uling road. It is also exposed along Manipis Road between Toledo and Tabunoc in central Cebu and in Sanggol River near Cebu City. The beds are greenish gray, highly contorted and steeply dipping. Aside from the limestone and clastic sequences, thick layers of thin bedded chert and pillow basalt intercalations were also mapped as part of the Pandan (Santos-Yñigo, 1951). The limestones are usually Globotruncana- bearing, silty and sometimes siliceous. The intercalated shales are black, laminated to thinlybedded with calcareous concretions. The thickest section is found in the northern highland between Tuburan and Catmon where the shale and other slightly metamorphosed sediments are recrystallized into dark hornfels (MMAJ-JICA, 1990). In places, the basalt flows are chloritized or epidotized.

BMG (1981) also included the unnamed Paleocene Formation of Balce (in Hashimoto and others, 1977) in the Pandan Formation. These Paleocene sections consist of subgraywackes, chocolate brown to gray shale and argillaceous limestone. The rocks crop out on the eastern and western flanks of Pandan anticline. Porth and others (1989), however, did not find any Paleocene rocks in the Pandan area. *Globotruncana* species recovered from the limestone and clastic rocks indicate a Late Cretaceous age for the Pandan. The estimated thickness of the Pandan is 2000 m.

Argao Group

The Argao Group (Barnes and others, 1958) represents the oldest sedimentary deposits mapped in southern Cebu. Its type locality is along the upper course of the Argao River. A composite type section for the unit was indicated along Maangtud Creek and Calagasan Creek (Huth, 1962). It is composed of three formations - Calagasan Formation, Butong Limestone and Linut-od Formation. Fossil contents identified in the Argao Group ranges from Late Oligocene to Early Miocene.

• Calagasan Formation

Lithology	Conglomerate, sandstone and shale with coal and limestone interbeds
Stratigraphic relations	In fault contact (Tacliad Fault) with the
	Pandan Formation; conformable or
	intertonguing with the overlying Butong
	Limestone
Distribution	Calagasan Creek in Barrio Calagasan,
	Argao; well exposed in a narrow elongated
	zone in the Argao-Dalaguete district; also
	west of the town of Boljoon
Age	Late Oligocene
Thickness	about 1,300 m maximum
Named by	Barnes and others (1958)
Correlation	Lower Coal Measures of Cebu Formation
	in northern Cebu; Kanglasog Formation

The Calagasan Formation was named by Barnes and others (1958) for the exposures of a thick succession of conglomerate, sandstone, mudstone and carbonaceous shale with interbedded limestone and coal at Barrio Calagasan, Argao. The basal beds consist dominantly of conglomerate with interbeds of coarse- to medium-grained sandstone. This grade into finer clastic rocks upsection. The conglomerate is dark greenish gray to yellowish brown with cobbly to pebbly sub-angular to sub-rounded clasts of andesite, quartz, indurated shales and chert with occasional jasper and dense limestone. The middle to upper components of the formation is predominantly sandstone and mudstone with sporadic lenses of limestone, coal beds and coal stringers. Coral- and orbitoid-rich limestone lenses are often set in sandy or shaly matrix. The sandstone is greenish gray, poorly sorted and carbonaceous while the shale is brown to dark greenish gray, thinly-bedded, and also carbonaceous.

Well bedded successions were observed along Cauluhan Creek in Calagasan, Argao and in Maangtud Creek in Mantalongon, Dalaguete. At Cauluhan Creek, the measured thickness totals 720 m while at Maangtud Creek a maximum thickness of about 1,300 meters was estimated. Based on the large benthic foraminifers in the rocks, the formation is dated Late Oligocene.

This is the equivalent of the Lower Coal Measures of the Cebu Formation and the Guindaruhan Conglomerate of Hashimoto and others (1974) in central and northern Cebu.

• Butong Limestone

Lithology	Dense crystalline limestone; calcarenite; calcisiltite
Stratigraphic relations	Intermediate between the Calagasan and Linut-od formations; conformable or intertonguing with the underlying Calagasan Formation and overlying Linut-
	od Formation
Distribution	Barrio Butong, Argao; limited to the
	highlands of Dalaguete and Argao district
Age	Late Oligocene to Early Miocene
Thickness	approximately 388 m maximum
Named by	Barnes and others (1956)
Correlation	Ilag Limestone of the Cebu Formation
Contolation	

The Butong Limestone (Barnes and others, 1956) refers to the massive to thin bedded, white to light brown and yellowish gray, medium-grained crystalline, sandy or shaly limestone outcropping in a narrow strip from Calagasan, Argao to Mag-alambac, Dalaguete. It is generally lenticular, varying in thickness from a maximum of 388 m along Maangtud Creek, to 36 m in Cauluhan Creek and to as thin as a feather edge in the Magalambac area. Its designated type locality is in Barrio Butong, Argao. Abundant fossils, mostly small orbitoids, corals and algae may be found in the limestone. In places, interbeds of calcareous sandstone and shale are also present. The limestone usually forms prominent ridges between the Calagasan and Linut-od formations.

Orbitoids contained in the Butong yielded *Lepidocyclina* species indicative of a Late Oligocene age. The Butong is probably equivalent to the Ilag Limestone of the Cebu Formation in the Naga-Uling district.

• Linut-od Formation

Lithology	Conglomerate, sandstone and shale with
	coal interbeds
Stratigraphic relations	Conformably overlies and intertongues
	with the Butong Limestone
Distribution	From Calagasan, Argao to Mag-alambac,
	Dalaguete
Age	Early Miocene
Thickness	325 m to 1,300 m
Named by	Barnes and others (1958)
Correlation	Basac Formation in Siguijor Island

The Linut-od is another coal-bearing formation in southern Cebu, which was found conformably overlying and intertonguing with the Butong Limestone. It was named by Barnes and others (1958) for the shale,

sandstone and conglomerate with occasional coal beds exposed at Barrio Linut-od, Argao. It is almost lithologically similar to the Calagasan except that in this formation the shales and mudstones are more dominant. The coal beds of the formation are mostly located in the lower sections of the unit. It reaches a thickness of more than 1,300 m along Maangtud Creek. The age of Linut-od is Early Miocene.

Siquijor Island

Kanglasog Volcanic Complex

Lithology	Basalt to pyroxene andesite breccia and tuff
Stratigraphic relations	Unconformably overlain by the Basac
Distribution	Mt. Kanglasog; central and northern part
Age	of Siquijor Probably Cretaceous
Previous name	Kanglasog Volcanics (Sorem, 1951)
Renamed by	MGB (this volume)
Correlation	Pandan Formation of Cebu Island

The Kanglasog Volcanics of Sorem (1951), here renamed Kanglasog Volcanic Complex, serves as the basement rocks of Siquijor Island. The type locality of the Volcanic Complex is located at Mt. Kanglasog at the northern part of the island. In most outcrops, the Kanglasog unconformably lies below the Basac Formation.

The Kanglasog consists of intercalated volcanic breccia, tuff and pillow breccia mostly exposed in the central and northern part of the island. This usually occupies topographic highs forming rugged slopes in the central part and plains in the north. The rocks are fine-grained to porphyritic, consisting of basalt and pyroxene andesite that exhibit intergranular, intersertal, glomerophyric and vesicular textures. At Lotloton River, phenocrysts are essentially plagioclase and pyroxene embedded in a matrix consisting of plagioclase microlites, pyroxene and glass. Amygdule fillings mostly consist of chalcedony and fibrous-type zeolite with chlorite at the rim. Stretching from Larena to barangay Lotloton, Maria, massive volcanic breccias form an irregular-shaped volcanic tract with a width of 6.5 km. The breccia consists of angular to sub-angular clasts of varied shapes and sizes. In the vicinity of Barangay Bagacay, massive, dark red to orange clay represents the weathered product of basaltic breccia. Tuff found along Taytayon and Sabang rivers is well bedded, hard, buff to brown made up of sandy angular grains with current ripple marks. The formation is believed to be of Cretaceous age.

Basac Formation

Members Lazi Member – conglomerate, biocalcarenite, tuffaceous sandstone, siltstone, mudstone Can-agong Limestone

Lithology	Limestone, biocalcarenite, and clastic
	rocks
Stratigraphic relations	Unconformably overlain by the Siquijor
	Limestone
Distribution	Barangay Basac, Larena, Eastern Siquijor
Age	Early to Middle Miocene
Named by	Sorem (1951)
Correlation	Wahig Formation of Bohol; Macasilao
	Formation of Negros Island

Unconformably overlying the Kanglasog Volcanic Complex is the Basac Formation of Sorem (1951). This was informally subdivided into the lower Basac and upper Basac members, here renamed, Lazi Member and Can-agong Limestone, respectively.

• Lazi Member

Lithology	Biocalcarenite, tuffaceous sandstone, siltstone and shale with basal conglomerate
Stratigraphic relations	Unconformable over the Kanglasog Volcanic Complex
Distribution	Barangay Lazi.; Eastern Siquijor
Age	Early to Middle Miocene
Named by	MGB (this volume)

The Lazi Member represents the lower part of Basac Formation, mostly composed of polymictic conglomerate and biocalcarenite that grades upward into shale, mudstone, siltstone, coarse sandstone, tuff, grainstone and green cherty clastic rocks. Its type locality is at Lazi. Fossiliferous and calcareous tuffs outcrop north and south of Larena and northwest of Lazi. Foraminiferal tests are common in the sandstone facies outcropping along the San Juan-Lazi national road and at Mt. Kangbandilaan. Manganese beds are occasionally encountered between the shale and agglomerate beds (Calomarde, 1987).

• Can-agong Limestone

Lithology Stratigraphic relations	Dominantly limestone Unconformably overlain by the Siquijor Limestone
Distribution Age	Barangay Can-agong, Eastern Siquijor Middle to Late Miocene
Named by	MGB (this volume)

Conformable over the Lazi Member is a limestone unit here referred to as the Can-agong Limestone. The unit is mostly exposed in eastern Siquijor, west of Barangay Basac up to Barangay Can-agong. It is dominantly composed of white to buff, massive to thickly bedded, sometimes porous, gently dipping limestone and calcareous siltstone. *Lepidocyclina* and other foraminifers contained in the limestone points to Middle to Late Miocene age for this member. Deposition was probably in a shallow lagoonal environment to a reefal depth.

Siquijor Limestone

Lithology	Dominantly limestone, with minor sandstone and shale
Stratigraphic relations	Unconformable over the Basac Formation
Distribution	Siquijor town; widespread in Siquijor
	Island
Age	Pliocene to Pleistocene
Named by	Sorem (1951)
Correlation	Carcar Limestone in Cebu Island; Caliling
	Limestone in Negros

Overlapping all older rocks in Siquijor is the cream to black, low dipping, hard, massive but cavernous, Siquijor Limestone. This unit was defined by Sorem (1951) from limestones widely exposed at the type locality in the town of Siquijor. It underlies most of the towns and coastal areas of the island. Calcarenite and calcirudite is common in Barangay Helen in Larena and Barangay Maite in San Juan. Abundant planktic foraminifers and other neritic benthic forms abound in sandstones at the base of the formation. Near the top, corals and molluscan remains are ubiquitous.

The Siquijor is closely identified with the Carcar and Caliling limestones in Cebu and Negros Islands, respectively. Planktic foraminifers identified in the interbedded clastics indicate a Pliocene to Pleistocene age for the unit. The Siquijor Limestone is inferred to be deposited in a shallow marine environment - the lower portion with open marine influences probably in a neritic depth as indicated by the planktic forms present; the upper section in a reefal setting is characterized by preponderant corals and molluscan remains.

BOHOL ISLAND (SG 17)

Alicia Schist

Lithology	Schist, amphibolite
Stratigraphic relations	At its type locality, the schist is generally
	overlain by the Ubay Formation
Stratigraphic correlation	Tunlob Schist of Cebu Island
Distribution	Alicia town and vicinity in the eastern part
	of Bohol
Age	Late Jurassic – Early Cretaceous (?)
Named by	Arco (1962)

The name Alicia Schist was proposed by Arco (1962) for the north-south trending elongated mass of foliated rocks outcropping in the town of Alicia. The unit has been previously grouped with the Basement Complex (Corby and others, 1951; BM Petroleum Division, 1966; Carozzi and others, 1976) that constitutes the basement of all formations in the island. The schists are light green to light gray, sheared along lines parallel to its schistosity and quite
GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	BOHOL
NEOGENE	HOLOCENE		0.0447	
	PLEISTOCENE	4 Late	0.0117 0.126 0.78 1.81	
	PLIOCENE	2 Late 1 Early	2.59 3.60 5.33	Maribojic Formation
		3 Late	7.25	Sierra Bullones Limestone
			11.61	Carmen Formation
	MIOCENE	2 Middle-	13.65	Wahig Formation
		1 Early	20.43	
	OLIGOCENE	2 Late	23.03	Jagna Andesite
		1 Early	28.4	Ilihan Shale Istofa Andesita Talihan Diarita
ш		4 Late	33.9	
reogen	EOCENE	3 Middle – 2	40.4	Ubay Formation
9		1 Early	55.8	
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7 65.5	Bohol Ophiolite
CRETACEOUS	Upper	Late	00.6	
	Lower	Early	99.0	
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.20 Stratigraphic column for Bohol Island

variable in composition. Its lithologic composition ranges from combinations of chlorite-epidote-albite, albite-epidote-actinolite and albite-sericite-mica-carbonate-quartz.

This formation is restricted in occurrence in the eastern region of the island, within an area of about 15 km by 5 km. At the type locality, the schist is unconformably overlain by the Ubay Formation. The **Maubid Amphibolite** mapped by UNDP (1987) east of Buenavista is also considered part of this unit. Outcrops exposed at Maubid River are banded and foliated, consisting of two inliers of amphibolite made up of plagioclase and hornblende with minor amounts of actinolite, apatite, sphene and opaque minerals.

The formation is devoid of fossils but a Cretaceous-Paleocene age was assigned by BMG (1981). Considering that it underlies the Early Cretaceous Bohol Ophiolite, a probable Late Jurassic-Early Cretaceous age is assigned to the Alicia Schist, which would make it correlative to the Tunlob Schist of Cebu.

Bohol Ophiolite

Lithology	Serpentinized peridotite, dunite, pyroxenite, layered and isotropic gabbro, pillow basalt, diabase dikes, mudstope
Stratigraphic relations	Thrusted over the Alicia Schist
Distribution	Various lithologic components of the
	ophiolite complex are exposed in separate
	areas of southeastern Bohol
Age	late Early Cretaceous
Previous name	Boctol Serpentinite (Arco, 1962)
Renamed by	MGB (this volume); Diegor and others
-	(1995) and Yumul and others (1995)
	renamed it as Southeast Bohol Ophiolite Complex (SEBOC)

The unit was originally named Boctol Serpentinite by Arco (1962) in reference to the highly crushed, brecciated and pervasively serpentinized bodies exposed at Boctol Hills, Jagna municipality. Aside from these serpentinites, Sajona and others (1986) noted large outcrops of red aphyric basalt, gabbro and diabase in Brys. Lombog and Danao in the town of Guindulman, which made them consider Boctol as an ophiolite complex. Chromite pods were likewise discovered in dunite exposures along the road in Barangay San Antonio, Duero (Berador and Aleta, 1991). On the basis of joint field mapping of the DENR-MGB-Region 7 and the University of the Philippines - National Institute of Geological Sciences (NIGS), Diegor and others (1995) and Yumul and others (1995) regarded the different mafic and ultramafic rocks in southeastern Bohol as part of an ophiolite suite, which they called the Southeast Bohol Ophiolite Complex (SEBOC). This was described as a complex consisting of residual harzburgite-dunite, layered harzburgite-duniteclinopyroxenite, massive and layered gabbro, diabase dike complex, massive and pillow basalt flows and associated chert-mudstone sedimentary rocks, which established the presence of a complete ophiolite sequence in southeast Bohol. Highly tectonized ultramafic to mafic sequences were also observed in roadcuts from Cansiwang to Labo, Barangay Tabunok, Guindulman. Along the road in a 20-meter section, two major thrusts were observed; first, serpentinized harzburgite over pillow basalts; and second, the lower horizons of the same basalt were thrusted over tuffaceous mudstone. Further up the road in the same barangay sedimentary rocks were found sitting on pillowed flows. Basalt, diabase, microgabbro, andesite and aplite dikes were observed to cut each other and the diabase country rock in barangays Lonoy and San Antonio, Duero municipality. These dikes range from 10-30 cm in thickness. The formation of a serpentinite mélange is likewise suggested by the presence of cobble-sized serpentinized harzburgite clasts floating or cemented in a serpentinite matrix.

Radiolarians and foraminifers in chert and mudstone intercalated with the pillow basalts that serve as carapace of the ophiolite indicate a late Albian age (Faustino and others, 2003).

Ubay Formation

Lithology	Andesite, basalt, dacite, agglomerate and intrusive rocks including gabbro and diabase; Sandstones and mudstones are intercalated with the volcanic rocks towards the top
Stratigraphic relations	In Alicia, the volcanic rocks apparently rest on the Alicia Schist; unconformably overlain by Jetafe Andesite. Wahig
	Formation and Carmen Formation
Distribution	Ubay and vicinity; Jetafe and Talibon areas; southwest of Trinidad down south to
	Mahayag; Lapinig Island and Lapinig Chico;
	Kabulao, Mabini
Age	Paleocene – Late Eocene
Previous name	Ubay Volcanics (Arco, 1962)
Renamed by	UNDP (1987)

The Ubay Formation (UNDP, 1987) was originally designated as Ubay Volcanics by Arco (1962) who described it as a heterogeneous mass of volcanic flows consisting of dacite, andesite, basalt and agglomerate as well as intrusive rocks consisting of gabbro and diabase. It is unconformably overlain by the Jetafe Andesite, Wahig Formation and Carmen Formation. The volcanic rocks cover a wide area in northern Bohol, approximately 600 km² from Jetafe, south of Talibon, southwest of Trinidad down south to Mahayag, all of Lapinig Island, Lapinig Chico, and south and southeast of Ubay and Kabulao, Mabini. Andesites predominate around Jetafe and Talibon areas, but amygdaloidal basalt becomes common southwest of Talibon. In the vicinities of Mahayag and Sto. Rosario, Talibon, basaltic flows are generally porphyritic consisting of phenocrysts of zoned labradorite laths and ferromagnesian minerals set in a pumiceous and glassy matrix.

Highly weathered, light to dark gray, massive, brecciated and highly jointed andesite and basalt were observed in Ubay town. Altered andesite porphyry, augite basalt, andesite and pyroclastic rocks were likewise identified in Anda Peninsula, Mabini and Guindulman. Exposures of dacite were noted in barrios Sto. Rosario, and Burgos, Talibon and in Lapinig Island, Ubay. The dacite consists essentially of albite, quartz and apatite with sericite and clay as alteration minerals. Embayed and rounded phenocrysts of quartz were also noted.

A gabbro dike was also mapped in Barrio Tugas, Lapinig Island, Ubay. It is mainly composed of plagioclase, pyroxene and olivine with minor actinolite minerals. At Barrio Cagawasan, Danao, three meter exposures of banded, cream to buff basaltic and pyroclastic flows unconformably overlain by limestone of the Wahig Formation were recognized.

UNDP (1987) informally subdivided the Ubay Formation into five members, namely: 1) San Vicente Basalt; 2) Rizal Basaltic Wackes; 3) Kauswagan Road Volcaniclastics; 4) Lubang Turbidites; and 5) Tulang Wacke. The San Vicente Basalt refers to the massive plagiophyric pillow basalt with minor basaltic wackes exposed near the headwaters of Lublob Creek and along the trail to Barrio San Vicente. It is pervasively propylitized with alteration minerals consisting of epidote, chlorite and calcite. The Rizal Basaltic Wackes are mainly basaltic wackes with interbedded pillow and massive basalt lavas, purple and green tuffaceous mudstone and fine- to coarse-grained tuff and lapilli tuff. The Kauswagan Road Volcaniclastics is primarily composed of conglomerates and wackes with zeolite-bearing pillow basalts intercalated with siltstone and mudstone in the upper part. The Lubang Turbidites dominantly consists of wackes, siltstones and mudstones, which usually exhibit parallel bedding and parallel and ripple cross lamination. Basal conglomerate is locally encountered. Thin beds of pillow basalt were observed intercalated with the clastic rocks exposed in Tugnao River. Calcarenites are present near the top of the formation. The **Tulang Wacke** outcrops a little southeast of Jetafe and was described as westward dipping beds of sandstone and siltstone apparently overlying the Rizal Basaltic Wackes.

A Cretaceous age was assigned to the unit by Corby and others (1951) and Arco (1962). Subsequent age determinations made by the MMAJ-JICA (1990) point to a Paleocene age. Paleontological analysis of the foraminiferal assemblage in a limestone sample collected from Lubang Turbidites indicated an Eocene age for the formation (UNDP, 1987).

Probably equivalent to the Lubang Turbidites is the **Calape Limestone** (BM Petroleum Division, 1966), which crops out as mere blocks and boulders along the slope and near the vicinity of the "Ilihan Plug". Its areal extent is less than 50 m, which proved unmappable on a 1:25,000 scale map. Here, the limestone is discussed only to represent the presence of this Eocene rock in Bohol Island. The limestone was informally designated by the BMG Petroleum Division (1966) as the *Camerina*-rich limestone exposed near "Ilihan Plug" in Tubigon, Bohol. It was earlier mentioned by Corby and others (1951) as the Eocene limestone located south of Tubigon. The limestone is probably an erosion remnant described as massive, white-cream to buff, highly crystallized and fossiliferous. This seems to overlie the Ilihan Plug. Boulders and pebbles of the limestone are widely scattered on top and along the slope of the plug.

Abundant remains of large benthic foraminifera recovered revealed a Late Eocene age for the limestone. Common genera present are: *Nummulites, Discocyclina, Biplanispira* and *Pellatispira* (Mula and Maac, 1995). Based on the dominance of species from the Genus *Pellatispira*, the assemblage is assigned to the *Pellatispira* Zone. Deposition was inferred to be in a quiet lagoonal setting with clear and warm waters manifested by the presence of nummulitids and algal species set in a micritic matrix.

Jetafe Andesite

Lithology Hornblende andesite

Stratigraphic relation	Unconformably overlies the Ubay
	Formation and intruded by the Talibon
	Diorite
Distribution	Jetafe, northwestern Bohol
Age	Late Eocene (?) - Oligocene
Previous name	Jetafe Porphyry (Arco, 1962)
Renamed by	MGB (this volume)
Synonymy	Salog Andesite Formation (UNDP, 1987)

Closely associated with the Talibon Diorite is the Jetafe Andesite, which refers to the hornblende andesite bodies closely associated with the quartz diorite in northern Bohol. This was originally named by Arco (1962) as Jetafe Porphyry in reference to isolated lenses of andesite identified in the town of Jetafe. This unit generally varies in composition ranging from fine grained hornblende andesite to porphyritic andesite. Phenocrysts of hornblende are set in a fine grained, white to greenish gray groundmass. Parallel quartz veins cut across these rocks. Alternating with these quartz veins are strips of the host rocks containing minor amounts of chalcopyrite and breccia.

The **Salog Andesite Formation** (UNDP, 1987), described as andesite and andesite pyroclastics exposed in southeast Jetafe is probably equivalent to the Jetafe Andesite. In Salog, two types of andesite were identified, namely, medium to coarse-grained hornblende andesite and andesite porphyry. The andesite unconformably overlies the Rizal Basaltic Wackes of the Ubay Formation. It is intruded by the Talibon Diorite.

A Late Eocene (?) to Oligocene age was inferred for the unit.

Talibon Diorite

onite
etafe
Э

The term Talibon Diorite was used by Arco (1962) for the sparsely distributed dioritic bodies outcropping in northern Bohol. The Talibon intrudes the Ubay Formation and the Jetafe Andesite. These small diorite exposures occupying a total area of 27 km² follow a northeast trend seemingly guided by structures observed from central Dagohoy to northern Talibon. The best exposures were observed in Baboy and Bagacay areas in Talibon municipality.

The diorite is quite variable in texture and composition, from coarsely crystalline to microgranitic hypidiomorphic granular, and consists of biotite hornblende diorite, hornblende quartz diorite, microdiorite and hornblende diorite (UNDP, 1987). At Catigbian, the pluton is quite rich in K-feldspar (quartz monzonite) while at Kauswagan it is generally rich in biotite. Along Tugnao River and Loly Creek deeply weathered coarse-grained diorite is

exposed. Minerals identified are generally subhedral, light-colored and medium- to coarse-grained, which include: andesine, hornblende and quartz with minor sphene, chlorite and epidote. Numerous sulfide-bearing quartz veinlets occur in these intrusive bodies. Ore minerals identified are pyrite, sphalerite, galena, magnetite and chalcopyrite with limited gold. Mineralized halos are concentrated near contacts of the diorite with the intruded volcanic rocks. The age of the Talibon is probably Late Eocene (?) to Early Oligocene.

Ilihan Shale

Lithology	Dominantly shale with sandy tuff and
• • • • • • •	calcareous volcanic rubble beds
Stratigraphic relations	Unconformably overlain by the Tubigon
	Conglomerate (BMG, 1981) and Carmen
	Formation
Distribution	llihan Sur, Tubigon
Age	Early Oligocene
Named by	Cruz (1956)

The term Ilihan Shale was introduced by Cruz (1956) for the clastic rocks exposed at Ilihan Sur, south of Tubigon. The Ilihan is unconformably overlain by the Carmen Formation, although it was previously considered a member of the Middle Miocene Carmen Formation. Later studies made by Mula and Maac (1995) revealed Early Oligocene planktic foraminiferal assemblages in the clastic rocks, confirming its designation as a separate unit.

The Ilihan consists dominantly of shale with some sandy tuff and hard calcareous volcanic rubble beds. The shale is cream to buff, contorted, fractured and indurated. Planktic foraminifers identified in the shale point to *Globorotalia increbescens* Zone of Stainforth (1975) or Zone P18-P19 of Blow (1969) equivalent to Early Oligocene age (Mula and Maac, 1995).

Jagna Andesite

Lithology Stratigraphic relations	Dominantly andesite breccia Not reported
Distribution	Observed in Palingkod Hill, Caloyahan Hill and Tubod Monte Creek, north of Jagna
	and around Anda Peninsula
Age	Late Oligocene
Correlation	The Ilihan Plug is considered part of the
	Jagna Andesite; equivalent to the Bulacao Andesite in central Cebu
Named by	Arco (1962)

The name Jagna Andesite was first used by Arco (1962) to designate the andesite breccia occurring about 2 km north of Jagna. It is gray and massive, containing phenocrysts of plagioclase set in a glassy matrix. Best exposures are found in Palingkod Hill, Caloyahan Hill, Tubod Monte Creek, north of Jagna; Ilihan Sur in Tubigon and around Anda Peninsula. Float and boulders of andesite presumably from Jagna Andesite are widely observed to the north of Jagna.

At the type area, the andesite is characterized by ocellar to vesicular structures and bears phenocrysts of plagioclase, hornblende and minor biotite embedded in a glassy matrix. Also considered part of this unit is the **"Ilihan Plug**", a porphyritic hornblende andesite body conspicuously towering over the Carmen Formation exposed about 5 km south of Tubigon. It has an elevation of about 240 masl. The rock is essentially composed of andesine, hornblende, glass, apatite and opaque ores with clinopyroxene and biotite in negligible amounts.

Small dacite bodies widespread in the Jetafe area are also correlated with the Jagna Andesite (UNDP, 1987), inferred as intrusions in the Talibon Diorite. The andesite bodies mapped in Jagna occupies a total area of 8.7 km². It probably corresponds to the Bulacao Andesite breccia of central Cebu. Radiometric K-Ar dating of the andesite indicates a 25.5 ± 1.3 Ma age (equivalent to Late Oligocene) of emplacement (Sajona and others, 1986; MMAJ-JICA, 1986).

Wahig Formation

Lithology	Limestone with basal conglomerate
Stratigraphic relations	Unconformably overlain by the Carmen
	Formation and lies above the Jetafe
	Andesite and Talibon Diorite
Distribution	Wahig River, Colonia, Carmen, central
	Bohol; At Jetafe, it is exposed in
	Mahayag-Danao road, at the headwaters
	of Hinuan Creek, at barangay Babog in
	Trinidad and in barrios Salog and Ondal
Age	Early to Middle Miocene
Previous name	Wahig Orbitoid Limestone (Corby and
	others, 1951)
Renamed by	Carozzi and others (1966)

The Wahig Formation was formerly named Wahig Orbitoid Limestone by Corby and others (1951) from its typical occurrence at the Wahig River gorge, Colonia, Carmen, central Bohol. Carozzi and others (1966) renamed it as Wahig Formation to include the basal conglomerate. This usage was followed by subsequent workers (Mula and Maac, 1995).

At Colonia, Carmen, the base of the formation unconformably overlies the Ubay Formation. In places it rests over the Jetafe Andesite and Talibon Diorite.

The Wahig is basically an orbitoid-bearing limestone, well bedded, massive, cream to buff with coarse basal conglomerate. At times the limestone is arcuate, thin and lenticular. The lower part consists of rounded to sub-rounded pebbles and boulders of basalt, andesite and cherty limestone clasts cemented by silty to sandy matrix. Agglomerate apparently caps the upper part of the formation. Aside from the type locality, the formation is also exposed along the Mahayag-Danao road, at the headwaters of Hinuan Creek, at barrio Babog in Trinidad, along Kantagom River and in barrios Salog, Kauswagan and Ondal in Jetafe municipality. Limestones containing Miocene foraminifers were noted in Kauswagan, Jetafe (UNDP-MGB, 1987). Low dipping mollusk-bearing mudstone and siltstone beds found southeast of Danao proper that was considered by Mula and Maac (1995) as part of the Carmen Formation probably belong to the Wahig Formation.

Large benthic foraminifers identified from samples collected from barrios Hinlayagan, Trinidad and Cagawasan, Jetafe indicate an Early to Middle Miocene age for this formation (Mula and Maac, 1995). Faunal assemblage correlative to *Cycloclypeus communis* Zone was determined for the unit. This can be equated to Blow (1969) Zone N4-N6 or to the nannoplankton NN5 Zone. Preponderance of large benthic foraminifers and shallow marine mollusks in the carbonate and clastic facies suggest deposition in an open lagoonal shelf environment. The basal conglomerate probably signifies the onset of marine transgression in Bohol area during Miocene time.

Carmen Formation

Lithology	Shale, sandstone, conglomerate and
	limestone
Stratigraphic relations	Unconformable over the Ilihan Shale and
	Wahig Formation; overlain by the
	Maribojoc Formation
Distribution	The valleys in the vicinity of Carmen,
	Danao, Sierra Bullones
Age	Middle Miocene
Thickness	400 - 800 m
Previous name	Carmen Sandstones and Shales (Corby
	and others, 1951)
Renamed by	Cruz (1956)
Correlation	Toledo Formation in Cebu Island

This unit was originally called Carmen Sandstones and Shales by Corby and others, (1951) in reference to its type occurrence in the town of Carmen in central Bohol. Cruz (1956) renamed it Carmen Formation to include members such as the Ilihan Shale, Carmen Sandstone and Shale, Tubigon Conglomerate and Sevilla Marl. Porth and others (1989) considered the Tubigon Conglomerate as the lower member of the Carmen. It was also mentioned that the volcanic components of both the sandstone facies of Carmen and the Tubigon originated from Middle Miocene volcanic activities. Mula and Maac (1995) however, opined that it is younger and instead placed it at the basal part of the Maribojoc Formation. They also found out that the Ilihan Shale contained Early Oligocene planktic foraminifers, which show a wide age gap between the Carmen Formation and the Ilihan Shale. The Sevilla Marl yielded planktic foraminifers equivalent to Blow's (1969) Zone N21-23 (Pliocene), which accordingly separates it from the Middle Miocene Carmen Formation. Based on their vague formational contact, distinct lithology and age, these members were split into separate formations (Mula and Maac, 1995).

The Carmen was found unconformably overlying the Ilihan Shale. At Carmen and Trinidad, it also unconformably overlies the Ubay Formation. It is mostly covered by the Maribojoc Formation. Along the Mahayag-Danao road the unit rests over the limestone of the Wahig Formation.

The use of Carmen Formation by Mula and Maac (1995) is strictly confined to the original unit described by Corby and others (1951). The formation consists of interbeds of tuffaceous sandstone, shale and mudstone with occasional lenses of calcarenite and calcisiltite. The sandstone is rich in feldspar in a clayey matrix and sparsely fossiliferous. Minor amounts of carbonate and chlorite were noted. An approximate thickness of 400 m to 800 m was estimated for the formation.

Faustino and others (2003) subdivide the Carmen Formation into three members, namely, Anda Limestone Member, Pansol Clastic Member and Lumbog Volcaniclastic Member. The **Anda Limestone member** was reported to interfinger with the **Pansol Clastic member**, which is characterized by thinly-bedded calcareous sandstone, siltstone shale and conglomerate. The sandstone, in places, contains quartz pebbles, shale lenses and coralline and shell fragments. The **Lumbog Volcaniclastic member** consists of conglomerate with pebble- to boulder-sized basalt and andesite clasts set in epiclastic andesite matrix. Occasional clasts of harzburgite, dacite, gabbro, carbonate and clastic rocks were observed in some exposures. The Lumbog typically occurs as valley fills in the Pansol Clastic member, but intertonguing relationship with the Pansol was also observed. The thickness of the Pansol and Lumbog, as estimated by Faustino and others (2003), is 1,000 m and 180 m, respectively.

The age of the Carmen Formation, based on paleontological identification of fossils in the Anda Limestone member is Early Miocene to Middle Miocene. In their stratigraphic column, however, Faustino and others (2003) did not include the Early Miocene Wahig Formation, which consists principally of limestone and could be partly equivalent to their Anda Limestone.

A Middle Miocene age was assigned by Corby and others (1951) to their Carmen Sandstones and Shales. Foraminifers equivalent to *Globorotalia foshi peripheroronda* Zone to *Globorotalia foshi foshi* Zone of Stainforth (1975) or to Blow's (1969) Zones 9 -10 were identified by Mula and Maac (1995). Likewise, nannoplankton zones NN5-NN6 were recognized by Muller and others (1989). Middle to outer neritic or even bathyal depth of deposition is inferred for the Carmen Formation.

Sierra Bullones Limestone

Lithology	Massive to rubbly limestone
Stratigraphic relations	Overlies the Carmen Formation and
	overlain by white marl
Distribution	Caps the Sierra Bullones Range and other
	mountain ranges of eastern Bohol
Age	Late Miocene
Named by	Corby and others (1951)
Correlation	Barili Formation in Cebu

This unit was originally named by Corby and others (1951) for the massive to rubbly limestone, rubble breccia, medium to thick biocalcarenite beds and reefal limestone and beds rich in coral fingers exposed in the mountain range east of Sierra Bullones. It is generally porous, cream to buff with few calcarenite lenses.

Calcareous mudstone lenses below the massive limestone yielded Late Miocene planktic foraminiferal assemblages. The limestone is correlative to the lower Limestone Member of the Barili Formation in Cebu.

Maribojoc Formation

Lithology	Conglomerate, marl and limestone
Stratigraphic relations	Unconformably overlies the Carmen
	Formation
Distribution	Tubigon, Sevilla and Cortes in the western
	part of Bohol and islets fringing Bohol
Age	Pliocene
Named by	Arco (1962)

The term Maribojoc Limestone was originally used by Arco (1962) to designate the youngest limestone unit blanketing most of the western part of the island and all the other islets fringing Bohol. Recent research, however, proves that other units are related to the Maribojoc. Mula and Maac (1995) recognized that previously identified members of the Carmen Formation, the Tubigon Conglomerate and the Sevilla Marl are younger deposits partly coeval or contemporaneous to the deposition of the limestone. Hence, three members are considered under the Maribojoc: the Tubigon Conglomerate, Sevilla Marl and Cortes Limestone.

• Tubigon Conglomerate

Lithology	Dominantly tuffaceous conglomerate with intercalations of ash tuff and volcanic breccia
Stratigraphic relations	Unconformably overlies the Ilihan Shale and the Carmen Formation
Distribution	South and east of Tubigon and on the west flank of Carmen Valley near Mt. Pinoonan
Age	Pliocene
Thickness	~1,000 m
Named by	Cruz (1956)

This member was named for the poorly sorted, massive series of tuffaceous conglomerate, sandstone, tuff beds, and flow breccia typically exposed along roads in the town of Tubigon. It was formerly mapped as part of the Carmen Formation by Cruz (1959). However, on the basis of their findings, Mula and Maac (1995) suggest that they are relatively younger, forming the lower member of the Maribojoc Formation. Clasts of the conglomerates are generally composed of hornblende andesite and basalt set in a sandy tuffaceous matrix. These rocks are well exposed in

the southern and eastern part of Tubigon and on the west flank of Carmen Valley near Mt. Pinoonan. The unit unconformably overlies the Ilihan Shale and the Carmen Formation. The Tubigon probably correlates with Arco's (1962)

The Tubigon probably correlates with Arco's (1962) Kabulao Conglomerate and Mt. Corte Conglomerate of UNDP (1987). The **Kabulao Conglomerate** outcrops along Kabulao River, 8 km north of Mabini, in the eastern coast of Bohol. It is about 150 m thick, with boulders, cobbles, and pebbles of volcanic and metamorphic rocks fixed in sandy tuffaceous cement. No fossil was identified from the conglomerate. However, a probable Pliocene age is inferred for this unit. The **Mt. Corte Conglomerate** refers to the conglomerate and sedimentary breccia with minor tuffs and calcareous sediments identified at Mt. Corte in Jetafe. At the type area, it was described as massive to thickly bedded, and consisting of angular clasts of andesitic rocks and porous silicic tuff.

• Sevilla Marl

Lithology	Dominantly tuffaceous marl with
	limestone interbeds
Type locality	Sevilla, in Loay River Valley
Stratigraphic relations	The unit presents a transitional to
	conformable relation with the overlying
	Cortes Limestone
Distribution	In the towns of Loboc, Sevilla and
	Sikatuna
Age	Pliocene
Thickness	500 m
Named by	Corby and others (1951)

The Sevilla Marl was originally established as a formation by Corby and others (1951). It was described as tuffaceous, dirty white, cream to buff and fossiliferous, observed mostly in the towns of Sevilla, Loay, Corella, Lila, Balilihan, Loboc and Sikatuna. Its type locality is assigned in the Loay River Valley, Sevilla municipality. Later, Arco (1962) considered it as a member of the Middle Miocene Carmen Formation. Findings made by Mula and Maac (1995) however revealed that the marl is much younger, being Pliocene in age. Its stratigraphic contact with the overlying Cortes Limestone is gradational to conformable where the Cortes overlaps the marl. Aside from the marly facies, low dipping beds of sandstone and shale with occasional limestone interbeds were also encountered. Corals, mollusks, foraminifers and nannofossils were identified from this member. Field relation showed that the marl is directly overlain by the Cortes Limestone. Its maximum thickness is estimated to be about 500 m. On the basis of physical appearance, the Marl may be correlated with the Merida Formation of northwest Levte and the Bolok- Bolok Formation of Cebu.

Foraminiferal zones identified in the clastic rocks point to the upper part of Stainforth's (1975) *Globorotalia margaritae* Zone and the *Pulleniatina obliqueloculata* Zone equivalent to a Pliocene age. The diversity and abundance of planktic foraminifers suggest a relatively deep environment of deposition for the marl, probably an outer neritic environment.

• Cortes Limestone

Lithology	Coralline limestone
Type locality	Cortes municipality
Stratigraphic relations	The contact with the underlying Sevilla
	Marl is gradational to conformable
Distribution	Widely distributed over a wide area from
	Batuan to the southwestern part of the
	island especially around Tagbilaran and
	Cortes municipalities
Age	Late Pliocene to Pleistocene
Stratigraphic correlation	Carcar Limestone in Cebu Island
Named by	Mula and Maac (1995)

Capping all the older formations in Bohol is the Cortes Limestone (Mula and Maac, 1995), previously identified as the Maribojoc Limestone. This represents the upper member of the Maribojoc Formation and is the youngest limestone body in the island. It is widely distributed in southwestern Bohol especially around Cortes and Tagbilaran districts. The haycock mounds of the Chocolate Hills are also believed to be part of the Cortes Limestone. The unit was sometimes referred to as Carcar Limestone (Huth, 1962).

The limestone is soft, chalky, non-compact, marly and coralline, varying from cream to brownish yellow or buff. It is usually massive to poorly bedded, porous and characterized by numerous caverns and sinkholes. It is apparently fossiliferous with abundant corals and algae associated with some foraminifers and mollusks. Though obviously fossiliferous, no index fossil was recognized from the limestone. However, a Late Pliocene to Pleistocene age was postulated for this unit.

LEYTE ISLAND (SG 17, 19, 20)

Leyte Island can be divided into three major tectonostratigraphic terranes. From west to east, these are northwestern Leyte (including Camotes Island), which is part of the Visayan Sea Basin (SG 17); Leyte Central Highlands (SG 19), which has an arc/ophiolite affinity and the northeastern Leyte ophiolitic association in the Leyte Gulf (SG-20).

Western Leyte and Camotes Island

The northwestern Leyte sedimentary sequence represents deposits of the marginal basin that constitutes the northeastern segment of the Visayan Sea Basin. This area, comprising the Calubian Peninsula, represents a north-northwest trending anticlinorium. On the other hand, the ophiolitic basement and Paleogene sedimentary rocks are represented in the southwest.

PERIOD	EPOCH	STAGE	Ма	WESTERN LEYTE/ CAMOTES ISLAND	CENTRAL HIGHLAND	EASTERN LEYTE
	HOLOCENE		0117			
	DI EISTOCENE	4 Late	0.126	San Isidro Limestone	Leyte Volcanic Arc Complex	
	PLEISTOCENE	2 Middle	0.78	Tuktuk Formation		
		1 Early	2.59	Inopacan Formation	Visares Limestone	
EZE Z	PLIOCENE	1 Early	3.60	Hubay Limestone		Bagahupi Formation
NEOGI		3 Late	7.25	Kadium Bata Conglomerate Formation	Pangasugan Formation	
	MIOCENE	1 1	13.65	Calubian Tagnocot Limestone Formation		San Ricardo Formation
			15.97	Laboon Conglomerate	Baybay Volcanic Complex	
		1 Early :	20.43	Taog Formation		San Jose Formation
		2 Late	23.03	Kantaring Batang Limestone Formation		
	OLIGOCENE	1 Early	28.4			
10		4 Late	33.9	Gilonon Formation	7	
OGENE	EOCENE	3 Middle	40.4	Amontay Sandstone	Albuera Diorite	
ALE		1 Early	48.6			
L.	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7			
Sol Color	Upper	Late	65.5	Malitbog Ophiolite		Tacloban Ophiolite
Cherry	Lower	Early	99.6			
JURASSIC						Babatngon Schist

LEYTE ISLAND

Table 2.21 Stratigraphic column for Leyte Island

Malitbog Ophiolite

g

The Malitbog Ophiolite consists of an almost complete ophiolitic sequence exposed as patches in the towns of Malitbog and Maasin (Florendo, 1984). It was named after its type locality at Malitbog, southern Leyte. The lithologic units constituting the ophiolite include: serpentinized harzburgite, minor dunite, cumulate and isotropic gabbro, diabase dike complex, pillow basalts and pelagic sedimentary rocks. Corby and others (1951) noted peridotite and basalt exposures overlain by the Early Miocene Taog Formation. Small outcrops of schist confined within fault zones at Brgy. Santiago and Tinubdan, Palompon that were mapped by Balce and others (1996) as **Santiago Schist** are probably products of dynamic metamorphism of basaltic rocks.

Thrust slabs of peridotite consist predominantly of harzburgite, tectonite and minor irregular bodies of dunite and dikes of websterite (Florendo, 1984). The rocks are banded and pervasively serpentinized, crosscut by mafic and intermediate dikes. The dikes are mainly pyroxene gabbro, hornblende-clinopyroxene gabbro, hornblende diorite and basalt. At the type area, dikes of plagiophyric basalt, diabase and pegmatitic hornblende diorite are also present.

The gabbro facies, represented by the *Lawagan Gabbro*, is mainly isotropic with lenses of noncumulate hornblende-clinopyroxene gabbro and transitional gabbro. The dike complex above the gabbro consists of parallel to subparallel diabase and basaltic dikes ranging from 0.5 to 1.5 meters wide. From this phase, the ophiolite grades upward into the *Cagbaong Basalt*, a thick pile of pillow basalt and breccia, which are locally massive. The basalt is aphyric, microporphyritic or hyalopilitic The *Tigbauan Formation* represents the pelagic sedimentary cover of the ophiolite.

The ophiolite complex is presumed to have been emplaced during Late Cretaceous time.

• Lawagan Gabbro

Lithology	Gabbro
Stratigraphic relations	Overlain by the Amontay Formation
Distribution	Lawagan River, Maasin; limited to some
	patches in Maasin area
Age	Late Cretaceous (?)
Named by	Florendo (1987)
Synonymy	Lawagan Metadiorite (MMAJ-JICA, 1988)

The formation was named by Florendo (1987) after its exposure in Lawagan River, Maasin. This represents the gabbro component of the Malitbog Ophiolite. The unit is mainly isotropic gabbro with lenses of noncumulate hornblende-clinopyroxene gabbro and transitional gabbro. The hornblende-clinopyroxene gabbro is massive and medium-grained, in places grading into irregular zones of coarse-grained to pegmatitic hornblende diorite; the transitional gabbro unit consists of clinopyroxene gabbro and minor hornblende-clinopyroxene gabbro. The contact between these gabbroic bodies and the sheeted dike complex is transitional. In places, the gabbro had been altered into a greenstone consisting of albite, chlorite, epidote, calcite, green fibrous amphibole and quartz. Along the sole of thrust planes and faults that cut the unit, schistose to semi-schistose cleavage had developed. The lower part is characterized by rhythmic layering and grain size layering.

The unit occurs only as small patches in the central part of southern Leyte. Florendo (1987) assigned a Late Cretaceous for the Lawagan. The Gabbro is probably synonymous to the Lawagan Metadiorite of MMAJ-JICA (1988).

• Cagbaong Basalt

Lithology

Pillow basalt and hyaloclastic breccia

Distribution	Cagbaong Creek, Maasin; occurs in patches in the towns of Maasin and
	Malitbog
Age	Probably Late Cretaceous
Thickness	250 - 300 m
Named by	Florendo (1987)

The volcanic carapace of the ophiolite is represented by the Cagbaong Basalt. The term was used by Florendo (1987) to designate the hyaloclastic breccia and pillow basalt, sheet flow and hyaloclastite exposures in Cagbaong Creek, Maasin. The pillow basalt typically consists of plagioclase microlites, quench-textured pyroxene and rare olivine set in grayish-green glass. The hyaloclastic breccia is sometimes bedded and graded, consisting of a mixture of small pillows, pillow fragments and finegrained particulate matrix of unaltered glass fragments.

At the headwaters of Biliran River, Malitbog, black, unaltered hyaloclastic breccia and pillow basalt are crisscrossed by numerous quartz-pyrite veinlets. Deposition of this formation probably occurred during Late Cretaceous time in a deep marine environment. The thickness is estimated to be 250-300 m.

• Tigbauan Formation

Lithology	Limestone, shale, chert, sandstone
Stratigraphic relations	Conformable over the Cagbaong Basalt
Distribution	Tigbauan River, Maasin; well exposed in
	the Malitbog-San Pedro area and also
	upstream of Bonbon River
Age	Late Cretaceous
Thickness	180-200 m
Named by	Florendo (1987)

Conformable over the ophiolitic pillow basalt is a sequence of pelagic sedimentary rocks, including turbidites and minor volcaniclastic rocks of the Tigbauan Formation (Florendo, 1987). The unit, which is well exposed at the Malitbog-San Pedro area, consists of small patches of red chert, red shale, limestone and sandstone. The argillaceous silica layers comprising the chert have shades that range from light to dark purple to dark red. The limestone is red micritic or pale red, medium-grained turbiditic calcarenite. Best exposures were observed at the headwaters of Bonbon River. The sandstone contains plagioclase, pyroxene, hornblende, biotite, quartz and occasional lithic fragments. Many of the quartz present show trains of fluid inclusions and slightly undulose extinction, which suggests plutonic origin. Lithic fragments consist of plagioclase, quartz and hornblende as well as andesitic clasts. Poor preservation of this unit may be attributed to both structural truncation and deformation-related brecciation, which facilitated its erosion.

Examination of the micritic limestone revealed *Helvetoglobotruncana helvetica* (Bolli), a planktic foraminifer that points to a Late Cretaceous (probably Turonian) age for the formation. The combined presence of pillow

basalts, pelagic limestone and radiolaria-bearing chert indicates a deep neritic to bathyal depth of deposition for the Tigbauan.

Amontay Sandstone

Lithology	Limestone, occasional shale, siltstone, sandstone and lenticular beds of
Stratigraphic relations	calcareous breccia
Oli aligraphic relations	Gabbro; conformable to the overlying
	Gilonon Formation
Distribution	Confluence of Amontay Creek and
	Bangkerohan River, Maasin; patches in
	southern Leyte
Age	Middle - Late Eocene
Named by	Florendo (1987)

The Amontay Sandstone was named by Florendo (1987) for the sequence of clastic rocks and limestone exposed at the confluence of Amontay Creek and Bangkerohan River, Maasin. The Amontay lies directly over Lawagan Gabbro (Florendo, 1987) and is conformably below the Late Eocene Gilonon Formation. Its basal part consists of well-indurated, interbedded white marbleized limestone and occasional tuffaceous shale, siltstone, sandstone and lenses of calcareous breccia. The limestone is fine-grained but locally recrystallized. The interbedded sandstone shows internal subhorizontal parallel and ripple laminations, medium- to small-scale trough cross-bedding, ripple bedding and tabular planar bedding. The upper part consists of a thick sequence of medium to fine-grained sandstone, siltstone and red and green mudstone, which coarsen upward. Occasional conglomerate with pebbles of quartz, andesite, clay and carbonized wood fragments are observed in the area. At the type locality, the rocks show slight effects of hydrothermal alteration.

No diagnostic fossil was identified from the Amontay Formation. However, its age assignment is constrained by its conformable relation with the overlying Gilonon Formation. Deposition of the Amontay probably occurred from Middle Eocene to Late Eocene.

Gilonon Formation

Lithology	Conglomerate, sandstone, siltstone and green tuff
Stratigraphic relations Distribution	Conformable over the Amontay Formation Gilonon Creek, Maasin; also exposed as small patches in thrust slabs at the headwaters of Bonbon River, east of the town of Maasin
Age	Late Eocene
Named by	Florendo (1987)
Correlation	Ubay Formation of Bohol Island

The Gilonon Formation was designated by Florendo (1987) for the clastic rocks overriding the "Basak thrust slabs" that spread from the headwaters of Bonbon River southwards to the town of Maasin. At the type locality along Gilonon Creek, the unit seemingly occurs as an erosional window covered by Quaternary limestone of the Masonting Formation. It lies conformably above the Amontay Formation.

This formation is divided into two lithologic facies: the dominantly conglomeratic strata in the southern part and the sequence of sandstone, siltstone and green tuff in the northern portion (Florendo, 1987). The southern facies is composed of multilateral and multilevel fining upward of channel-fill sequences; characterized by basal, dominantly pebbly to cobbly, conglomerate that passes upward to coarse to fine-grained sandstone. Clasts of the conglomerate consist of basalt and andesite with occasional limestone fragments. Mudstone lenses with desiccation cracks indicative of channel fill deposits in a fluvial environment are also features of the formation. This facies is also marked by trough cross-bedding, channel scours and foresets, which are mainly directed to the northeast. These generally indicate sedimentation in the lower reaches of braided alluvial plains. Fossils contained in the limestone clasts suggest a Late Eocene age.

The northern facies of the thrust slab is characterized mainly by marine successions of dark gray and greenish gray volcanogenic turbidites, siltstone, green tuff and green lime mudstone. This is well exposed in the lower stretch of the Amparo River. The dominance of deep marine benthic foraminifers and turbidite structures in these clastic deposits suggest sedimentation in a deep marine fan.

Also included in the Gilonon Formation are associated volcanic and hypabyssal rocks and minor intrusive rocks. The volcanic rocks consist of plagiophyric basalt and plagioclase-pyroxene-phyric andesite. These volcanic rocks could also be equivalent to the **Salug Volcanics** of MMAJ-JICA (1988), consisting of andesite and andesitic agglomerates. Minor dacitic breccia is interbedded with the conglomerate. Dioritic intrusions apparently cut across some portions of the formation. These intrusions could be associated with the **Hindang Diorite** of MMAJ-JICA (1988), which is correlatable with the Eocene Albuera Diorite of the Central Highlands of Leyte.

Kantaring Limestone

Lithology	Bioclastic limestone
Stratigraphic relations	Unconformable over volcanic rocks
Distribution	Kantaring Valley, Maasin, Leyte
Age	Late Oligocene to Early Miocene
Named by	Jurgan (1980)
Synonymy	Cansirong Limestone (Florendo 1987)
Correlation	Limestone of the Wahig Formation in
	Bohol; Butong Limestone and Cebu
	Limestone of Cebu

The Kantaring Limestone was introduced by Jurgan (1980) for the limestone boulders found along the road from Nonok to Acacia at the west

slope of Kantaring Valley, north of Maasin, southern Leyte. On the other hand, Florendo (1987) named this unit **Cansirong Limestone** as a member of the Dacao Formation. The term Kantaring was adopted in the subsequent reports of Cosico and others (1989), Jurgan and Domingo (1989) and Aurelio (1989). According to the original description, the Kantaring was observed as boulders in poorly sorted conglomeratic sandstone exposed at the type locality. It was also observed as biomicrite beds overlying 1-2 m pebbly claystone, which rests on volcanic basement rock in a roadcut at Acacia district (Jurgan and Domingo, 1989). The biomicrite beds, measuring 5 m thick, contain detritus of finger and head corals. Other exposures were recognized in Mts. Lunas and Lanoy (Laboon) in the eastern side of the Kantaring Valley.

The limestone is cream-coloured, dense and fossiliferous containing abundant *Spiroclypeus* and sparse *Lepidocyclina* species. Other fossil forms include *Amphistegina* sp., *Austrotrillina striata, Sorites* sp., *Operculina* sp., *Halimeda* flakes, red algae, branching corals, echinoid spines and molluscan fragments. The carbonates earlier ascribed as Cansirong refers to the buff coloured algal and bioclastic limestone with finger coral and molluscan shell fragments. Foraminiferal remains identified in the limestone suggest a Late Oligocene to Early Miocene age for the unit, which was probably deposited in a shallow shelf environment (BED, 1986b).

Batang Formation

Lithology	Sandstone, siltstone, mudstone
Stratigraphic relations	Overlain by Early Miocene clastic
	sequence.
Distribution	Exposed along Batang Creek and
	Kantaring River near Laboon
Age	Probable Late Oligocene to Early Miocene
Thickness	750 m
Named by	Florendo (1987)
Renamed by	MGB (this volume)
Correlation	Cantabaco Member of the Malubog
	Formation in Cebu

This was originally defined by Florendo (1987) as a member of his Dacao Formation for the turbiditic sequence consisting of sandstone, siltstone, silty mudstone and occasional lime mudstone exposed along Batang Creek, northeast of Maasin. It occurs in two thrust slabs that appear as erosional remnant of a thrust sheet folded into a northeast trending antiform. A maximum of 750 m was measured in the type area. Observed sedimentary structures include low-angle gently undulating lamination or hummocky cross-stratification.

No diagnostic fossil was identified in the samples, but a probable Late Oligocene to Early Miocene age was assumed for the unit relative to the overlying Early Miocene sequence designated by Florendo (1987) as Tagabaca Member of his Dacao Formation. Shales and siltstones in Barrio Nonok, north of Maasin in southwest Leyte, which could be part of the Batang Formation, were determined to be Late Oligocene in age as reported by Porth and others (1989), based on nannoplankton analyses.

Taog Formation

Lithology	Sandstone, sandy shale with occasional interbeds of coal, carbonaceous shale and conglomerate
Stratigraphic relations	Unconformable over the basement rocks and unconformably overlain by Tagnocot Formation
Distribution	Extends from Ginabuyan in the north down to the central part of western Leyte west of Merida
Age	Early Miocene
Thickness	2,375 m
Named by	Corby and others (1951)
Synonymy	Tagabaca Member and Salomon Member of Dacao Formation (Florendo, 1987)

The Taog Formation was named by Corby and others (1951) but the type locality was not mentioned. It rests unconformably over volcanic basement rocks and is in turn unconformably overlain by the Tagnocot Formation. The Taog stretches for 32 km in northwest Leyte, from Ginabuyan in the north up to the central part of western Leyte, west of Merida. In the original definition made by Corby and others (1951), the Taog was divided into two formations: the 775-m thick lower Taog and the 1,600-m thick upper Taog. Taken together, the formation consists of well-bedded brown sandstone and sandy shales with occasional interbeds of conglomerate. The beds vary in thickness ranging from several centimeters to a few decimeters. The clasts in the conglomerates consist mostly of igneous rocks. Occasional black carbonaceous shales and coal stringers were noted by Corby and others (1951). The sparse fossils present in the Taog indicate an Early Miocene age for the unit.

The **Tagabaca Member** of the Dacao Formation of Florendo (1987) in the southwest is probably equivalent to the Taog Formation. The Tagabaca is an Early Miocene clastic sequence consisting of basal sandstone, siltstone and mudstone and upper conglomerate beds exposed in one of the tributaries of the Kantaring River, where it was observed to rest directly over the Kantaring Limestone. The **Salomon Member** of the Dacao Formation of Florendo (1987), likewise, could also be equivalent to the Taog Formation and may be considered as a facies of the Tagabaca. The Salomon consists of medium- to very coarse-grained sandstone and sparse shale and calcareous mudstone observed in the thrust slab at the headwaters of the Kantaring River, Maasin. Parallel laminations are common in the sandstone facies. No diagnostic fossil was identified in this member, but a probable Early Miocene age is inferred based on its position with respect to the overlying Middle Miocene Danao Limestone of Florendo (1987).

Laboon Conglomerate

Lithology

Conglomerate

Stratigraphic relations	Discordant over the Tagabaca Member of
	the Dacao Formation and overlain by the
	Calubian/Danao Limestone
Distribution	Laboon, Maasin and northward in the
	central part of southern Leyte
Age	Middle Miocene
Named by	Florendo (1987)
Correlation	Kabulao Conglomerate in Bohol; Hubasan
	Conglomerate in northwest Leyte

The Laboon Conglomerate was introduced by Florendo (1987) for the coarse clastic deposits exposed on the west bank of Kantaring River near the village of Laboon, Maasin. It consists predominantly of pebbly to cobbly conglomerate with pebbly sandstone and minor coarse sandstone beds. The clasts, usually rounded, consists of metagabbro, diorite, monzonite, indurated sandstone and siltstone, marbleized limestone, green tuff, andesite, basalt, chert and conglomerates presumably derived from the older formations around the area. The formation was observed to be discordant over the Tagabaca Member of the Dacao Formation of Florendo (1987) and is also unconformably overlain by his Danao Limestone, which is equivalent to the Calubian Limestone. These conglomerates are well distributed from Laboon to the central part of southern Leyte. A Middle Miocene age is inferred for the formation on the basis of the age of the overlying Middle Miocene Danao Limestone.

Calubian Limestone

Lithology	Coralline limestone, locally marly
Stratigraphic relations	Overlies the Laboon Conglomerate
Distribution	Ridges parallel to the western coast from
	Balite to the southern end of the peninsula
	and northwest of Ormoc Bay; Tinobdan,
	Mt. Lundag, Mt. Mahayag
Age	Middle Miocene
Thickness	150 m
Named by	Corby and others (1951)
Synonymy	Danao Limestone in southwestern Leyte
	(Florendo, 1987)

The Calubian Limestone was designated by Corby and others (1951) for the narrow limestone ridges in Calubian, on the east coast of the peninsula. It is essentially white, coralline and lenticular limestone with local marly and porous facies. The area west and northwest of Calubian was identified by Porth and others (1989) as the type locality of the formation. Limestone ranges such as Tinobdan, Mt. Lundag and Mt. Mahayag were mapped as part of the Calubian. The Calubian also underlies the ridges parallel to the west coast from Balite to the southern end of the peninsula as well as northwest of Ormoc Bay. According to Muller and others (1989) nannoplankton zone NN5 (Middle Miocene or Langhian) has been determined in marly inclusions within the limestone exposed along the east flank of the Calubian Range. The maximum thickness of the formation is 150 m east of Palompon.

The Calubian is equivalent to the **Danao Limestone** of Florendo (1987) in southwestern Leyte. The Danao Limestone is defined as a massive, coralline-algal type limestone in the north and central parts of southern Leyte and in the mountainous part of the central highlands. A thickness of 140 -160 m was measured for an exposure of the limestone. The formation unconformably overlies the Late Oligocene – Early Miocene Dacao Formation of Florendo (1987) and is in turn conformably overlain by the Masonting Formation. Based on its foraminiferal content, the formation is dated Middle Miocene (Florendo, 1987).

Tagnocot Formation

Lithology	Shale, siltstone, minor conglomerate, sandstone
Stratigraphic relations	Unconformable over the Taog Formation; overlain by the Bata Formation
Distribution	Tagnocot, Tabango; San Isidro to Quiot, east of Ginabuyan; west of Mt. Masango and from Villaba to Palompon
Age	Middle Miocene
Thickness	1575 m
Named by	Corby and others (1951)

The Tagnocot Formation was designated by Corby and others (1951) for the clastic rocks stretching from San Isidro to Quiot. The formation unconformably overlies the folded Taog Formation. In Dunlop River, it is overlain by the conglomerates of the Bata Formation (Porth and others, 1989). The Tagnocot underlies two large areas in northwestern Leyte. The northern area extends south-southeast for 60 km from west of San Isidro Bay to Quiot. The other area defines a belt that extends 34 km in the same direction from Villaba to Palompon. It consists largely of massive to poorly bedded dark gray shales and siltstones with minor interbeds of conglomerate, coarse sandstone and sandy shale, seldom over a few meters thick. The type locality is in Tagnocot, Tabango. It outcrops most extensively at Ginabuyan. Patchy outcrops west of Calubian have also been noted. Paleontological analyses of samples indicate foraminiferal zones N9 to N14 (?) and nannoplankton zones NN6 to NN7 (?), corresponding to Middle Miocene (Porth and others, 1989; Muller and others, 1989). The maximum thickness is 1,575 m (Corby and others, 1951).

Kadlum Conglomerate

Lithology	Conglomerate
Stratigraphic relations	Unconformable over the Tagnocot
	Formation
Distribution	Kadlum Creek, west of Calubian; Sitio
	Hubasan, Barrio Abijao, Villaba; ridge
	parallel to the east coast from Gutusan
	north to Villalon
Age	Late Miocene
Thickness	50 m
Named by	Corby and others (1951)

Synonymy

Hubasan Conglomerate (Llaban, 1989); Masaba Conglomerate (Balce and others, 1996)

The Kadlum Conglomerate was named by Corby and others (1951) for the conglomerate pile exposed at Kadlum Creek, west of Calubian. At the type locality, the Conglomerate is overlain by marls and limestones dated Late Miocene (Porth and others, 1989). The Kadlum also underlies a high ridge parallel to the east coast, running north from Gutusan to Villalon. It consists mainly of pebble conglomerate with occasional thin stringers of sandstone and shale. The maximum diameter of the pebble clasts is 5 cm. The clasts are composed largely of quartz, andesite, chert and silicified shale held together by a sandy matrix. The reported presence of thick conglomerate at the base of the Bata Formation in Dunlop River suggests that the Kadlum is a local time-equivalent facies of the Late Miocene Bata Formation (Muller and others, 1989). The maximum exposed thickness of Kadlum is 50 m (Corby and others, 1951).

The *Hubasan Conglomerate* of Llaban (1989) is probably equivalent to the Kadlum Conglomerate. The Hubasan is exposed near the headwaters of Tagbubunga and Abijao. Its designated type locality is in Sitio Hubasan, Abijao, Villaba. It consists predominantly of pebble to boulder clasts of schist, serpentinites, shales and limestone embedded in sandy matrix. It is generally massive to poorly bedded clast- to matrixsupported conglomerate.

Bata Formation

Lithology	Tuffaceous marl and tuff with interbeds of sandy to silty mudstone and minor conglomerate, sandstone and
Stratigraphic relations	conglomeratic interbeds; limestone lenses Unconformable over the Calubian
	Limestone; unconformably overlain by the
	Hubay Formation
Distribution	Tabango-San Isidro-Calubian Road;
	Balite; Abijao; Polompon
Age	Late Miocene
Thickness	850 m
Previous name	Bata Shale (Corby and others, 1951)
Renamed by	Pilac (1965)
Synonymy	Masonting Formation (Florendo, 1987)

The formation was originally named Bata Shale by Corby and others (1951). Pilac (1965) redefined it as Bata Formation to include both the Tuktuk Formation and the Bata Shale. Here, the name Bata Formation is adopted although the Tuktuk Formation is considered as a separate formation.

The Bata Formation unconformably overlies the Calubian Limestone and is in turn unconformably overlain by the Hubay Limestone. It consists of light gray to white tuffaceous (bentonitic) fossiliferous marls, and greenish-gray, brownish or black, silty to sandy claystones. Sandstone interbeds are common and limestone lenses were observed near the base of the formation. Turbiditic layers with basal conglomerates exposed at Hubasan, Abijao and Abanga rivers are also considered part of the formation. In the Balite area, sandstone impregnated with bitumen (tar sands) mark the base of the formation (Corby and others, 1951). In Abanga River east of Palompon, Porth and others (1989) report the presence of angular basalt boulders within the formation. Foraminiferal and nannoplankton assemblages corresponding to zones N16 to N18 and NN11, respectively, indicate a Late Miocene age for the formation (Muller and others, 1989). The exposure west of Villahermosa has a thickness of 850 m (Corby and others, 1951).

The **Masonting Formation** of Florendo (1987) exposed along the Masonting River in Malitbog is probably equivalent to the Bata Formation. The Masonting consists of volcaniclastic rocks and andesite flow breccias with intertonguing tuffaceous marl, sandstone and minor pumice beds. It overlies the Danao Limestone of Florendo (1987), which is equivalent to the Calubian Limestone. Exposures are scattered in the San Pedro – Malitbog area around Sogod Bay. The formation is dated Late Miocene to Pliocene (Florendo, 1987).

Hubay Limestone

۱
ear
e

The Hubay Formation was named by Corby and others (1951) for the sequence of limestone interbedded with sandstones and shales at Barrio Jubay, Calubian, The name Hubay, instead of Jubay, however, has become established. The formation consists of cream to buff, porous, coralline, poorly bedded to massive limestones interbedded with sandstones and shales. For the most part, the formation is dominantly limestone, and for this reason, Maac-Aquilar (1995) renamed it Hubay Limestone. It fringes most of the coastal areas of northwest Leyte, including Balite, Villaba and Palompon. At the Abanga River gorge, Porth and others (1989) report that well-bedded bioclastic limestones alternating with sandy and partly tuffaceous marls yielded foraminifera and nannoplanktons, which were dated Early Pliocene (N19 and NN13 - NN15?, respectively). Bentonitic marls and marly siltstones in a tributary of Salug River east of Hilongos in the southwest were also dated Early Pliocene (N19) on the basis of planktic and benthic foraminifera (Porth and others, 1989). In places, the limestone lies unconformably over the Bata Formation. The average thickness of the formation is 50 m (Corby and others, 1951) although it could attain a maximum thickness of 100 m.

The Hubay may be divided into two members: *Merida Member* and *Tinobdan Limestone*, which were originally recognized by Maac-Aguilar (1995) as formations. These are probably facies of the Hubay, representing differing proportions of the limestone and clastic contents of the units. The Tinobdan Limestone is probably the shallow water counterpart of the calcareous conglomerate, sandstone and shales of the Merida and contemporaneous deposition is postulated for the limestone and the calcareous clastics. The Early Pliocene light gray to white bentonitic marls and marly siltstones sampled by Porth and others (1989) in a tributary of the Salug River, near Barrio Kapodlusan, east of Hilongos, west-central Leyte is considered part of the Merida.

Inopacan Formation

Lithology	Dominantly conglomerate with interbeds of mudstone and calcareous tuff
Stratigraphic relations	Unconformably overlies the Pangasugan Formation of central Levte
Distribution	Inopacan; northern, western and southern parts of Maasin
Age	Late Pliocene (?)
Previous name	Inopacan Clastics (Florendo, 1987)
Renamed by	MGB (this volume)
Correlation	Dolores Formation in Leyte Central
	Highlands

This unit was originally named Inopacan Clastics by Florendo (1987), here renamed Inopacan Formation. It consists mainly of well-sorted rounded pebble- and cobble conglomerate with subordinate poorly bedded mudstone and calcareous tuff. It is exposed in the northern, western and southern parts of Maasin. The Inopacan unconformably overlies the Pangasugan Formation and is apparently equivalent to the Dolores Formation, both of which are grouped under Leyte Central Highlands. It is dated Late Pliocene on the basis of its stratigraphic position and similarity with the Dolores Formation.

Tuktuk Formation

Lithology	Tuffaceous sandstone and shale with intercalations of pumice and tuffaceous marl
Stratigraphic relations	Unconformably overlies the Calubian Limestone.
Distribution	Barrio Tuktuk, Calubian; east coast of the Calubian Peninsula, from Tigbawan to Villahermosa; also Balite and Palompon, southwards
Age	Early Pleistocene
Thickness	475 m
Named by	Corby and others (1951)

The term Tuktuk Formation was established by Corby and others (1951) for the clastic rocks at Barrio Tuktuk, Calubian. It unconformably

overlies the Calubian Limestone. The Tuktuk consists of a thick sequence of Pleistocene tuffaceous sandstone and shale with lavers of pumice and thin intercalations of tuffaceous marl exposed from Barrio Villahermosa to Barrio Tuktuk, Calubian. Sedimentary outcrops along the road from Matagob to the east are also considered as part of the Tuktuk Formation. According to Corby and others (1951) it includes exposures along the east coast of the peninsula from Tigbawan to Villahermosa: those surrounding the ridges formed by the Calubian Limestone: outcrops southeast of Balite: and along the coast from Palompon to the south end of the peninsula. Aguilar (1995) extended the limit of the formation down to Calaguise. Levte. Two members are recognized, namely, Dao and Gutusan members. The lower Dao Member consists of white, bentonitic shale named after Dao Creek, west of Gutusan. It has an estimated thickness of 225 m. The upper Gutusan Member consists of thin bedded sandstone, limestone and shale outcropping along roadcuts in Gutusan. The thickness of the Gutusan near the Tuktuk type section is 250 m (Corby and others, 1951).

A big discrepancy exists in the age assignment of the Tuktuk Formation, from Middle Miocene (Corby and others, 1951) to Early Pleistocene (Mueller and others, 1989 and Porth and others, 1989). The Early Pleistocene age assigned to the Tuktuk was established by the presence of NN19 nannofossils and N22-N23 planktic foraminifers. The presence of *Globorotalia truncatulinoides* Bolli (?) is very conspicuous. Late Neogene molluscan fossils were also recognized from the tuffaceous calcareous siltstones and sandstones exposed in Calaguise, Tuktuk, and Bunao districts (Aguilar, 1995). Based on the repeated successions, graded bedding, cross-bedding and laminations, a turbiditic sequence is indicated. Corby and others (1951) report a thickness of 475 m measured near the type section.

San Isidro Limestone

Coralline limestone			
Unconformably o	overlies	the	older
formations			
San Isidro Bay			
Pleistocene			
50 m			
Corby and others (1	951)		
Matalom Limestone	(Florendo,	1987)	
Carcar Limestone in	n Cebu		
	Coralline limestone Unconformably formations San Isidro Bay Pleistocene 50 m Corby and others (1 Matalom Limestone Carcar Limestone ir	Coralline limestone Unconformably overlies formations San Isidro Bay Pleistocene 50 m Corby and others (1951) Matalom Limestone (Florendo, Carcar Limestone in Cebu	Coralline limestone Unconformably overlies the formations San Isidro Bay Pleistocene 50 m Corby and others (1951) Matalom Limestone (Florendo, 1987) Carcar Limestone in Cebu

The San Isidro Limestone was named by Corby and others (1951) for the flat-lying Pleistocene coralline limestone at San Isidro Bay. Porth and others (1989) and Mueller and others (1989) consider the San Isidro to be equivalent to the Tuktuk Formation. Their assumption was established on the similarity of age of both units. Corby and others (1951) estimate the thickness of the San Isidro to be at least 50 m. It is equivalent to the Carcar Limestone in Cebu.

In southern Leyte, a probable lateral extension of the San Isidro Limestone is the **Matalom Limestone** of Florendo (1987). It refers to the sequence of bioclastic deposits and coralline limestone extensively

exposed in the peripheral and coastal areas of southern Leyte. The calciclastics are composed of calcarenite, calcisilitie and calcirudite with occasional calcareous mudstone. The Matalom unconformably overlies the Inopacan Formation. The Limestone is dated Pleistocene (MMAJ-JICA, 1985).

Leyte Central Highland

The Central Highland is largely underlain by igneous rocks, which are related to the two stages of subduction. The earlier stage is characterized by arc magmatism consequent to the west-verging subduction of the West Philippine Basin along the length of the eastern Philippines, from northern Luzon down to Mindanao from Eocene to earliest Miocene time. The second stage is mainly manifested as arc volcanism related to the reactivation of subduction along the same zone from southern Luzon to Mindanao since Late Miocene-Pliocene time.

Albuera Diorite

Lithology	Diorite
Distribution	Albuera municipality, mostly along Tabgas
	and Taroc creeks in Albuera
Age	Eocene (?)
Named by	Cabantog (1989)

The Albuera Diorite was named by Cabantog (1989) after the diorite bodies that crop out along Tabgas and Taroc creeks south of Albuera town. This is equivalent to the "Gabbro" discussed in the report of Pilac (1965). The rock is described as jointed quartz diorite composed principally of andesine, hornblende, biotite and quartz with magnetite, sphene and apatite as accessory minerals. Outcrops measuring up to about 1,500 m long and 550 m wide were observed along the west slope of the central range, mostly blanketed by the Pangasugan Formation.

The contact of the Albuera Diorite with other units is not clear, hence, determination of the age of its emplacement is conjectural. However, an Eocene age is postulated for the intrusion of this body probably as a manifestation of arc magmatism occasioned by the subduction of the West Philippine Basin along eastern Philippines during the Eocene. The Albuera is correlatable to the Hindang Diorite of MMAJ-JICA (1988) in western Leyte.

Kanturao Volcanic Complex

Lithology	Hornblende-pyroxene andesite, basalt,
Stratigraphic relations	dacite and associated pyroclastic rocks Unconformably overlain by the Dolores
	and Pangasugan formations
Distribution	Highlands of central Leyte
Age	Late Oligocene - Early Miocene
Previous name	Central Highland Volcanics (Pilac, 1965)
Renamed by	MGB (this volume)

Forming rugged terrains and irregular slopes in the highlands of central Leyte is the Central Highland Volcanics of Pilac (1965), which is equivalent to the **Kanturao Volcanics** of White Eagle Overseas Oil Co. (1957, in BMG, 1981), here renamed Kanturao Volcanic Complex. It covers a continuous belt from barrio Nilapnitan, Baybay to barrio Lemon, Capoocan. The unit basically consists of hornblende-pyroxene andesite, basalt, dacite and pyroclastic rocks. The andesite consists of phenocrysts of hornblende, pyroxene and plagioclase set in glassy matrix. The unit is presumed to have been emplaced during Late Oligocene to Early Miocene time, before the cessation of earlier subduction along the eastern Philippines.

The Kanturao is apparently coeval with the **Hibulungan Volcanics** (White Eagle Overseas Oil Co., 1957, in BMG, 1981) in western Leyte. The Hibulungan is reported to unconformably overlie the lower Taog Formation.

Pangasugan Formation

Lithology	Coarse conglomerate, volcanic and
	pyroclastic rocks with occasional lenses of
	sandstone and shale
Stratigraphic relations	Unconformable over the Kanturao
	Volcanic Complex
Distribution	Pangasugan River, Barrio Pangasugan,
	Baybay; widespread in the central
	highlands
Age	Late Miocene – Early Pliocene
Thickness	1,200-1,500 m
Named by	Pilac (1965)

The Pangasugan Formation was named by Pilac (1965) for the thick sequence of coarse conglomerate and volcanic and pyroclastic rocks exposed along the Pangasugan River, in Barrio Pangasugan, Baybay (Pilac, 1965). The formation is distributed chiefly along the flanks and rims of the Kanturao Volcanic Complex. Clasts of the conglomerate consist mainly of andesitic fragments, which suggest direct derivation from the Kanturao Volcanic Complex. Proximal to the slopes, the conglomerates are coarser and clast-supported, which laterally grades into matrix-supported conglomerates distal to their provenance. The unit is generally massive, poorly bedded, poorly sorted but well compacted. Intercalating with the conglomerates are volcanic agglomerates and breccia associated with some tuffs. Occasionally alternating with the conglomerates especially along the upper sections are lenses of coarse sandstone and tuffaceous shale. Clasts of the conglomerates range in size from cobbles to pebbles. which are mostly angular to sub-angular in shape. Fine sand and argillaceous materials serve as matrix and cementing materials.

The Pangasugan is extensively distributed in the central highlands extending from the Capoocan area to southern Leyte. The formation generally underlies rugged terrains with prominent peaks reaching up to 1,000 m elevation. Along the Pangasugan River, the basal part of the formation intercalates with basaltic flows. Andesitic sills and dikes are sporadic within the Pangasugan. The total thickness of the formation reaches 1,200 - 1,500 m. The formation is devoid of fossils but a Late Miocene to Early Pliocene age was inferred by Pilac (1965).

Dolores Formation

Conglomerate, sandstone, shale and
limestone
Unconformable over the Pangasugan
Formation
Barrio Dolores, Tongonan; outcrops occur
on the eastern and western slopes of the
central highlands
Late Pliocene
Pilac (1965)
Bagahupi Formation (Pilac, 1965)

The Dolores Formation was named after its type locality in Barrio Dolores, municipality of Tongonan (Pilac, 1965), northeast of Ormoc City. It is composed of matrix-supported volcaniclastic successions occurring as flat-lying units mantling the slopes of the central highlands. It unconformably covers part of the Pangasugan Formation. The formation consists of well-bedded conglomerate, sandstone, shale and limestone. The conglomerate is pebbly with clasts of sub-rounded andesite fragments set in sandy, tuffaceous matrix. Along Taruc River, sandy, friable and porous limestone covers the clastic rocks of the Dolores. This carbonate facies is probably equivalent to the Hubay Limestone or could be extensions of the limestone. Compared to the Pangasugan, the Dolores Formation is finer and better sorted, probably representing distal sedimentation of the Pangasugan Formation. At the type area and along major structures, the beds of the Dolores Formation dip steeply. The nannofossils contained in the formation support a Late Pliocene age for the Dolores (MMAJ-JICA, 1990).

Visares Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over the Dolores
	Formation
Distribution	Visares, Capoocan
Age	Late Pliocene
Named by	Maac-Aguilar (1995)

The Visares Limestone was named by Maac-Aguilar (1995) for the isolated limestone outcrop at Visares, Capoocan. It is considered as a separate unit because of its detachment from the continuous belt of the Hubay outcrops in the northwest and its distinctive planktic foraminiferal contents indicative of Late Pliocene age. At the type locality, the limestone unconformably overlies the Dolores Formation.

Leyte Volcanic Arc Complex

Lithology	Andesitic volcanic cones and flows; minor basalt
Stratigraphic relations	Intrudes and covers the older volcanic rocks in Leyte
Distribution	Controlled by the lineation of the Philippine Fault from Biliran down south to Panaon Island
Age	Late Pliocene to Recent
Previous name Renamed by	Quaternary Volcanics (Pilac, 1965) MGB (this volume)

The term Quaternary volcanics was suggested by Pilac (1965) for the young volcanic cones and flows distributed from Biliran Island in the north down south to Panaon Island, here renamed Leyte Volcanic Complex. These comprise a volcanic chain related to the subduction of the Philippine Sea Plate beneath the Leyte segment of the Philippine Trench. Biliran Island in the north is an active volcano, while Maripipi Island in the north and Cancajanag and Gumdalitan in Ormoc are considered by PHIVOLCS (1998) as potentially active volcanoes. The 30 or so volcanoes comprising this chain are distributed near or along the Leyte segment of the Philippine Fault. The volcanic rocks extruded from these volcanoes are mostly calcalkaline andesites and a small proportion consists of basalts. Radiometric dating of the volcanic rocks indicates that volcanic activity along this chain started as early as 3 Ma or Late Pliocene (Sajona and others, 1997).

• Cabalian Volcanic Complex

Mt. Cabalian, a young solfataric stratovolcano with a crater lake, stands on the tip of the southeastern peninsula of Leyte (Comvol, 1981). Inactive volcanoes that are included in this volcanic complex are Cantoloc, Silago and Nelangcapan in Panaon Island. The rocks of this complex consist mainly of andesite flows and pyroclastic breccias. A maximum age of 2.53 Ma is indicated by radiometric K-Ar dating of a high-K andesite sample from Sogod (Sajona and others, 1997). The youngest radiometric K-Ar dating for this complex was obtained from Cabalian, which gave a value of 0.2 Ma (MMAJ-JICA, 1986).

• Biliran Volcanic Complex

The volcanic island of Biliran is an active volcano whose last recorded eruption was in 1939 (PHIVOLCS, 1995). The Biliran Volcanic Complex consists of numerous volcanic edifices, mainly stratocones and domes, made up of lava flows and pyroclastic deposits. The inactive volcanoes in Biliran Island as listed by PHIVOLCS (2002) are: Capinyahan, Caraycaray, Giron, Guiauasan, Gunansan, Maliwatan, Panamao, Sayao, Tabuanan and Vulcan. On the other hand, Pagado and others (1995) subdivide the Biliran Volcanic Complex into nine (9) sub-units consisting of either a single or several volcanic deposits traceable to a well-defined region of eruption, namely: Panamao, Anas, Acaban, Gumansan dome, Aslunan, Sayao domes, Tagburok, Busalis domes, and Suiro. Acaban and Asluman are characterized by basalts that have been extruded as early as Late Pliocene. The pyroxene basalt comprising Gumansan dome, however, was extruded much later. The other sub-units are characterized by andesitic rocks. Mt. Sayao dome represents the latest volcanic activity in the island. Subsurface data indicate that the Biliran Volcanic Complex sits on Late Miocene-Early Pliocene sedimentary rocks. Radiometric dating of samples from Biliran gave values that range from 1.39 Ma to 0.24 Ma (Sajona and others, 1997). The other volcanic islands in the north, namely, Maripipi, Camandag, Costa Rica and Kirikite, may be regarded as part of the Biliran Volcanic Complex.

• Cancajanag Volcanic Complex

The Cancajanag Volcanic Complex is dominated by the 1,350 m high Mt. Cancajanag, a potentially active volcano located around 20 km east of Ormoc City. To the south, 10 km away, is Mt. Gumdalitan, another potentially active volcano. Other inactive volcanoes comprising this volcanic complex in the central highlands of Leyte are: Abunug, Aguiting, Alto Peak, Danao, Janagdan, Proto-Janagdan, Laao, Lobi, Maagonoc and Macape (PHIVOLCS, 1995). The Tongonan geothermal field north of Cancajanag is situated within this volcanic complex. Andesites from Tongonan gave radiometric K-Ar ages of 1.37 Ma – 0.85 Ma (Sajona and others, 1997).

Eastern Leyte

Tacloban Ophiolite

Lithology	Serpentinized harzburgite, gabbro, sheeted dikes, basalt and overlying pelagic sedimentary rocks
Distribution	Northern Tacloban Highlands from Babatngon to Abuyog
Age	Cretaceous
Named by	Cabantog and Escalada (1989)
Synonymy	Malitbog Ophiolite (Florendo, 1984)
Correlation	Samar Ophiolite in Samar Island

The term Tacloban Ophiolite was introduced by Cabantog and Escalada (1989) in place of the unit formerly mapped as Tacloban Volcanics by Pilac (1965). The Ophiolite consists of serpentinized harzburgite, undifferentiated gabbro, sheeted diabase complex, andesite and associated pelagic sedimentary rocks. This was subdivided by Cabantog and Escalada (1989) into: Tagawili Ultramafics, Tigbao Gabbro, Paglaum Sheeted Dikes, Caibaan Pillow Basalt and Palanog Pelagic Sediments. These ophiolitic rocks were observed as elongated patches extensively distributed in the Tacloban Highland district from Babatngon to Tanauan and Abuyog municipalities. Few small exposures of quartz monzonite are regarded as plagiogranite facies representing a product of differentiation within the ophiolite sequence (Balce and Cabantog, 1998). This complex is equivalent to the Malitbog Ophiolite of Florendo (1984) in southern Leyte.

Cabantog and Escalada (1989) noted that foliated and gneissose rocks designated as **Babatngon Schist** (Pilac, 1965) grades into unmetamorphosed country rocks such as basalt and gabbro , which are associated with the Ophiolite. They therefore postulate that the foliation exhibited by the schists and gneissose textures are local effects of intense shearing. Outcrops of these metamorphic rocks are quite extensive in the vicinities of Babatngon and Palo. In places, the schist is highly folded and crenulated, with schistosity verging steeply in an east-west direction

• Tagawili Ultramafic Complex

Lithology	Serpentinized harzburgite with occasional
	dunite lenses
Distribution	Tagawili, Babatngon; Abuyog, McArthur
	and Babatngon districts
Age	Cretaceous
Previous name	Tagawili Ultramafics (Cabantog and
	Escalada, 1989)
Renamed by	MGB (this volume)
-	

The Tagawili Ultramafic Complex refers to the ultramafic phase of the Tacloban Ophiolite. The term Tagawili was established by Cabantog and Escalada (1989) for the serpentinized harzburgite, dunite lenses and bands of pyroxenite exposed in Tagawili, Babatngon district. It was also observed in the vicinities of Abuyog, McArthur and Babatngon (Pilac, 1965). The rocks primarily consist of olivine, augite, enstatite and labradorite. Crisscrossing magnetite stringers were also noted on rock surfaces. At the Abuyog-McArthur area, the serpentinized harzburgite occupies a continuous northwesterly trending belt for about 10 km. MMAJ-JICA (1990) identified the rocks as websterite and Iherzolite. At Guinbon-an River, a moderate-sized massive chromite-bearing dunite lense was likewise observed (Balce and Cabantog. 1998). This unit is probably correlative to the ultramafic complex mapped by Santos-Yñigo (1951) in McArthur, Samar.

Tigbao Gabbro

Lithology	Dominantly gabbro
Distribution	Barangay Tigbao, Babatngon; Tanauan
	and Palo districts
Age	Cretaceous
Named by	Cabantog and Escalada (1989)

Small patches of gabbroic masses found in Barangay Tigbao are grouped under Tigbao Gabbro (Balce and Cabantog, 1998). Gabbroic rocks were also observed by Pilac (1965) in Kawayan, Tanauan, Tolosa and Binangkawan, Palo. These usually form rugged ridges flanked by irregular slopes or either rise as isolated hills. At Palo-Babatngon area, gabbro outcrops describe large northwesterly trending elongated masses. The rocks are usually massive, occasionally layered and pegmatitic, medium- to coarse-grained and exhibit either allotriomorphic or hypidiomorphic granular texture. Subophitic and intergranular textures were also recognized. Pegmatitic troctolite gabbro was observed by Balce and Cabantog (1998) at the headwaters of Anapao Creek. Gabbroic dikes up to 5 m thick exposed in Adel quarry, west of Tanauan manifest chilled borders along contacts with the serpentinite (Pilac, 1965). The rock is light gray and consists of fresh idiomorphs of augite and laths of plagioclase enclosed in saussuritized plagioclase. At Binangkawayan, the rocks essentially consist of clinopyroxene and calcic plagioclase with minor chlorite, saussurite, uralite, leucoxene and opaque minerals.

• Paglaum Diabase Complex

Lithology	Diabase, subordinate gabbro and basalt
Distribution	Paglaum, Tacloban City and vicinity
Age	Cretaceous
Previous name	Paglaum Sheeted Dikes (Cabantog and
Renamed by	MGB (2000)

The Paglaum Diabase Complex is a sheeted dike complex exposed in Barangay Paglaum, Tacloban, which was previously designated by Cabantog and Escalada (1989) as Paglaum Sheeted Dikes. The dikes consist generally of diabase with few gabbroic and basaltic types. The diabase is greenish gray to gray with fine- to medium-grained saccharoidal texture. Petrographic analysis of the samples revealed subparallel tabular and elongated green hornblende and plagioclase laths admixed with small amounts of pyroxene, chlorite, epidote and illite. The thickness of individual dike ranges from 15 cm to 30 cm.

Caibaan Basalt

Lithology	Pillow basalt
Distribution	Caibaan, Tacloban City
Age	Cretaceous
Previous name	Tacloban Volcanics (Pilac, 1965)
Renamed by	Cabantog and Escalada (1989) as
	Caibaan Basalt
	Balce and Cabantog (1998) as Caibaan
	Pillow Basalt
Correlation	Cancuevas Volcanics (Santos-Yñigo, 1951)

The Caibaan Basalt was previously designated by Pilac (1965) as Tacloban Volcanics in reference to the pillow basalt in Tacloban area. However, in order to avoid the duplication of geographic names (Tacloban Ophiolite and Tacloban Volcanics), the name Caibaan Basalt introduced by Cabantog and Escalada (1998) is herein adopted. It includes andesite porphyry occurring in the northeastern part of Leyte, especially in the vicinities of Tacloban City, Palo and Tolosa. It is bounded to the east by a fault extending from Barrio Rizal, at the northeastern edge of the island, towards Palo and continues down to Tolosa. Another northwest-trending fault passes through its southern end. The pillow basalt represents the volcanic carapace of the Tacloban Ophiolite.

• Palanog Formation

Lithology	Chert; minor mudstone, shale, sandstone
	and vitric tuff
Stratigraphic relations	Caps the Caibaan Basalt
Distribution	Barangay Palanog, between Tacloban and
	Palo areas
Age	Cretaceous
Previous name	Palanog Pelagic Sediments (Cabantog
	and Escalada, 1989)
Renamed by	MGB (this volume)

The pelagic sedimentary rocks capping the Caibaan Basalt were collectively designated by Cabantog and Escalada (1989) as Palanog Pelagic Sediments, here renamed Palanog Formation. The unit consists essentially of chert with subordinate mudstone, shale, sandstone and vitric tuff. Outcrops of these rocks are usually observed as irregular masses or patches in Tacloban and Palo area especially in Barangay Palanog. The chert contains microcrystalline quartz, hematite and recrystallized radiolarian tests. Microcrystalline calcite, smectite, zeolite and illite are distinctly discernible in the vitric tuff. The formation constitutes the pelagic sedimentary cover of the Tacloban Ophiolite.

San Jose Formation

Lithology	Conglomerate, sandstone, shale and fine
	tuffaceous sequences with intercalations
	of volcanic flows
Stratigraphic relations	In some isolated outcrops it apparently
	rests over older volcanic rocks.
Age	Early Miocene
Thickness	950 m
Named by	Pilac (1965)

The term San Jose Formation refers to the slightly metamorphosed clastic deposits occuring in an isolated hill located in the east coast at Barrio San, Jose, Tolosa (Pilac, 1965). It covers an expanse of about 7 km by 2 km at an elevation of 300 masl. At the type area, the formation apparently rests over older volcanic rocks and schist.

The clastic rocks are indurated and slightly metamorphosed. These consist of successions of conglomerate, sandstone, shale and fine tuffaceous beds with intercalations of andesitic volcanic flows. The conglomerate consists predominantly of pebbly rounded andesite clasts with few limestone fragments set in sandy matrix. The interbedded shale and sandstone are calcareous. The beds generally strike northwest and dip at an average of 45 degrees.

A maximum thickness of 950 m was measured for the formation. Fossils sparsely distributed in the clastic rocks indicate an Early Miocene age.

Lithology	Conglomerate, sandstone and shale with occasional limestone interbeds
Stratigraphic relations	Unconformably overlies rocks associated with the Tacloban Ophiolite and San Jose
	Formation
Distribution	San Ricardo, Babatngon; Tacloban City,
	Cablawan, Barrio Rizal, Babatngon area
Age	Middle Miocene
Named by	Pilac (1965)
Correlation	Daram Formation (Corby and others,
	1951) in Samar Island

San Ricardo Formation

The term San Ricardo Formation was introduced by Pilac (1965) for the thick sequence of conglomerate, sandstone and shale with intercalated volcanic flows and limestone at Barrio San Ricardo, Batbangon. Previously the rocks near Tacloban City characterized by similar age and lithology were included by Corby and others (1951) in the Daram Formation, a unit found in western Samar. Its designated type locality is at Barrio San Ricardo, Babatngon where 600-700 m of the section is exposed. It unconformably overlies the rocks associated with the Tacloban Ophiolite and the San Jose Formation. The formation, which is limited to the northeastern part of the island, forms a low ridge near Tacloban City extending to the vicinity of Cablawan to Barrio Rizal and terminating in the Babatngon area. It also occurs as patches in the northeastern slope of the Tacloban Range. The beds are steeply dipping, occasionally vertical or overturned (MMAJ-JICA, 1990).

Based on the contained large benthic foraminifers in the limestone facies, the formation is dated Early to Middle Miocene (Pilac, 1965; BMG, 1981). A Middle Miocene age was however, assigned to it by MMAJ-JICA (1990). The formation could have been formed in a shallow marine depositional environment.

Bagahupi Formation

Lithology	Sandstone and marly tuffaceous shale with basal conglomerate
Stratigraphic relations	Unconformable over the San Ricardo
Distribution	Bagahupi, in the vicinity of Tacloban City; east of Barubo town
Age	Late Miocene to Pliocene
Thickness	150-250 m
Named by	Pilac (1965)
Correlation	Pangasugan Formation

This formation refers to the sequence of polymictic basal conglomerate, sandstone and marly tuffaceous shale typically exposed in the vicinity of Bagahupi, at the northeastern edge of Tacloban City near San Juanico Bridge. It also occurs in the west side of Sapaniton River east of Barugo town and in a road cut along Magsaysay Boulevard in Tacloban

City. At Sapaniton, the sequence has a thickness of about 150-250 m. The formation unconformably overlies the San Ricardo Formation. It is dated Late Miocene to Pliocene.

The formation is broadly folded along a north-northeast axis. The conglomerates are pebbly and consist of sub-rounded andesite, basalt, serpentine, schist, gabbro and limestone clasts. The sandstones are arkosic while the shales are calcareous and tuffaceous. Fine tuffs intercalate with the marls and sandstones.

SAMAR ISLAND (SG 18, 20)

The stratigraphy of Samar Island comprises two stratigraphic groupings: the Leyte Gulf (SG 18) and the Samar Block (SG 20). The Leyte Gulf stratigraphic grouping includes southwestern Samar as well as the islands of Dinagat, Siargao, Bucas Grande and Homonhon. Except for southwestern Samar, the rest of the island constitutes the Samar Block.

Samar Ophiolite

Peridotite, dunite, gabbro, sheeted dikes,
pillow basalts,
pyroclastic rocks
Constitutes the basement rocks
southeastern Samar
Cretaceous, probably Early Cretaceous
MMAJ-JICA (1990)

The Samar Ophiolite in eastern Samar is part of the Samar-Surigao segment of the Eastern Bicol-Eastern Mindanao Ophiolite Belt (BMG, 1981, 1986). It embodies a nearly complete ophiolite sequence consisting of peridotite, dunite, gabbro, sheeted dykes and pillow basalts (Garcia and Mercado, 1981; MMAJ-JICA, 1990; Moon and others, 1991). The ophiolite is characterized by a series of north trending thrust slices constituting a repetitive sequence of ophiolite suite and characterized as Alpine-type intrusion (Franco and others, 1993).

The Giporlos Ultramafic Complex, sheeted dikes and Camcuevas Volcanics in southeastern Samar comprise the Samar Ophiolite. The Anagasi Formation in central Samar is correlative to the sheeted dikes and the Camcuevas Volcanic Complex, which are both overlain by the Upper Cretaceous Balo Formation. The Lawaan Formation, which underlies the Anagasi Formation, is partly equivalent to the Felsic Volcanic Rocks of Garcia and Mercado (1981) and BMG (1981). The Lawaan and Anagasi formations could be part of the ophiolite suite.

• Giporlos Ultramafic Complex

Lithology	Peridotite, dunite, gabbro
Distribution	Southeastern Samar
Age	Cretaceous
Named by	Garcia and Mercado (1981)

PERIOD	EPOCH	AGE	Ма	SAMAR ISLAND
NEOGENE	HOLOCENE			
	PLEISTOCENE	4 Late 3 2 1 Early	0.0117 0.126 0.78 1.81	Calicoan Formation
	PLIOCENE	2 Late	3.60	
		3 Late	5.33 7.25 11.61	Catbalogan Formation
	MIOCENE	2 Middle-	13.65	Hagbay Formation
		1 Early	15.97 20.43	Daram Formation
PALEOGENE	0110005115	2 Late	23.03	
	OLIGOCENE	1 Early	28.4	
	EOCENE	4 Late 3 Middle – 2	37.2 40.4	Mapanas Limestone
	PALEOCENE	1 Early 3 Late 2 Middle 1 Early	55.8 58.7 61.7	Lawaan Formation
CRETACEOUS	Upper	Late	00.0	Balo Formation
			99.6	Anagasi Formation
	Lower	Early		Samar Ophiolite
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	161.2	
	Lower	1 Early	175.6	

Table 2.22 Stratigraphic column for Samar Island

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Santos-Ynigo and others (1951) first reported the occurrence of serpentinized peridotite in the Camcuevas property of Samar Mining Company in MacArthur as overthrust sheet overriding the metavolcanics of the Camcuevas Volcanics and the sedimentary rocks of their Balo River Series (now Balo Formation). Peridotite, serpentinized dunite and minor gabbro collectively called ultramafic complex by Garcia and Mercado (1981), occur as discontinuous irregular bodies along northwest trending thrust faults in southeastern Samar where they are juxtaposed over metamorphosed spilitic and pillow basalts and associated sedimentary rocks as observed in the upper reaches of Giporlos River. Along Vigan
River in the Camcuevas area, small chromite bodies are found in the serpentinized ultramafics. Thick laterite mantles the serpentinized ultramafics in several places.

• Camcuevas Volcanic Complex

Basalt, pyroclastic rocks
Intruded by diorite; overlain by Balo
Formation
General MacArthur, Eastern Samar
Late Cretaceous
650 m
Santos-Yñigo and others (1951)

Santos-Yñigo and others (1951) gave the name Camcuevas Volcanics for the Cretaceous volcanic rocks on the southeastern part of Samar Island. It covers over three-fifths of General MacArthur, Eastern Samar. The unit consists of agglomerate, about 50 m thick, overlain by 30 m of basaltic lava , which in turn, is overlain by 70 m of bedded pyroclastic rocks with limestone fragments. These bedded pyroclastics are overlain by 500 m of massive lavas, which generally exhibit ellipsoidal pillow structures. According to Santos-Yñigo and others (1951), the Camcuevas is intruded by diorite and forms a dome structure around a large diorite mass in the center of the area. Post-diorite thrusted sheets of ultramafic rocks overlie the above rocks in the eastern part. The Camcuevas is overlain by the Balo Formation at Borongan, Giporlos and San Jose de Buan. Radiometric K/Ar for a sample from the central Bagacay area gave a dating of 98.7 \pm 4.9 Ma (MMAJ-JICA, 1988), equivalent to early Late Cretaceous (Albian-Cenomanian).

Anagasi Formation

Andesite, tuff, tuff breccia; basalt, flow breccia;
manganiferous chert; calcarenite
Underlies the Balo and Lawaan formations
Anagasi, southeastern Samar; Lawaan
area
Late Cretaceous
Cabantog and Quiwa (1982)

The Anagasi Formation was named by Cabantog and Quiwa (1982) for the intermediate volcanic and pyroclastic rocks and basic volcanic rocks associated with manganiferous beds and cherty limy strata. The intermediate volcanic rocks are characterized by andesite dikes and flows; the pyroclastic rocks consist of green tuff and subordinate green tuff breccia of dacitic-andesitic composition. The Anagasi is overlain by the San Jose Formation of Cabantog and Quiwa (1982), which is equivalent to the Balo Formation described below.

Some andesite flows are intercalated with the green tuff and tuff breccia. The green tuff sequence covers most of the northwestern portion of the Lawaan area, which is traceable in a belt from the lower reaches of Talahib Creek on the south to Salak Creek on the north. This unit is equivalent to an extensive thick pyroclastic unit (Green Tuffs) of daciticandesitic composition in the Anagasi district consisting of coarse lapilli tuffs, which grade into finer siliceous tuffs (Portacio, Jr., 1982). In places, thin-bedded calcareous and ferruginous/manganiferous cherty tuffs are interfingered with fine-grained upper green tuff sequence. Cherty layers, measuring 1 to 100 cm thick, with notable amounts of manganese oxides and radiolarian fossils were found interbedded with finer tuff. Southeast of Anagasi, pyroclastic beds are intercalated with a 1 m thick layer of buff, fine grained, radiolaria-bearing calcarenite.

Included in this unit are amygdaloidal basalt flows, dikes and sills, basaltic agglomerate and flow breccia, pyroxene andesite flows and breccia, and diabase-gabbro-basalt sills and dikes (Portacio, Jr., 1982). Basalt dikes, sill and flows were observed cutting and overlying the green tuff sequence at the lower reaches of Talahib Creek on the south and extend northwest along the lower portion of Bawa, Kalumanggan, Cantaraok, and Salak creeks in the north. Thick basaltic flows were observed north of Casandig from barangays Tapol to Anagasi in the Boliden area.

The Anagasi Formation is considered Late Cretaceous based on the age of the conformably overlying sedimentary strata.

Balo Formation

Lithology	Limestone, conglomerate, sandstone, mudstone, shale
Stratigraphic relations	Overlies the Camcuevas and Anagasi Formations
Distribution	Balo River, southwest of General
	MacArthur; Bagacay and Sulat area;
	Borongan, Giporlos, San Jose de Buan
Age	Late Cretaceous
Thickness	400 m
Previous name	Balo River Formation (Santos-Yñigo and
	others, 1951)
Renamed by	MGB (this volume)

Santos-Yñigo and others (1951) introduced the name Balo River Formation to designate the rocks along Balo River, southwest of General MacArthur. It consists of highly folded metamorphosed thin bedded conglomerate, sandstone and shale with associated marbleized limestone, manganiferous mudstone and chert (Balce and Esguerra, 1974). These rocks crop out at Bagacay and Sulat area (Balce and Esguerra, 1974), as well as in the vicinity of Borongan, Giporlos and San Jose de Buan (Garcia and Mercado, 1981) where they overlie the Camcuevas Volcanic Complex. The thickness of the formation was estimated by Santos-Ynigo and others (1951) to be 400 m along Balo River. Nannofossil assemblages indicate a Late Cretaceous age for the Balo (MMAJ-JICA, 1988).

The **San Jose Formation** of Cabantog and Quiwa (1982), which conformably overlies the Anagasi Formation in central Samar, is equivalent

to the Balo Formation. The formation is designated as **San Jose Limestone** by BED (1986b), and described as thinly-bedded deep water micrite exposed in the central part of Samar Island. The limestone interbeds in San Jose and Maylube contain various species of *Globotruncana* and *Rugoglobigerina* with *Heterohelix globulosa* (Ehrenberg) pointing to a Late Cretaceous (Turonian) age (Reyes and Ordonez, 1970).

Lawaan Formation

Lithology	Diorite, monzonite, quartz diorite, granodiorite; andesite
Stratigraphic relations	dacite, rhyodacite; pyroclastic rocks; chert Intrudes Camcuevas Volcanic Complex
Distribution	Lawaan, southeastern Samar
Age	Paleogene, probably Late Cretaceous –
-	Early Eocene
Named by	Cabantog and Quiwa (1982)
Synonymy	Felsic Volcanic Rocks (BMG, 1981; Garcia and Mercado, 1981)

Cabantog and Quiwa (1982) first used the term Lawaan Formation in relation to the different lithologic units and mineralization in the Lawaan area, central Samar, which is related to felsic igneous activity. The formation consists of: a) felsic subvolcanic rock and lava flows (also termed felsic plutono-volcanic rocks, b) felsic pyroclastics, c) mineralized rocks, and d) ferruginous chert. The felsic plutono-volcanic rocks have various phases: quartz diorite, granodiorite and monzonite, which grade into the finer phases of dacite, rhyodacite and andesite flows. These rocks form the core of the felsic lava dome that change from a coarser phase at the center to a finer one at the periphery, yet do not show any intrusive relations or clear boundaries with the overlying felsic rocks (Cabantog and Quiwa, 1982). Portacio, Jr. (1982) reported coarse-grained plutonic rocks equivalent to these rocks in the Anagasi area and suggested that these possibly represent the magma chamber of the overlying pyroclastics and flows. Diorite also crops out along Gilagila Creek in Bagacay, Hinabangan, central Samar and in Camcuevas area. Cutting through the sedimentary and volcanic rocks in Camcuevas is an elongated diorite body striking northwest. It is roughly 500 m wide and 3 km long. Although its contact with the surrounding rocks is obscure, the metamorphic effects resulting from its emplacement are clearly discernible.

The felsic pyroclastic rocks in the Lawaan area are made up of tuff breccia with intercalated quartz-bearing crystal tuff, which grades into lapilli tuff to lithic tuff to ash tuff. Veins, veinlets, stringers and stockworks of sulfide minerals, mainly pyrite, chalcopyrite, sphalerite and quartz were deposited in this felsic pyroclastic sequence. Mineralized rocks of the massive sulphide type are stratigraphically above the altered felsic pyroclastics. Ferruginous chert lies above the massive sulfide bodies.

The Felsic Volcanic Rocks of Garcia and Mercado (1981) and subsequently adopted by BMG (1981) - consisting of a thick series of

interlayered dacitic lavas, volcanic breccia and lapilli tuff - is considered part of the Lawaan Formation. The Lawaan is thought to have been emplaced during the Paleogene (MMAJ-JICA, 1988), probably during Late-Cretaceous – Early Eocene.

Mapanas Limestone

Lithology	Limestone
Stratigraphic relations	Intertongues with San Nicolas Claystone
Distribution	Peripheries of Mapanas Bay in
	northeastern Samar
Age	Eocene
Thickness	200 m
Named by	PNOC-EC (1979, in BED, 1986b)

The Mapanas Limestone was reported to have been named by PNOC-EC (1979, in BED, 1986b) for exposures of limestone around Mapanas Bay in northeastern Samar. The Limestone intertongues with its basinal clastic equivalent, the San Nicolas Claystone, which overlies the San Jose Limestone in central Samar (BED, 1986b). The Mapanas is a massive orbitoidal and shelfal limestone that was also encountered in North Samar A-IX well (BED, 1986b). It was reported by BED (1986b) to be Eocene in age with a thickness of 200 m.

The **San Nicolas Claystone** is considered as the basinal clastic equivalent of the Mapanas Limestone (BED, 1986b). It consists of thinly laminated claystone and siltstone with carbonaceous material and disseminated pyrite. Increase in fossil content was observed along with increase in calcareous content, which was also confirmed in North Samar A-IX well. It is dated Eocene.

Daram Formation

Lithology	Sandstone, conglomerate, shale, volcanic
	flows, limestone
Stratigraphic relations	Unconformable over the Camcuevas
	Volcanic Complex
Distribution	Daram, Buad and Paracan Islands;
	northwestern and
	south-central part of Samar; San Pedro
	Bay, Bassey
Age	Late Oligocene to Early Miocene
Thickness	1,000 m
Named by	Corby and others (1951)
Synonymy	Mawo Volcanics (Garcia and Mercado,
	1981)
	Loquilocon Limestone (Garcia and
	Mercado, 1981)

This formation was named by Corby and others (1951) for the rocks typically exposed at Daram Island southwest of Catbalogan, Samar. It may also be encountered at Buad and Paracan Islands and occupies the northwestern and south-central part of Samar Island. The 1,000-m thick formation is a highly folded sequence of hard calcareous volcanic sandstone, pebble conglomerate, black sandy shale, volcanic flows and sills and massive to thin-bedded fossiliferous orbitoidal limestone. A large foraminiferal assemblage containing *Lepidocyclina (Eulepedina)* but without *Miogypsina* was found in San Pedro Bay, Hilaba, Basey. This assemblage points to a Late Oligocene age for the base of the Daram. Based on these findings, the age of the Daram is considered Late Oligocene to Early Miocene.

The present Daram Formation includes the volcanic rocks in the Bagacay-Sulat area (Balce and Esguerra, 1974) and the Mawo Volcanics, as well as the Loquilocon Limestone of Garcia and Mercado (1981). The Loquilocon Limestone is equivalent to the Oligocene Malajog Limestone, which is sporadically distributed in western Samar (BED, 1986b). The Mawo Volcanics (Garcia and Mercado, 1981) in northern Samar consists of andesite and basalt with intercalated pyroclastics. Minor limestone lenses are interbedded with the volcanics.

Hagbay Formation

Lithology	Reefal limestone, siltstone
Stratigraphic relations	Overlain by the Catbalogan Formation
Distribution	Barrio Hagbay, San Jose de Buan
Age	Middle Miocene
Named by	Carozzi and others (1976)
Synonymy	Hinabangan Formation

Coral-red algal reefal carbonates exposed in the area of San Jose de Buan were designated by Carozzi and others (1976) as Hagbay Formation, named after Barrio Hagbay where these are prominently exposed. This carbonate unit contains larger foraminifers of Middle Miocene affinity. Intercalations of siltstones were observed particularly near the contact with the overlying shale of the Catbalogan Formation.

The Hagbay is equivalent to the **Hinabangan Formation** (BED, 1986b), which crops out around the central core of Samar. It consists of limestone breccias at the base and grades into reefs at the middle portion and bioarenites at the upper portion of the formation (BED, 1986b). It is dated Early – Middle Miocene and has an estimated thickness of 500 m.

Catbalogan Formation

Lithology	Marl, siltstone, sandstone, pebble conglomerate
Stratigraphic relations	Underlain by the Hagbay Formation
Distribution	Road from Catbalogan to Lope de Vega;
	road to Wright;
	east of Loquilocon, Bassey; Dolores River
Age	Middle Miocene – Early Pliocene
Thickness	450 - > 500 m
Previous name	Catbalogan Sands and Marls (Corby and others, 1951)
Renamed by	Garcia and Mercado (1981)

The Catbalogan Formation was originally designated by Corby and others (1951) as Catbalogan Sands and Marls. The gray marl, siltstone, sandstone and pebble conglomerate may be encountered along the road from Catbalogan to Lope de Vega, Northern Samar; on the road to Wright, east of Loquilocon, in Bassey; and along Dolores River in the northern part of Eastern Samar. Carozzi and others (1976) renamed the formation Catbalogan Shale for the sequence of coarse, dark sandstone, which grades upward to fossiliferous thinly interbedded sandstone and shale and highly calcareous shale. A conglomerate facies of the Catbalogan containing clasts of diorite, basalt, andesite, schist, marble and chert was reported by Garcia and Mercado (1981) who renamed the unit Catbalogan Formation. It is Middle Miocene to Early Pliocene in age (Garcia and Mercado, 1981). The formation is estimated to be over 500 m thick, but BED (1986b) reports a thickness of only 450 m.

Calicoan Formation

Lithology	Limestone, claystone
Stratigraphic relations	Not reported
Distribution	Calicoan Island; southeastern tip of
	Eastern Samar
Age	Late Pliocene to Pleistocene
Previous name	Calicoan Limestone (Corby and others,
	1951)
Renamed by	BMG (1981)

The Calicoan Formation was previously designated by Corby and others (1951) as Calicoan Limestone in reference to the limestone at Calicoan Island and at the southeastern tip of Eastern Samar. This reefal limestone was dated Pliocene. Garcia and Mercado (1981) further described the limestone as buff to pink, soft, porous and contains mollusks, corals and algae. Underlying the limestone is a clastic member, *Taclaon Clay*, which is composed of alternating layers of brownish, sandy, bluish gray claystone beds. The formation is dated Late Pliocene to Pleistocene.

The limestone member of the formation is equivalent to the **Palapag Limestone**, which is distributed mainly along the coastal areas in eastern Samar and to a lesser extent, in westernmost Samar (BED, 1986b). It consists of coralline rubbles, limestone breccias, biocalcarenites and coralalgal deposits.

GEOLOGY OF THE PHILIPPINES



MINDANAO

DINAGAT GROUP OF ISLANDS (SG 20)

Nueva Estrella Schist

Lithology	Amphibolite schist, garnet-amphibolite schist, biotite-quartz schist, guartzofeldspathic schist
Stratigraphic relations	Metamorphic sole of the Dinagat Ophiolite
Distribution	Melgar Bay, San Jose, Cagdianao; Nonoc
Age	probably Cretaceous
Named by	Wright and others (1958)

The Nueva Estrella Schist constitutes the metamorphic sole of the Dinagat Ophiolite. It consists mainly of amphibolite schist, garnetamphibolite and biotite-quartz schist and to a lesser extent quartzofeldspathic schist. Its present structural disposition is in the form of an irregular tectonic window within the ophiolite. The window stretches from Melgar Bay through San Jose and Cagdianao to Nonoc and Awasan Islands.

The amphibolite schists are typically dark, distinctly foliated rocks made up predominantly of hornblende or tremolite and intimately mixed with coarse granoblastic aggregates of epidote. The latter mineral also occurs with interstitial albite and carbonates in fractures that cut along the schistosity. Attitudes of schistosity in the amphibolite schists are variable but locally parallel to the thrust zone. Schistosity planes generally dip toward serpentinite at variable angles. Cataclasites and talc-chlorite schists occur near the contact zone. The chlorite schists exhibit well-developed cleavage and contain magnetite metacrysts.

Petrographic studies of representative samples reveal the amphibolite schists to contain 85% hornblende crystals, 7% plagioclase aggregates, 6% quartz, and 2% crystalline calcite and epidote plates. Accessory minerals include traces of titanite and pyrite. The low concentration of silica indicates that the protoliths of the amphibolite schists may be basaltic rocks or tuffs.

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	DINAGAT GROUP OF ISLANDS
NEOGENE	HOLOCENE		0.0447	
	PLEISTOCENE	4 Late 3 Middle 2 Late	0.0117 0.126 0.78 1.81	Siargao Limestone
	PLIOCENE	2 Late 1 Early	2.59 3.60 5.33	
		3 Late	7.25	Loreto Formation
			11.61	Timamana Limestone
	MIOCENE	2 Middle-	13.65	Mabuhay Formation
		1 Early	20.43 23.03	Bacuag Formation
	OLIGOCENE	2 Late 1 Early	28.4	
ш		4 Late	33.9	Madanlog Formation
PALEOGENE	EOCENE	3 2 1 Early	37.240.448.6	
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
CRETACEOUS	Upper	Late	00.6	Dinagat Ophiolite
	Lower	Early	99.0	
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.23 Stratigraphic column for Dinagat Group of Islands

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Previous workers have assigned a general Cretaceous or late Cretaceous age for this formation (Wright and others, 1958; Sunga and Palaganas, 1986 and MMAJ-JICA, 1990).

Dinagat Ophiolite

Amphibolite, residual peridotite, cumulate peridotite, massive and layered gabbros, sheeted dike/sill complex; pillow basalt
Overthrusts Nueva Estralla Schist;
overlain by the Loreto Formation
From Desolation Point up north to Mt.
Gaboc down south in Dinagat Island;
Burgos, Esperanza, Sta. Monica, (Sapao)

and San Benito in Siargao Island; Nonoc, Hibuson, Bucas Grande and Hinituan Islands Late Cretaceous MGB (this volume)

Overthrusting the Nueva Estrella Schist is an assemblage of ultramafic and mafic rocks collectively known as the Dinagat Ophiolite. These are extensively exposed in a north-south direction extending from Desolation Point at the northern tip southward to Mt. Gaboc. From bottom to top, the ophiolite consists of a residual peridotite, cumulate peridotite, massive and layered gabbro, sheeted dike complex and pillow basalts.

Aae

Named by

The residual peridotite unit is composed of harzburgite with minor dunite and chromitite lenses. The cumulate peridotite is made up of thin alternating layers of orthopyroxenite, harzburgite and dunite. Intense serpentinization characterizes the ultramafic rocks particularly near the thrust zone. The gabbro sequence consists of massive gabbro and layered gabbro. The sheeted dike/sill complex is overlain by pillow basalt and basalt breccias.

The bulk of ultramafic rocks in Dinagat Island consists principally (about 80 per cent) of harzburgite enclosing irregular lenticular bodies of dunite that are on the average 2-5 m thick. The harzburgite extends from Desolation Point in the north to Manolijao in the south and forms the northsouth trending Dinagat Island ridge, including Albor and Tubajon areas. It also outcrops in Nonoc, Hinituan, and Bucas Grande Islands. By and large, the harzburgite is massive and does not display any layering. Small bodies of lherzolite and gabbro may occur as windows.

Two large massive bodies of dunite occur in the northern and southern part of Dinagat Island. The northern dunite body is about 400 m thick and is traceable along a 12 x 3 km belt through Mt. Kanbunlio and the western side of Desolation Point (UNRFNRE, 1986). The other dunite body stretches for 18 km in the Albor-Veloro tectonic zone, with widths of 1 - 3 km. The dunite is highly tectonized and almost totally serpentinized.

The transition zone between the dunite unit and harzburgite tectonite consists of 700 m thick cyclic succession of harzburgite and dunite interlayers containing massive and disseminated chromite (UNRFNRE, 1986). Harzburgite layers vary in thickness from 1 m to a few tens of meters, while dunite layers and tabular lenses range from a few millimeters to 30 m thick, although they are usually 0.5 - 1 m thick. Occasional lenses of pyroxenite and clinopyroxene peridotite are also present in this transition zone.

Outcrops of gabbro and pyroxenite have a restricted distribution. Small bodies of isotropic gabbro, named Dongohan Gabbro by Sunga and Palaganas (1986), are situated in the northern part and in the Malinao-Loreto Valley in Dinagat Island. Pyroxenite occurs as veins cutting older rocks and as mappable thin lenses in the transition zone and in dunite units.

Dike swarms of diabase, meta-basalt and micro-gabbro associated with basalt flows and pillow lavas form two broad but irregular windows in harzburgite. Basalt flows cover small areas measuring roughly 4 by 2 km, one located immediately south of Loreto and the other due east of Velore.

The Dinagat Ophiolite is represented in the central and northwestern areas of Siargao Island, particularly in Burgos, Esperanza, Sta. Monica (Sapao) and San Benito, by NE-SW trending bodies of basalt flows with pillow structures, underlain by volcanic rocks cut by diabase dikes. Occasionally, tuff and tuffaceous sandstone, siltstone and shale were found intercalated with the basalt flows along the vicinity of Sapao, which may suggest an event of submarine intra-volcanic sedimentation. The diabase-basalt complex has also been mapped in the eastern part of Bucas Grande Island.

The ophiolite has a radiometric K-Ar age of 84 Ma corresponding to Late Cretaceous period of Santonian age (Sunga and Palaganas, 1986; MMAJ-JICA, 1990).

Madanlog Formation

Lithology	Conglomerate, sandstone and shale with
	limestone lenses
Stratigraphic relations	Unconformable over the Dinagat Ophilite
	and Nueva Estrella Schist
Distribution	Tubajon-Loreto area, Melgar-Quezon
	area, Dinagat Island
Age	Late Eocene
Thickness	Not reported
Named by	Santos-Yñigo (1944)

The Madanlog Formation was used by Santos-Yñigo (1944) to refer to rocks at Mt. Madanlog, its type locality, and scattered patches in Surigao del Norte. On the western side of Dinagat Island, this is represented by conglomerate with interbeds of calcareous sandstone and shale. The formation rests unconformably over the basalt-diabase complex in Libjo and Tubajon-Mabini areas and on serpentinized peridotite and schist between Melgar and Quezon. Clasts of the conglomerate consist mainly of mafic rocks with subordinate serpentinized peridotite and schist. This is equivalent to the Eocene Loreto Clastics described by Sunga and Palaganas (1986) and apparently distinct from the Loreto Clastics of Wright and others (1958).

Bacuag Formation

Lithology	Basalt flows with intercalated basaltic agglomerate; conglomerate, sandstone,
	mudstone
Stratigraphic relations	Unconformable over the Madanlog
	Formation in mainland Surigao del Norte
Distribution	Masapelid Island
Age	Late Oligocene – Early Miocene
Thickness	~ 1,500 m

Previous name	Bacuag Series (Santos-Yñigo, 1944)
Renamed by	Santos and others (1962) as Bacuag
	Formation

The term Bacuag was first applied by Santos-Yñigo (1944) for the rocks at Bacuag, Surigao del Norte. It is represented in Masapelid Island by basalt flows with intercalated basaltic agglomerate, conglomerate, sandstone and mudstone. The age of the formation is Late Oligocene – early Miocene. (See Bacuag Formation under Northern Pacific Cordillera)

Mabuhay Formation

Sandstone and mudstone with minor
limestone and conglomerate
Conformable over Bacuag Formation;
conformably overlain by the Timamana
Formation
Masapelid Island
Early – Middle Miocene
700 m
Santos-Yñigo (1944)

Conformably overlying the Bacuag Formation is the Early-Middle Miocene sedimentary sequence on mainland Surigao del Norte designated by Santos-Yñigo (1944) as Mabuhay Formation. It is represented in the northwestern part of Masapelid Island by interbedded grayish to greenish brown shales and calcareous sandstone with lenses of conglomerate, thin limestone beds and occasional coal seams. Clasts of the conglomerate consist mainly of basaltic rocks. (see Mabuhay Formation under Northern Pacific Cordillera)

Timamana Limestone

Lithology	Massive reef limestone
Stratigraphic relations	Unconformably overlies the volcanic rocks
	of the Dinagat Ophiolite
Distribution	western coast of Dinagat Island; Tubajon
	Peninsula; Melgar Bay; Masapelid Island
Thickness	~ 200 m (maximum)
Age	Middle Miocene
Named by	Santos-Yñigo (1944)

The Timamana Limestone was named by Santos-Yñigo (1944) for the coralline limestone at Timamana, Tubod, Surigao del Norte. It is represented on Dinagat, Siargao and Masapelid Islands by grayish white, massive dense limestone that unconformably rests on the volcanic rocks of the Dinagat Ophiolite. In some places, interbeds of limy shale and sandstone and chert horizons were observed. The limestone occurs as discontinuous outcrops along the western coast of Dinagat island where it forms prominent cliffs and escarpments. The limestone is also present at Tubajon peninsula, Melgar Bay and Masapelid Island. The limestone is usually tough, compact and hard with a splintery sub-conchoidal or granular fracture.

The maximum thickness inferred from contours of the limestone scarps is 200 m. It is Middle Miocene in age. (See Timamana Limestone under Northern Pacific Cordillera)

Loreto Formation

Lithology	Conglomerate, sandstone, shale and
	mudstone
Stratigraphic relations	Conformably overlies the Loreto
	Formation
Distribution	Siargao, Nonoc, Buenavista and
	Bayagnon Islands
Thickness	less than 100 m
Age	Late Miocene
Previous name	Loreto Clastics (Wright and others, 1958)
Renamed by	MGB (this volume)

The Loreto Formation, formerly designated as Loreto Clastics (Wright and others, 1958), forms intermittent outcrops along or near the contact between the underlying ophiolite and overlying reef limestone on the western coast of Dinagat Island. These are usually less than 100 m thick. The base consists of polymictic conglomerate overlain by a succession of sandstones, shales and mudstones with subordinate amount of tuff. The conglomerate contains clasts of basalt, diabase, gabbro, peridotites and crystalline schists in varying proportions at a scale of a few kilometers. The beds generally strike northwest to northeast and dip 20°-35° to the west.

The formation is present in Nonoc, Buenavista and Bayagnon Islands. In Nonoc Island, the formation consists of coarse conglomerate with interbedded sandstone and mudstone forming shallow basins approximately 3 km across and 5 km long. The conglomerate includes reworked fragments of Eocene limestone and foraminifera. Paleontologic studies of samples from the formation indicated a probable Late Miocene age (Wright and others, 1958).

Siargao Limestone

Lithology	Massive reef limestone, subordinate sandstone
Stratigraphic relations	Overlies the Loreto Formation
Distribution	Siargao Island
Age	Pleistocene
Previous Name	Siargao Formation (Sunga and
	Palaganas, 1986)
Renamed by	MGB (this volume)

Resting above the Loreto Formation is the Siargao Limestone consisting of massive, oolitic, porous reefal limestone. The limestone frequently contains masses of broken corals, shells and casts of small gastropods. Conspicuous bedding is present, particularly towards its base where it becomes increasingly sandy and marly. Well-bedded calcarenite, calcisilitie, and gritty sandstone characterize the base of the limestone. Sunga and Palaganas (1986) cites a report of Malicdem and others (1958)

describing thinly-bedded limestone containing Miocene to Pleistocene fossils that overlies an earlier Miocene limestone formation, probably the Timamana Limestone. The fossil assemblage indicates a Pleistocene age for the later Siargao Limestone.

Recent Deposits

Recent deposits include mainly latosols and alluvium and local occurrences of shallow marine sediments and loosely unconsolidated rock talus.

The alluvium is mostly confined in the valleys and associated confluent alluvial fans and plains of the principal rivers. Continued uplift of the western coast of the island resulted in a regressive overlap of the floodplain debris, so that thin, younger alluvium caps marine sediments. Repeated uplift is evidenced by both river and beach terraces.

Laterites represent residual products of chemical weathering of ultramafic and associated rocks. These are characteristically reddish to yellow-brown latosols composed mainly of iron and aluminium oxides and hydroxides. Nickel-bearing ferruginous and chromite-bearing laterites are associated with these latosols. The former is characterized by relatively high porosity (spec. grav. = 1.2), high iron content (40-50%) and progressive increase of Ni and Co contents with depth. The latter are mainly represented by clayey latosols of much lower porosity and iron content.

SULU ARCHIPELAGO (SG 21)

Sulu Serpentinite

Lithology	Serpentinite
Distribution	Tawi-Tawi, Tumbagaan, Basbas and
	Tabolongon Islands
Age	Cretaceous – Eocene (?)
Named by	MGB (this volume)

The oldest rocks of Sulu Archipelago are serpentinites and associated metavolcanic intrusives with thick quartz veins. These rocks are found in the Islands of Tawi-Tawi, Tumbagaan, Basbas and Tabolongon. In the northeastern part of Tawi-Tawi Island, the serpentinite is exposed as a fault-bounded lenticular mass trending southwest. The formation is probably Cretaceous to Eocene in age and is correlative to the serpentinized ultramafic rocks in southwest Zamboanga.

Sibutu Diorite

Lithology	Diorite
Stratigraphic relations	Intrudes the Sulu Serpentinite
Distribution	Sibutu Island; Tawi-Tawi Island
Age	Late Miocene (?)
Named by	MGB (this volume)

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	SULU ARCHIPELAGO
NEOGENE	HOLOCENE		0.0447	
	PLEISTOCENE	4 Late 	0.0117 0.126 0.78 1.81	Jolo Volcanic Complex
	PLIOCENE	² Late 1 Early	2.59 3.60 5.33	
	5	3 Late	7.25	Sibutu Diorite
	MIOCENE	2 Middle-	13.65	Bongao Formation
		1 Early	20.43	
PALEOGENE	OLIGOCENE	2 Late 1 Early	23.03 28.4	
	EOCENE	4 Late	33.9 37.2	
		Middle – 2 1 Early	40.4 48.6	Sulu Serpentinite
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
CEOUS	Upper	Late	00.6	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
CRETA(Lower	Early	55.0	, , , , , , , , , , , , , , , , , , ,
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.24 Stratigraphic column for Sulu Archipelago

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Diorite bodies mainly occupy the 150-m high Sibutu Hill located at the central portion of Sibutu Island. This rock unit is medium-grained, crystalline and mineralogically distinct from the basic volcanic rocks of Jolo-Basilan-Siasi area. Northwest of Tawi-Tawi, quartz diorite, which is partly orthogneissic, is intrusive into serpentinite along a zone of major northeast shear. The diorite bodies in the Sulu Archipelago are correlated with the Vitali Diorite of southwestern Zamboanga.

Bongao Formation

Lithology	Conglomerate, sandstone
Stratigraphic relations	Not reported
Distribution	Bongao, Tawi-tawi and Sanga-sanga Islands
Age	Miocene (?)

Previous name	Bongao Conglomerate and Sandstone
	(Corby and others, 1951)
Renamed by	MGB (this volume)

The Bongao Formation was earlier designated by Corby and others (1951) as the Bongao Conglomerate and Sandstone. As described by these authors, the proportion of conglomerate to sandstone is three is to one (3:1). The conglomerate contains clasts of volcanic rocks that attain a diameter of 1.5 m, although the average size is around 30-60 cm. The sandstone beds, which are seldom more than one meter thick, are lenticular. The formation as a whole is poorly bedded. Exposures of the formation are found on Bongao and Sanga-sanga Islands and northwestern part of Tawi-Tawi Island. The age of the formation is probably Miocene. The formation could be correlative with the Anungan Formation of southwest Zamboanga.

Jolo Volcanic Complex

Lithology	Basalt
Distribution	Jolo, Pata, Basilan Islands; Samales
	Island Group
Age	Pliocene-Recent (?)
Named by	MGB (this volume)

Numerous volcanic centers consisting of volcanoes, cinder cones, tuff cones and maars underlie the Islands of Jolo, Pata, Basilan and Samales Island Group. The main rock types produced by volcanic activity associated with these forms are basalts (PHIVOLCS, 1995). There are more than 20 such volcanic centers in Jolo Island alone. Basilan has four volcanic centers, of which Basilan Peak rises to 1,011 masl. Bud Dajo in Jolo is a cinder cone whose last reported eruption was in 1897 (PHIVOLCS, 1997). In Basilan and Jolo, the lowlands surrounding the volcanic peaks and extending to the coast are covered with red lateritic alluvium consisting of fine silt and volcanic boulders.

ZAMBOANGA – MISAMIS OCCIDENTAL (SG 21)

Zamboanga – Misamis Occidental is part of the area covered by the Sulu-Zamboanga Arc. This includes north-central Zamboanga, Sibuguey Peninsula – Olutanga Island and southwest Zamboanga. The Pliocene – Pleistocene volcanic arc is represented by Mt. Malindang, North Peak and Ampiro in Misamis Occidental and a string of volcanic centers in Zamboanga del Sur.

Zamboanga Peninsula

Tungauan Schist

Lithology

Schist, marble, quartzite, gneiss, slate, phyllite

PERIOD	EPOCH	STAGE	Ма	ZAMBOANGA PENINSULA	NORTH-CENTRAL ZAMBOANGA	SIBUGUEY PENINSULA - OLUTANGA ISLAND
	HOLOCENE		0.0447			
	PLEISTOCENE	$\frac{4}{-\frac{3}{2}\frac{3}{2}}$	0.126	Sta. Maria Volcanic Complex Tigpalay Conglomerate	Aurora Formation	Labangan Formation Suttanga Linestone Zamboang Volcanic Comple
IN	PLIOCENE	2	3.60	Panganuran Formation	Timonan Formation	Colo Formatio
NEOGE		3	7.25	Curuan Formation Vitali Diorite Soleplep Volcanic Complex	Pictoran Formation	Midsalip Diorite
	MIOCENE	2	13.65	Anuncan Formation	Camanga Formation	Dumaguet Sandstone
		1	20.43		Tampilisan Melange	Lumbog Formation
_		2	23.03		Sunyan melange	Sibuguey Formation
	OLIGOCENE 1	20.4				
EOCENE PALEOCENE		4	37.2			
	EOCENE	3	40.4	Sirawai Formation		Mannabel Formation
		2	48.6			margaser i omstan
		1	55.8			
	3	58.7				
	1	61.7				
S.S.	К2		65.5	Bunglao Melange	Sindangan Basalt	
Cherry Ch	К1		99.6	Tungauan Schist	Dansalan Metamorphic Complex	
JURASSIC			145.5			

Table 2.25 Stratigraphic column for Zamboanga-Misamis Occidental

Stratigraphic relations	Represents the basement of Zamboanga
	Peninsula; unconformably overlain by the
	Sirawai Formation
Distribution	Tungauan; Siocon, Vitali, Lawit,
	Pasonanca watershed, Emmaco, Bungiao
	and Lantawan
Age	Cretaceous (?)
Named by	Santos-Yñigo (1953)

The Tungauan Schist was named by Santos-Yñigo (1953) for the metamorphic rocks exposed at Tungauan, Zamboanga del Sur, on the east coast of the peninsula. It probably represents the basement of western Mindanao (Pubellier and others, 1991). The widest outcrop stretches across the Peninsula from Tungauan to Siocon. Other exposures of the Tungauan are in Lawit, Pasonanca watershed, Emmaco, Bungiao and Lantawan.

The metamorphic rocks comprising the Tungauan include chloriteamphibolite, mica-quartz-amphibolite and calcite-actinolite schist with minor occurrences of marbles, quartzites, gneisses, slates and phyllites. The schists are essentially made up of hornblende, quartz, calcite, actinolite, mica flakes, chlorite, epidote, feldspar and interstitial sericite. Locally, they also carry notable amounts of specular hematite. Most of the schists represent thermodynamically metamorphosed clastic sediments as suggested by the presence of occasional marble and phyllite layers. The protoliths of some of the chlorite-amphibolite schists, however, could represent intercalated volcanic rocks. At Tumao Point, coarse-grained, gneissic rocks interweave with the more dominant chlorite schists. In the Vitali area, the metamorphic rocks consist of phyllite, slate, quartzite and marble (Paderes and Miranda, 1965). These are closely associated with serpentinized peridotite. Marble occurs in lenses and is confined to the upper part of the sequence, reaching up to 15 m in maximum thickness. Individually, the phyllite, slate and quartzite layers are less than 50 cm thick. A pre-Paleogene age, possibly Cretaceous, is assigned to the Tungauan Schist.

Bungiao Mélange

Lithology	Blocks of schists, ultramafic and other igneous rocks in matrix of serpentinized
	The sector of a sector of the True sector Cabiety
Stratigraphic relations	I nrusted against the Tungauan Schist;
	overlain by Anungan Formation
Distribution	Bungiao, Pilar, Tarlago, Lubay, Lunday,
	Ludasal, Sapa Manok, Vitali, Siocon River,
	Sta. Maria
Age	Cretaceous (?)
Named by	Yumul and others (2001)
Correlation	Serpentinized Peridotite (Santos-Yñigo,
	1953)

The Bungiao Mélange was named by Yumul and others (2001) for the mélange at Bungiao, consisting of schist and serpentinized harzburgite blocks with minor marble clasts in highly sheared serpentinized matrix. It is a tectonic mélange usually thrusted against the Tungauan Schist. Exposures were also noted in Pilar, Tarlago, Lubay, Lunday, Ludasal, Sapa Manok, Vitali, Siocon River and Sta. Maria. The clasts of the Mélange may reach hill-sized proportions consisting of schists, phyllite, slate, marble, sedimentary rocks, harzburgite and andesitic igneous rocks in serpentinized matrix. In Vitali, the Mélange is inferred to be unconformably overlain by a sedimentary clastic sequence belonging to the Anungan Formation. The Bungiao is tentatively assigned a Cretaceous age.

The Serpentinized Peridotite, of Santos-Ynigo (1953), which occurs as lenticular bodies that are commonly thrusted against the Tungauan Schist, is probably equivalent to the Bungiao Mélange. The largest outcrop, about six kilometers long and one to two kilometers wide, is found along one of the main tributaries of Vitali River. Smaller bodies are exposed along the northeastern coast of Vitali Island, and in the western side of Zamboanga Peninsula along Siocon River and in Sta. Maria. The peridotites are aligned along major fault zones and are strongly brecciated and sheared.

Sirawai Formation

Lithology	Conglomerate, sandstone, shale
Stratigraphic relations	Unconformable over the Tungauan Schist
Distribution	Sirawai, Siocon, Vitali, Linguisan-Vitali
	ridgeline, Panubigan Island
Thickness	~ 2,000 m

Age	Eocene (?)
Named by	Santos-Yñigo (1953)

The Sirawai Formation was named by Santos-Yñigo (1953) after the thermally metamorphosed green clastic rocks exposed at the Siocon-Sirawai area in western Zamboanga. This formation also outcrops along the east coast of Vitali Island, near the headwaters of Vitali River, and at Panubigan Island along the southern projection of the Linguisan-Vitali ridgeline. At its type locality, the formation attains a maximum thickness of about 2,000 m. It lies unconformably over the Tungauan Schist, and is presumed to be of Eocene age, for lack of any fossils by, which to date the unit.

The formation consists mainly of conglomerates and minor shales and sandstones. These clastic rocks seem to have been derived chiefly from schist terrain. The conglomerates are poorly sorted and contain angular to sub-angular, pebble- to boulder-sized clasts of schists and numerous quartz fragments. On the other hand, the shales and sandstones exhibit cross-bedding features. Both the fine-grained clastic rocks and the conglomerates are typically epidotized in the vicinity of diorite intrusive bodies.

Anungan Formation

Lithology	Sandstone, shale, conglomerate,
	limestone
Stratigraphic relations	Unconformable over the Bungiao Mélange
Distribution	Anungan, Melano and Tagpangi rivers;
	Vitali Island; Tupilac; Culianan;
	Manicahan; vicinity of Pasonanca
Age	Early to Middle Miocene
Previous name	Anungan Clastics (Paderes and Miranda,
	1956)
Renamed by	MGB (this volume)
Synonymy	Partly equivalent to the Tupilac Formation,
	Pasonanca Formation and Culianan
	Limestone of Santos-Yñigo (1953)
	5 ()

The Anungan Formation was previously named Anungan Clastics by Paderes and Miranda (1965) for the thick sequence of sandstone, shale, conglomerate and limestone exposed along the lower Tagpangi River down to the confluence of Melano and Anungan Rivers in the southwestern part of Zamboanga Peninsula. The formation also crops out in Vitali Island, in Tupilac in the north, in the vicinity of Pasonanca, and between Culianan and Manicahan in southeastern Zamboanga. An Early to Middle Miocene age is assigned to the formation. The Anungan was observed to unconformably overlie the Bungiao Mélange at Campo Dos-Campo Tres area (Yumul and others, 2001).

The sandstone comprising the Anungan is arkosic, massive, gray to greenish gray, and fine- to medium- grained and exhibits cross-bedding and ripple marks. On the other hand, the shale is dark gray to black,

carbonaceous, highly indurated and fissile. The limestone is coralline, massive, gray to pink, and fine- to coarse-grained.

The Anungan Formation is partly equivalent to the Tupilac Formation, Pasonanca Formation and Culianan Limestone of Santos-Yñigo (1953). At Tupilac, the shale is interbedded with coal seams, and forms part of the **Tupilac Formation** of Santos-Yñigo (1953). Thick beds and pebble- to boulder-sized clasts characterize the conglomerates. The equivalent of the Anungan Formation in Sibuguey Peninsula and Olutanga Island are the Lumbog Formation and the Dumaguet Sandstone of Ibañez and others (1956).

Soleplep Volcanic Complex

Lithology	Andesite, basalt and pyroclastic rocks
Stratigraphic relations	Intruded by Vitali Diorite
Distribution	Soleplep, Anungan and Panganuran rivers
Age	Late Miocene
Previous name	Soleplep Volcanics (Paderes and Miranda,
	1965)
Renamed by	MGB (this volume)

The Soleplep Volcanic Complex, previously named Soleplep Volcanics by Paderes and Miranda (1965) consists of thick sequence of altered basic lava flows and pyroclastic rocks along Soleplep River. In the upper reaches of Anungan and Panganuran Rivers where the largest exposure is found, it is intruded by diorite.

The lava flows are usually thick, massive and fine grained to porphyritic. These are gray to black when fresh and greenish to dark green when altered. Weathered exposures vary in color from light orange to brown or reddish brown. The lava flows range in composition from andesite to basalt with varying degrees of alteration, from comparatively fresh to highly chloritized and epidotized. Porphyritic andesite is characterized by phenocrysts of euhedral hornblende and feldspar crystals that are set in cryptocrystalline matrix consisting of the fine grained equivalent of the phenocrysts and some iron oxides, glass, epidote and chlorite. Hornblende is usually altered to epidote and chlorite, while feldspar is fragmented and corroded.

Intermittently interlayered with the lava flows are pyroclastic rocks, generally tuffs and volcanic breccia. The breccia consists of fragments of altered andesite and basalt embedded in a tuffaceous matrix. The Soleplep is assigned a tentative age of Late Miocene.

Vitali Diorite

Lithology	Hornblende diorite
Stratigraphic relations	Intrudes Soleplep Volcanic Complex and
	Anungan Formation
Distribution	Vitali; Lunday Valley; Panganuran River;
	Piacan-Sirawai; Limbong and Tagpangi
	rivers; Litawan and Sibaet creeks

Age	Late Miocene
Named by	Paderes and Miranda (1965)

The Vitali Diorite refers to the irregular stocks, dikes and sills of diorite and genetically-related rocks such as hornblende diorite, quartz diorite, aplitic diorite and pyroxene diorite, the largest exposure of which is found in the vicinity of Lunday Valley and extends north to upper Panganuran River covering an area of about 60 km² (Paderes and Miranda, 1965). Another large diorite body, roughly 6 km long by 2 km wide, outcrops at the western coast between Piacan and Sirawai (Santos-Yñigo, 1953). Smaller intrusive bodies are also found scattered at Limbong and Tagpangi Rivers, Litawan and Sibaet Creeks and at the headwaters of the Anungan River (Antonio, 1972).

The typical diorite is a medium to coarse-grained, mesocratic rock essentially composed of hornblende and plagioclase, with minor quartz and accessory / secondary iron oxides, epidote and calcite. The more acidic variety, which commonly occurs as dikes and confined along the periphery of the stock, is composed predominantly of quartz, biotite, hornblende and orthoclase.

In Palanas, Kawit, Ayala District, Zamboanga City, where the southward extension of Vitali Diorite is located, microdiorites intrude Early - Middle Miocene sedimentary rocks. The intrusive rock is leucocratic, fine to coarsely porphyritic and characterized by strong polygonal joints (Antonio, 1972).

The intrusive relationship between the Diorite and the Early to Middle Miocene Anungan Formation and the Soleplep Volcanic Complex strongly indicates that it could have been emplaced towards the close of Miocene. This intrusive body may be correlated with the Midsalip Diorite and the Tres Reyes Microdiorite of Ibañez and others (1956).

Curuan Formation

Lithology	Sandstone, shale with minor
	conglomerate, limestone
Stratigraphic relations	Overlaps the Culianan Limestone of the
	Anungan Formation
Distribution	Curuan, Bungiao and Vitali areas
Thickness	~ 1,000 m
Age	Late Miocene
Named by	Santos-Yñigo (1953)

The Curuan Formation was named by Santos-Yñigo (1953) for the sedimentary rocks exposed at Curuan. The Formation consists of sandstone and shale with lenses of conglomerate and thin beds of limestone occurring as discontinuous belt between Bungiao and Vitali areas, Zamboanga del Sur. Near the mouth of Tungauan River, the formation overlaps the Culianan Limestone, which is considered part of the Anungan Formation.

The limestone belonging to the Curuan Formation could be regarded as a member. It is characterized by light to buff, occasionally friable, coralline limestones. These occur at Masaba, Curuan Presa, Latuan and along the road south of Quiniput Peak all the way to Tuktuk-Kalaw. Limestones exposed west of Lunday Valley and Lantawan, Sibuco could also represent the limestone member of the Curuan Formation.

At its type locality, the Curuan Formation attains a thickness of at least 1,000 m. Paleontological analysis of a shale sample indicates a Late Miocene age for the formation.

Panganuran Formation

Lithology	Dacite, andesite, basalt, pyroclastic rocks,
	tuffaceous clastic rocks
Distribution	Panganuran; Mantibo River
Age	Pliocene
Previous name	Panganuran Andesite-Dacite-Basalt
	Series (Paderes and Miranda, 1965)
Renamed by	MGB (this volume)

The Panganuran Formation was previously named Panganuran Andesite-Dacite-Basalt Series by Paderes and Miranda (1965) for the thick sequence of volcanic and sedimentary rocks exposed about 6 km inland from the western coast between Anungan and Sibuco, Zamboanga del Norte. The formation consists of highly disturbed and folded flows and beds of rhyodacite and andesite with minor basalt, pyroclastic rocks and tuffaceous sedimentary rocks. This rock unit is considered to be of Pliocene age.

The rhyodacite and andesite are relatively unaltered and in some places, as in the tributaries of Anungan and Panganuran Rivers, intrude the Soleplep Volcanic Complex. They occur in layers that rarely exceed two meters thick, with chert bands in between. In Mantibo River, glassy, perlitic layers are found associated with rhyodacite. The rhyodacite is composed essentially of biotite, hornblende, feldspar and quartz phenocrysts in a cryptocrystalline to glassy matrix. Well-crystallized phases are typically gray to green, while the glassy counterparts are mainly green. The mafic minerals occur in bands that reach up to 5 cm in thickness. The andesite is generally fine-grained, light to medium gray and unaltered. Both rock types weather to bright colors of red, green and brown.

Intermittently interlayered with the rhyodacite and andesite is finegrained basalt. Fairly consolidated pyroclastic breccia and tuff also rhythmically alternate with the flows. The breccias are composed of angular to sub-angular fragments of volcanic flows in a tuffaceous matrix. Lenticular beds of tuffaceous shale and sandstone are occasionally interlayered with the pyroclastic rocks.

The Panganuran Formation is equivalent to the Andesite-Basalt Series of Santos-Yñigo (1953). This Series consists of dark-colored and vesicular or amygdaloidal flows fringing the eastern margin and the headwaters of Lobo Creek. Andesite intrusive bodies were also noted to occur as sills in coal measures in Sibuguey and Olutanga Island. The Panganuran may also be correlated with the Coloy Formation of Ibañez and others (1956) in Sibuguey Peninsula.

Tigpalay Conglomerate

Lithology	Conglomerate with lenses of sandstone,
o	
Stratigraphic relations	Not reported
Distribution	Tigpalay, Tagasilay
Age	Pleistocene
Named by	Paderes and Miranda (1965)

The Tigpalay Conglomerate was named by Miranda and Paredes (1965) for the coarse clastic rocks exposed from Tagasilay to Tigpalay. Aside from conglomerates, the rock unit also includes lenticular beds of sandstone and shale. The conglomerate is thickly bedded with pebble to boulder sized clasts of schist, quartz and other metamorphic rocks set in a sandy matrix. The sandstone is arkosic and coarse-grained. The Tigpalay Conglomerate is considered Pleistocene in age.

Sta. Maria Volcanic Complex

Lithology	Andesite, basalt, pyroclastic rocks, flow
	breccias
Stratigraphic relations	Not reported
Distribution	Mt. Sta. Maria, eastern coast of
	Zamboanga Peninsula.
Age	Pleistocene
Named by	Paderes and Miranda (1965) as Sta. Maria Volcanics

The Sta. Maria Volcanic Complex was named by Paderes and Miranda (1965) as Sta. Maria Volcanics for the hornblende andesite and basalt flows and flow breccias around Mt. Sta. Maria. These volcanic rocks and associated pyroclastic rocks also constitute the northeasterly aligned clusters of intrusive plugs manifested as rounded hills along the east coast of Zamboanga Peninsula. Dark gray to black dikes that probably represent a later phase of volcanism are also noted. These rocks consist of phenocrysts of hornblende and plagioclase that are embedded in a fine-grained to glassy matrix. The Sta. Maria complex is believed to be of Pleistocene age and can be correlated with the Zamboanga Volcanic Complex in Sibuguey Peninsula.

North - Central Zamboanga

Dansalan Metamorphic Complex

Lithology	Quartz-chlorite schist, quartz-sericite
	schist, amphibolite
Stratigraphic relations	Not reported
Distribution	Mt. Dansalan; Labason
Age	Cretaceous (?)

Previous name	Dansalan Metamorphics (Querubin and
	others, 1999)
Renamed by	MGB (this volume)

The Dansalan Metamorphic Complex was previously named Dansalan Metamorphics by Querubin and others (1999) for the exposures of schists and amphibolites in Mt. Dansalan. Significant outcrops may be found in Labason. The amphibolites are generally medium to coarse-grained and usually exhibit banding and layering, and occasionally show cross-bedding and plastic flow structures (Querubin and others, 1999). At Mt. Dansalan, the amphibolites occupy the central portion surrounded by quartz-chlorite schist and quartz-sericite schist in the peripheral portions. Foliation measurements indicate that the metamorphic complex has a domal structure. On the other hand, along the southeast sector of Mt. Dansalan, foliations generally trend northeast. On the northwest sector of Mt. Dansalan midway between the amphibolite and the schists, epidotebearing gabbroic rocks have been observed. Relict gabbroic textures exhibited by the amphibolites suggest that the amphibolites could have been derived from isotropic and layered gabbros. This suggests that the Dansalan could represent the metamorphosed equivalent of mafic rocks of the Polanco Ophiolite (described below). The age of the Dansalan is presumed to be Cretaceous.

Polanco Ophiolite

Lithology	Serpentinized dunite, pyroxenite, peridotite, gabbro, sheeted dike complex,
	Dasall
Stratigraphic relations	Not reported
Distribution	Fault-bounded blocks between Sindangan and Molave
Age	Cretaceous
Previous name	Mindanao Ultramafic Complex (Antonio, 1972)
Renamed by	Yumul and others (2000)

The Polanco Ophiolite was previously named by Antonio (1972) as Mindanao Ultramafics for the serpentinized peridotite, dunite and pyroxenite, which occur as thrusted elongate bodies and erosional windows in younger formations between the towns of Sindangan and Molave. These bodies trend northwest-southeast, parallel to a northwestsoutheast structure called Sindangan-Cotabato Fault or Sindangan-Siayan Suture Zone (Pubellier and others, 1993).

As described by Yumul and others (2000), the ophiolite consists of a complete crust-mantle suite that includes residual peridotite, cumulate peridotites and gabbro, sheeted dike complex and basalt. The residual peridotite, principally harzburgite, is highly sheared and occasionally intruded by dikes of anorthosite, aplite and diabase. Exposures of wehrlite and gabbro, which are intruded by troctolite, represent the cumulate sequence. The sheeted dike complex consists of microgabbro, diabase and some basalt. The thickness of the dikes ranges from a few centimeters to half meter. The Sindangan Volcanics of Antonio (1972) apparently constitute the volcanic carapace of the ophiolite. The volcanic rocks consist

of pillow basalt with associated lenses of agglomerate. The Sindangan is well represented by a northeast trending elongated body that starts from Timonan River in the north and extends south of Ingin River. In the Titay area, pelagic mudstones that unconformably overlie basalt probably constitute the sedimentary cover of the ophiolite.

Megablocks of the ophiolite occur as components of the Gunyan Mélange and Tampilisan Mélange. The Polanco is assigned a probable Cretaceous age.

Sindangan Basalt

Lithology	Basalt, agglomerate
Stratigraphic relations	Represents the volcanic carapace of the
	Polanco Ophiolite
Distribution	Timonan River, Ingin River
Age	Cretaceous (?)
Previous name	Sindangan Volcanics (Antonio, 1972)
Renamed by	MGB (this volume)

The Sindangan Basalt was previously named Sindangan Volcanics by Antonio (1972) for the hydrothermally altered, intricately folded and faulted volcanic rocks near Sindangan. It is well-represented by a northeast trending elongated body that starts from Timonan River in the north and extends farther south of Ingin River. The southern contact probably extends towards the central part of the Peninsula (Antonio, 1972). The Sindangan probably represents the volcanic carapace of the Polanco Ophiolite.

Along Ingin River, faulted and altered porphyritic basalt flows are associated with thin lenses of agglomerate. These rocks vary from greenish gray to light brownish gray when fresh, and purplish to reddish brown and spotty when weathered. Outcrops are commonly characterized by poorly developed pillow structures. Individual pillow surfaces are epidotized and chloritized. The age of the Sindangan is presumed to be Cretaceous.

Gunyan Mélange

Lithology	Megablocks of harzburgite, gabbro, basalt, chert, dunite, as well as chlorite schist,
	sandstones, limestone in serpentinite and
	clayey matrix
Stratigraphic relations	Emplaced along major fault structures
Distribution	Gunyan in Siayan; Polanco
Age	Early Miocene (?)
Named by	Yumul and others (2000)

The Gunyan Mélange was named by Yumul and others (2000) for the chaotic megablocks of igneous and sedimentary rocks set in serpentinized and clayey matrix. The Mélange is a combination of tectonic and sedimentary mélange distributed in a linear manner near the center of the so-called Siayan-Sindangan Suture Zone (also known as SindanganCotabato Fault) in Gunyan, Siayan. The tectonic mélange consists mainly of ophiolite-derived blocks of harzburgite, gabbro, basalt and chert in a serpentinite matrix. The blocks range in size from tens of meters to kilometer-sized hills. The ophiolite-derived blocks even include chromitites enveloped in dunite at Gunyan and its vicinity. The sedimentary mélange, on the other hand, consists of sandstones, andesites, schists, as well as limestone ranging in size from boulders to kilometer sized blocks set in a clayey matrix. An Oligocene age determined for one of the limestone blocks suggests an Early Miocene age for the Suture Zone as well as for the mélange.

Tampilisan Mélange

Lithology	Megablocks of harzburgite, gabbro, basalt, chert, dunite, as well as chlorite schist, in serpentinite and clayey matrix
Stratigraphic relations	Emplaced along major fault structure
Distribution	Tampilisan, Kalawit and Liloy areas in
	north-central Zamboanga
Age	Early Miocene (?)
Named by	Querubin and others (1999)

The Tampilisan Mélange was named by Querubin and others (1999) for the mélange disposed along a NE-SW shear zone cutting across Tampilisan, Kalawit and Liloy areas. The Mélange consists of boulders and blocks of peridotites, gabbros, schists, diabase dikes, volcanic rocks (including pillow basalts) and chert in highly sheared serpentinite matrix. The Tampilisan is apparently sandwiched between the exposures of Dansalan Metamorphic Complex and Camanga Formation along the NE-SW shear zone. Near New Calamba in Kalawit, light to dark gray rounded to sub-rounded cobble to boulder-sized volcanic rocks are embedded in sheared serpentinite. On the other hand, in Overview, Liloy, reddish brown massive chert boulders were also noted in serpentinite. In the Camanga area in the vicinity of Titay, exposures of pillow basalt and bedded reddish brown to green chert are considered megablocks that form part of the Mélange. Exposures of these ultramafic rocks that are considered parts of the Tampilisan were previously regarded as part of a separate unit known as Mindanao Ultramafics (Antonio, 1972). The Tampilisan is considered post-Oligocene, probably Early Miocene in age.

Camanga Formation

Lithology	Volcanic rocks; sandstone, shale, conglomerate; limestone
Stratigraphic relations	Unconformably overlies pelagic sedimentary rocks
Distribution	Northern part of Zamboanga Peninsula: Dagum-Limanawan, Piccio-Piwan, Talinga- Podongan, Makasing, Nato-Kutangil.
Age	Early – Middle Miocene
Previous name Renamed by	Zamboanga Formation (Antonio, 1972) Querubin and others (1999)

The Camanga Formation was previously named Zamboanga Formation by Antonio (1972) for the thermally metamorphosed volcanic rocks, clastic rocks and marbleized limestone of Early to Middle Miocene age exposed in the northern part of Zamboanga Peninsula. This was later renamed Camanga Sediments by Querubin and others (1999) and redefined it to include only the sedimentary rocks. The formation takes its name after Camanga area, in the vicinity of Titay. It hugs the Tampilisan Mélange along its southeast interface.

As described by Antonio (1972), the sedimentary rocks consist primarily of interbedded sequence of thin- to medium-bedded sandstone and mudstone, including argillite, with thin lenses of conglomerate. Basal conglomerates unconformably overlie pelagic sedimentary rocks. The conglomerates are generally matrix supported, highly compacted and poorly sorted, and contain angular to sub-rounded, pebble- to bouldersized clasts of metavolcanic rock, metasedimentary rock and marbleized limestone. In places, the sandstones exhibit cross-bedding and oscillation ripple marks. Petrographic analysis of the sandstone shows that the rock is essentially a highly indurated graywacke consisting of plagioclase, clinopyroxene and rounded- to sub-rounded volcanic rock fragments set in a chloritized and clayey matrix. At Teabag and Matigdao creeks, these sedimentary rocks contain carbonaceous materials. The widest exposures of conglomerates are found at Dagun-Limanawan, Piccio-Piwan and Talinga-Podongan areas (Antonio, 1972).

The clastic sequences described above are capped by light to dark gray limestones that are in places thermally metamorphosed. They occur as NE-SW trending erosional remnants and exhibit manganese deposits at the interface with the clastic sequences, especially in the Titay area. This sedimentary unit was previously dated Early to Middle Miocene.

Pictoran Formation

Lithology	Conglomerate, sandstone, mudstone; minor
	limestone
Stratigraphic relations	Not reported
Distribution	Pictoran-Laperia, Ikwan-Bacaran, Lanbangan-
	Danlugan
Age	Late Miocene
Thickness	~ 500 m
Named by	Antonio (1972)

Antonio (1972) applied the name Pictoran Formation for the Late Miocene sedimentary units exposed at Pictoran area and vicinity. This formation is mainly confined in the northwest trending strip of low rolling hills at Pictoran-Laperia, at Ikwan-Bacaran and at Labangan-Danlugan in east-central Zamboanga Peninsula. At Ikwan-Bacaran area, the formation attains a thickness of approximately 500 m.

The Pictoran consists of basal conglomerate and interbedded shale, sandstone and mudstone with thin limestone at the upper section. The basal conglomerate is often poorly sorted and well-compacted. Along Linkian Creek, it contains clasts of predominantly andesite and basalt as well as limestone and quartz set in a sandy and/or tuffaceous matrix (Antonio, 1972). In contrast, at the Danlugan-Labangan area, the conglomerate commonly contains granule- to boulder-sized clasts of volcanic and sedimentary rocks.

The sandstone is greenish gray to dark gray, usually thin bedded and in some places, strongly sheared. Likewise, the intercalated shale is thin bedded and is grayish green when fresh and yellowish brown when weathered (Antonio, 1972). In a section along Pictoran Creek, the sandstone is medium-grained and consists of fragments of volcanic rocks, ferromagnesian minerals, quartz and chert. The same section also yielded thick, milky, white fossiliferous limestone as well as thick impure limestone containing pebble-sized fragments.

Timonan Formation

Limestone, marl; minor shale, sandstone,
congiomerate
Not reported
Timonan area
Pliocene
Antonio (1972)

The Timonan Formation represents the Pliocene sedimentary sequence observed at Timonan area (Antonio, 1972). It consists mainly of limestone and marl with minor shale, sandstone and conglomerate. At Timonan, the limestone is typically white to milky white or pinkish and is coralline, fossiliferous and partly dolomitized. It is underlain by intercalations of dark gray to blackish, thin to medium bedded shale and sandstone. The sandstone contains grains of quartz and ferromagnesian minerals as well as small rock fragments. The intercalated sandstone and shale are, in turn, underlain by poorly sorted, compacted conglomerate containing granule- to boulder-sized clasts of metavolcanic rock, diorite, amygdaloidal basalt, limestone, serpentinite and highly indurated clastic rocks. Along Timonan River, the conglomerate beds commonly contain diorite clasts.

Aurora Formation

Lithology	Sandstone, shale, conglomerate; limestone
Stratigraphic relations	Not reported
Distribution	Aurora plateau, Molave, Dumingag area,
	Timonan River
Age	Pleistocene
Thickness	260 m
Named by	Antonio (1972)

The Aurora Formation was adopted by Antonio (1972) for the Pleistocene shale and sandstone and shallow marine sub-terrestrial sedimentary rocks principally consisting of volcanic detritus covering the whole east-west trending Aurora plateau. This formation also outcrops in the northwestern parts of Molave, and Dumingag area, between Dipolo River and the southwestern flank of Timonan River.

The formation consists of thin to medium bedded shale, sandstone to pebbly sandstone with thin pyroclastic beds. These beds can be traced over long distances and in places, contain cross-bedding and oscillation ripple marks. The section at Dumingag area, where pyroclastic beds are also present, attains a thickness of 260 m (Antonio, 1972).

Sibuguey Peninsula – Olutanga Island

Mangabel Formation

Lithology	Sandstone, shale, minor limestone,
	conglomerate, volcanic rocks
Stratigraphic relations	Not reported
Distribution	Mangabel Creek, Igaog River, Sumigod
	Creek
Age	Eocene
Named by	Antonio (1962)

The Mangabel Formation was named by Antonio (1962), for the exposures of sedimentary rocks along the middle and upper reaches of Mangabel Creek. Good exposures are also found along Igaog River and the upper Sumigod Creek. The formation consists of interbedded sequence of shale and sandstone with minor intercalations of limestone and basal conglomerate, directly overlain by a thick sequence of volcanic rocks, clastic rocks, and marbleized limestone.

In Mangabel area, the formation occurs mainly as thin interbeds of shale and sandstone. In some places, these rocks are intensely sheared. The sandstone is gray to green, fine- to medium-grained and highly indurated. It is mainly composed of rounded fragments of volcanic rocks, ferromagnesian minerals, quartz and chert. The shale is likewise greenish, highly indurated and friable. Both the shale and sandstone contain disseminated pyrite grains.

At Mangabel and Sumigod Creeks, thin lenses of dense, slightly crystalline, fine- to medium-grained limestone occur in sandstone and shale. The rock varies in color from dark gray to grayish white to milky white to pinkish. It is usually barren, but where fossils are found, *Camerina* is common, indicating an Eocene age for the Formation.

Sibuguey Formation

Lithology	Shale with interbeds of limestone and
	volcanic rocks
Stratigraphic relations	Conformably overlain by the Lumbog
	Formation
Distribution	Sibuguey River valley; Dipili-Lake Wood
	area
Thickness	>385 m
Age	Oligocene-Early Miocene
Named by	Brown (1950)

The Sibuguey Formation was named by Brown (1950) for the fairly uniform and thin-bedded sequence of clastic rocks and coralline limestone along the Sibuguey River Valley. It is conformably overlain by the Lumbog Formation. The Sibuguey covers most of the central Sibuguey area, Dipili-Lake Wood area and most of the northern part of the Zamboanga Peninsula divide.

The lower portion of the Sibuguey consists of mudstones with interbedded sandstone; the middle portion is characterized by sandstones with interbedded mudstones and sandy shale; the upper portion is composed of sandy shale with interbeds of limestone, calcareous shale and sandstones (Ibañez and others, 1956). Antonio (1972) adopted the term to include the folded and thermally metamorphosed interbedded sequence of clastic rocks and andesites with lenses of irregular masses of marbleized limestone widely exposed west of Sibuguey River from Siogan in the south to Luanan in the north. An Early Miocene age was assigned by Ibañez and others (1956) for the rock unit, although Antonio (1972) extends its age down to Oligocene. Brown (1950) gave a maximum thickness of 170 m for the formation, whereas Ibañez and others (1956) estimate the thickness to be more than 385 m.

The limestone of Sibuguey Formation occurs as white to black, fine to coarsely crystalline rocks. At Mount Mujoh and near the headwaters of Bulacan River, the limestone is reef-like and is at least 30 m thick (Brown, 1950). In few localities, the limestone was observed to occur as small lenses in metavolcanic rocks (Antonio, 1972).

Lumbog Formation

Members	Lalat, Gotas, Dumagok
Lithology	Mudstone, shale, sandstone with
	interbeds of pyroclastic rocks, limestone
	and coal
Stratigraphic relations	Conformable over the Sibuguey Formation
Distribution	Sibuguey River Valley; Dipili-Lake Wood
	area
Thickness	525 m
Age	Early Miocene
Named by	Ibañez and others (1956)

The Lumbog Formation was named by Ibañez and others (1956) for the sequence of clastic and pyroclastic rocks with interbeds of coal in the Malangas-Kabasalan region. The Lumbog rests conformably over the Sibuguey Formation. It is Early Miocene in age and estimated to have a maximum thickness of 525 m (Ibañez and others, 1956). It is divided into three members, namely: lower Lalat, middle Gotas and upper Dumagok.

Lalat Member

The Lalat Member was originally defined as a separate formation by Brown (1950) for the exposures along Lalat Creek, a tributary of Sibuguey River. It consists of mudstone, sandy shale and sandstone with interbeds of pyroclastic rocks, coal and limestone. The mudstone and shale are medium to dark gray, thin to medium bedded, but massive in places. The sandstone is light to dark gray, generally poorly bedded, and in places shows cross-bedding. It is composed of fine to coarse sub-angular to sub-rounded grains of quartz, feldspar and chloritized lithic fragments. The coal beds attain a thickness of 3 m. The Lalat is well exposed at the Diplahan-Butog and Lalat areas and is estimated to be 285 m thick. Fossils in this member reported by Brown (1950) include *Vicarya callosa, Ceritheum herklotsi, Cerithium kenkinsi, Cerithium bandongensis* and *Terebra bicincta*.

Gotas Member

The Gotas Member is well-exposed along Gotas Creek. It consists of fine to coarse-grained pyroclastic rocks interbedded with minor mudstones and sandstone, and occasional lenticular coal seamlets. It is distinguished from the Lalat and Dumagok members by the abundance and coarseness of pyroclastic material and absence of thick coal beds. At the type locality along Gotas Creek, pyroclastic breccia consists of basaltic and andesitic fragments reaching 10 mm in diameter set in a tuff matrix. At Sitio Gotas on the west side of the project area, the lithology consists of fine- to medium- grained sandstone interbedded with tuffaceous clastic rocks. The maximum measured thickness is 110 m (Ibañez and others, 1956).

• Dumagok Member

The *Dumagok Member* is the uppermost member of the Lumbog Formation. The unit outcrops at the southwest part of the project area and consists dominantly of moderately consolidated gray to greenish gray, fine-to medium-grained lithic sandstones interbedded with lesser dark gray mudstones, pyroclastic rocks, carbonaceous mudstones and coal seams. It may be distinguished from the Lalat member by the greater proportion of sandstone in the Dumagok with respect to mudstone, while the Lalat has a greater proportion of mudstone instead of sandstone. The thickness of the Dumagok, as measured in the Dumaguet, Gotas and Lumbog areas by Ibañez and others (1956) ranges from 100 m to 150 m.

Dumaguet Sandstone

Sandstone with interbeds of sandy shale
and conglomerate lenses
Not reported
Dumaguet River
Middle to Late Miocene
> 185 m
Ibañez and others (1956)

The Dumaguet Sandstone was named by Ibañez and others (1956) for the thick sequence of clastic rocks at Upper Dumaguet River. The formation consists of medium to coarse-grained arkosic sandstone and graywacke with lenses of conglomerate and interbeds of sandy shale. The sandstone is irregularly bedded and commonly exhibits cross-bedding. It is made up of sub-angular to sub-rounded grains of quartz, feldspar and chloritized minerals and rock fragments. The conglomerate lenses contain granule to pebble size clasts of schists, chloritic rocks, quartz and shale. It is dated Middle to Late Miocene in age. The Dumaguet Sandstone has a thickness of at least 185 m (Ibañez and others, 1956).

Midsalip Diorite

Lithology	Diorite, quartz diorite
Stratigraphic relations	Intrudes Zamboanga, Sibuguey and
	Lumbog Formations
Distribution	Midsalip; Mt. Tres Reyes
Age	Late Miocene
Previous name	Sibuguey Diorite (Antonio, 1972)
Renamed by	MGB (this volume)
Synonymy	Tres Reyes Microdiorite (Ibañez and others, 1956)

The Midsalip Diorite was named by Antonio (1972) as Sibuguey Diorite for the diorite and quartz diorite stocks, dikes and sills in the Sibuguey District. However, it is here renamed Midsalip Diorite for the diorite bodies in Midsalip and other areas in east-central Zamboanga. At Midsalip, the diorite is semi-circular in plan with an average width of 11 km. In Sibuguey, quartz diorite occurs on the west bank of Sibuguey River. The diorite can be traced from Matalay River in the north to Diplo River in the south. Smaller diorite bodies considered as apophyses of the main intrusive body crop out in several areas. The Midsalip Diorite is considered Late Miocene in age.

The Tres Reyes Microdiorite of Ibañez and others (1956) probably represents a facies of the Midsalip Diorite. It occupies the core of Mt. Tres Reyes and is exposed along Luminibed Creek, northeast of Mt. Tres Reyes, and along a tributary of Butog Creek and can be traced for 6 km along its longer dimension. The Microdiorite intrudes the Sibuguey and Lumbog formations.

Coloy Formation

Lithology	Pyroclastic rocks, conglomerate, sandstone, shale
Stratigraphic relations	Disconformable over the Lumbog Formation
Distribution Thickness	Coloy Creek, Lalat 150 m
Age Previous name Renamed by	Pliocene Caloi Formation (Brown, 1950)
Nenamed by	1000000000000000000000000000000000000

The Coloy Formation was previously named Caloi Formation by Brown (1950) and renamed Coloy for the sequence of pyroclastic and clastic rocks along Coloy Creek. This nearly flat sequence lies disconformably over the Lumbog Formation. The Coloy consists of poorly consolidated pyroclastic rocks and tuffaceous conglomerates with associated tuffaceous sandstones and shales. The pyroclastic rocks are light gray fine grained

tuff and gray volcanic breccia. The conglomerate contains angular to rounded, pebble to boulder size, clasts of andesite, petrified wood, quartz and basalt. It is considered Pliocene in age and has an estimated thickness of 150 m.

Olutanga Limestone

Lithology	Limestone, tuff
Stratigraphic relations	Conformable over the Coloy Formation
Distribution	Olutanga Island
Thickness	50 m
Age	Pliocene - Pleistocene
Named by	Santos-Yñigo (1953)

The Olutanga Limestone was named by Santos-Yñigo (1953) for the limestone at Olutanga Island, off Sibuguey Peninsula. It lies conformably over the Coloy Formation. The Olutanga is characterized by alternating layers of thin tuffaceous rocks at the base that grade upward into coralline limestone. It is considered Pliocene – Pleistocene in age and has an estimated maximum thickness of 50 m.

Zamboanga Volcanic Complex

Lithology	Basalt, andesite, dacite, pyroclastic rocks
Stratigraphic relations	overlies and intrudes older formations
Distribution	Margosatubig-Malangas plateau; Mt.
	Muntay; Midsalip, Mt. Sampakang Laboyo,
	Datagan II and III, Mt. Pinokis; Pagadian-
	Malangas road; Dinas-Balungating area;
	Mt. Kaladis, Buug, Lakewood, Ipil, Mt.
	Maria
Age	Pliocene - Pleistocene
Named by	Antonio (1972)

Antonio (1972) gave the formational name Zamboanga Volcanics to the Pliocene - Pleistocene volcanic rocks, which include basalt-andesite flows and associated pyroclastic rocks, hornblende andesite plugs, and dacitic plugs and cinder cones. The basalt-andesite flows constitute the most dominant rock unit of the formation. These blanket almost the entire Margosatubig-Malangas volcanic plateau, although smaller bodies are also found sporadically in the area. In general, the basalt is vesicular and amygdaloidal, while the andesite is characterized by well defined flow bands.

At Mt. Muntay area, the basalt flows cover almost the whole peak and the surrounding slopes. Their textures vary from fine-grained to porphyritic, with some exhibiting vesiculated texture. At Sitio Datagan I near Barrio Midsalip, plagioclase and olivine phenocrysts of the basalt have been altered to clay minerals. Similar exposures can be found at Mt. Sampakang Laboyo, Datagan II and Datagan III.

Associated with the basalts and andesites are glassy flows, flow breccias and agglomerates. Santos-Yñigo (1953) previously mapped this

basalt-andesite flow unit under his Mio-Pliocene Andesite-Basalt Series. However, field observations showing its relationship with the surrounding rocks led Antonio (1962) to assign a younger age to this unit.

Hornblende andesite plugs constitute the conical peaks in the northeastern portion of the region. These volcanic plugs, ranging in elevation from 300 masl to 1563 masl, with Mt. Sugar Loaf (locally called Mt. Pinokis) as the highest, are disposed along the general fault pattern in the area. In general, the rock is light to dark gray when fresh and pinkish to brick red when weathered.

Also included in the Zamboanga Volcanic Complex are the dacitic plugs along Pagadian-Malangas road and in Dinas-Balungating area, and the cinder cones at Camp VI, along Ozamis-Pagadian Road and farther west of the area. Along the Pagadian-Malangas road, the dacitic plugs may be porphyritic or glassy. The former is dark gray to greenish and massive, while the latter is light yellowish to gray. The cinder cones are characterized by poorly cemented but fairly sorted thin to medium bedded cinder materials. These are mainly angular, granule- to boulder-sized scoriaceous basalt fragments cemented by finer cinder materials and/or tuffaceous ash.

Radiometric K-Ar dating of samples of volcanic flows from east-central Zamboanga show that the products of Recent arc volcanism in the area range from 2.58 Ma to 0.41 Ma (Sajona and others, 1997). Tabular andesitic flows sampled at Pagadian gave ages of 2.58 Ma and 1.91 Ma; a sample from Buug gave an age of 1.71 Ma; basaltic andesite and basalt at Mt. Kiladis were dated 1.21 Ma and 1.08 Ma, respectively. Radiometric K-Ar dating of dacites from Lakewood gave ages of 0.97 Ma and 0.82 Ma. Cinder cones and lava domes overlying Middle Miocene and Late Miocene sediments in east-central Zamboanga and the Plio-Pleistocene basalts on the northernmost outcrops are dated 1.0 - 0.7 Ma. The youngest K-Ar age (0.4 \pm 0.05 Ma) is from a basaltic andesite flow collected northwest of Ipil.

The Zamboanga Volcanic Complex may be correlated to the Sta. Maria Volcanic Complex in Zamboanga Peninsula.

Labangan Formation

Lithology	Terrace sediments, reef limestone
Stratigraphic relations	Not reported
Distribution	Labangan, Midsalip; Punta Fletcha
Thickness	> 150 m
Age	Pleistocene
Named by	Antonio (1972)

The Labangan Formation was named by Antonio (1972) for the Pleistocene terrace sediments and uplifted reef limestone in Labangan, Midsalip and Punta Fletcha. The horizontal terrace sediments are composed of angular to sub-rounded fragments of older volcanic rocks, clastic rocks, peridotite, diorite and marble. On the other hand, the reef limestone is made up of poorly consolidated corals and other calcareous debris, and has a thickness of about 150 m. Its equivalent in Olutanga

Island and the southern portion of the western lobe of Sibuguey Peninsula is the **Olutanga Limestone** of Santos-Yñigo (1953).

CENTRAL MINDANAO (SG 22)

Central Mindanao belongs to Stratigraphic Grouping 22 representing an ancient arc that covers Misamis-Oriental-Bukidnon-Lanao and the Mindanao Central Cordillera with a superimposed Quaternary volcanic complex defined by a north-northwest belt from Camiguin Island in the north down to Mt. Parker in the south. The stratigraphy of Central Mindanao is subdivided into Misamis Oriental-Bukidnon-Lanao, Mindanao Central Cordillera and Central Mindanao Volcanic Complex, representing volcanic deposits from eruptions of Quaternary volcanic centers.

Misamis Oriental – Bukidnon – Lanao

Tago Schist

Schist, slate, amphibolite, phyllite
In fault contact with ultramafic rocks
Mt. Tago, Mangima Canyon, Sayre
Highway between Manolo Fortich and
Damay, Alae-Damilag area and vicinity of
Mt Tagiptip in Bukidnon. Barangays
Cugman, Balubal and Pigsag-an, Umalag
Creek, Cagayan and Bobonawan Rivers in
Misamis Oriental
Cretaceous (?)
MGB (this volume)

The pre-Cenozoic metamorphic rocks composed of garnetiferous quartz-sericite-epidote-amphibolite, greenschists, phyllite and slate described by Pacis (1966), are the oldest rocks in the region. The largest exposure in Bukidnon underlies the western slope of Mt. Tago, bounded by Amusig and Tagaloan Rivers on the northwest and southwest, respectively. In Misamis Oriental, the schist is extensively exposed along an east-west trending belt from Malasag in Brgy. Cugman to the upper reaches of Agusan River in Brgy. Balubal, Cagayan de Oro City. Other large exposures are to be found within the vicinity of Brgy. Pigsag-an, Cagayan de Oro City and the upper reaches of Cugman River. Smaller isolated bodies occur as erosional windows along Umalag Creek and Cagayan and Bobonawan rivers in Misamis Oriental and along Sayre Highway between Manolo Fortich and Damay, Mangima Canyon, and the western portion of Alae-Damilag area in the vicinity of Mt. Tagiptip in the province of Bukidnon. Most of the schists, which are intensely folded, are in fault contact with ultramafic rocks.

The garnetiferous quartz-sericite schist is fine-to medium-grained and contains sericite, quartz, plagioclase and garnet. The epidote-amphibolite schist is closely associated with the garnetiferous quartz-sericite schist.

					CENTRAL MINDANAO	
PERIOD	EPOCH	STAGE	Ma	MISAMIS ORIENTAL-BUKIDNON- LANAO	MINDANAO CENTRAL CORDILLERA	CENTRAL MINDANAO VOLCANIC ZONE
	HOLOCENE				Cabanglasan Gravel	
		4	0.0117	Cagayan Gravel	Malambo	Katanglad / Musuan Volcano/S
	PLEISTOCENE		0.78	Bukidson Formation	Koronadal Andesite	Malanday Matutum
		1	1.81		Formation	Lanao
	PLIOCENE	2	3.60	Iponan Formation	Lumbayao Formation	Andesite Volcanic O Volcanic
		1	5.33	Indahag Limestone		Complex Complex
ENE		3	7.25	Opol Formation	Locawan Diorite	
NEOG			11.61			
	MIOCENE	2	13.65	Maniki Quartz Diorite	Tagbacan Formation	
			15.97			
		1	20.43	Tuod Formation	Kalagutay Formation	
		2		Balongkot Limestone		
	OLIGOCENE	1	28.4	······	State States	
		4	33.9		Kilapagan Formation	
ENE		3	31.2	1. 10. 10.		
061	EOCENE	2	40.4	Himalyan Formation	Umavan Limestone	
ALE		1	48.6		unity in units one	
P/		3	55.8			
	PALEOCENE	2	61.7			
		1	65.5			
05	К2			Awang Ultramafic Complex	Pantaron Ultramafic Complex	
A.		-	99.6	Torrestation	Taxa Schiet	
E	К1			tago Schist	logo Schist	
JURASSIC			145.5			
				L		

Table 2.26 Stratigraphic column for Central Mindanao

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

More widely distributed are greenschists, phyllites and slates. These rocks exhibit alternating shades of green, black and dark gray, which signify former beddings. Other associated metamorphic rocks include piedmontite schist, quartzites and marbles. The Tago Schist is assigned a probable Cretaceous age.

Awang Ultramafic Complex

Lithology	Serpentinite, dunite, peridotite
Stratigraphic relations	in fault contact with Magina Schist;
	unconformably underlies the Himalyan
	Formation
Distribution	Caballero Range, Cagayan de Oro City;
	Iponan River
Age	Cretaceous (?)
Previous name	Awang Serpentinite (Capistrano, 1946)
Renamed by	MGB (this volume)
Renamed by	MGB (this volume)

The Awang Ultramafic Complex was previously named Awang Serpentinite by Capistrano (1946). The Complex occurs as three large bodies in the Caballero Range within the vicinity of Lourdes, southeast of Opol and between Bigaan and Agusan rivers. Serpentinites make up the largest portion of the Cretaceous ultramafic rocks. In the vicinity of Cagayan de Oro City, the rocks are lenticular bodies within a northeast trending fault zone. The serpentinite is usually highly sheared, locally schistose and contorted. It varies from dark to bluish green; when mylonitized, it is gravish, reddish or light greenish. It consists mainly of
serpentine and chlorite with minor amounts of actinolite and talc. Along Iponan River, an elongated body of serpentinized peridotite is medium to coarse-grained, olive green to gray when fresh and reddish brown when weathered. It exhibits a shiny luster and has a soapy feel.

Protoliths of the serpentinite are mainly harzburgite and dunite with minor pyroxenite. Fine- to medium-grained dunite usually occurs as small lenses interlayered in places with chromite. It is dense and dark when fresh and yellowish brown or dirty white when weathered.

Himalyan Formation

Lithology	Graywacke, metaconglomerate,
	metavolcanics, mylonite, metadiabase
Stratigraphic relations	Underthrusted by the Awang Ultramafic
	Complex; unconformably capped by
	Balongkot limestone
Distribution	Himalyan, Mambuaya, Brgys. Donsolihon,
	Alat in Cagayan de Oro City; Naawan,
	Misamis Oriental; Mt. Tagiptip, Libona, in
	northwestern Bukidnon
Age	Eocene
Thickness	400-450 m
Named by	Pacis (1966)

The Himalyan Formation was named by Pacis (1966) after Sitio Himalyan, south of Mambuaya, Cagayan de Oro City. The formation overlies the metamorphic rocks and is underthrusted by serpentinite of the Awang Ultramafic Complex. It consists of graywacke, metaconglomerate, mylonite, metavolcanics and metadiabase. Clasts of the metaconglomerate are composed mostly of fragments of pumiceous porphyritic basalt. Contact zones with the serpentinite are usually phyllonitic. The phyllonite is foliated, light gray to yellowish green and fine-grained. Exposures of the unit can also be found southwest of Barangay Donsolihon and west of Barangay Alat, Cagayan de Oro City; in elevated areas west of Iponan River; part of the high ranges east of the town of Naawan, southwestern Misamis Oriental; and at Mt. Tagiptig, Libona, northwestern Bukidnon The thickness of the Himalyan ranges from 400 to 450 m. An Eocene age was assigned to the unit.

Balongkot Limestone

Carbonaceous limestone
Unconformable over the Himalyan
Formation and Tago Schist; overlain by
Opol Formation
Sitio Balongkot, Barangay Dansolihon,
Cagayan de Oro; Maniki Creek, Iponan
River, Dodiongan, Lugait, Lo-oc; Barangay
Kiliog
Late Oligocene to Early Miocene
MGB (this volume)

Pacis (1966) recognized several small bodies of recrystallized limestone in the region although he did not give a name to the formation. This unit is designated here as Balongkot Limestone for the outcrops at Sitio Balongkot, southwest of Barangay Dansolihon, Cagayan de Oro City. Other exposures are found along hill slopes near the Avancena iron claim; and near the headwaters of Maniki Creek. In these localities, the limestone occurs as patches unconformably overlying the Himalyan Formation. The limestone also occurs along the tributaries of Iponan River in the western part of Misamis Oriental, as well as in the vicinities of Dodiongan, Lugait and Looc. The limestone south of Barangay Kiliog caps both the schist and the Himalyan Formation.

The limestone is carbonaceous, massive, black and dark gray with white bands. In some cases it is fossiliferous and schistose. Recent reports confirm the presence in the limestone of abundant foraminifera, algae, radiolaria, and rudists, which were dated Late Oligocene to Early Miocene (MGB-X, 1998).

Tuod Formation

Lithology	Conglomerate, sandstone, siltstone, shale, limestone, basalt, basaltic breccia
Stratigraphic relations	Unconformable over the Himalyan Formation; conformably overlain by Opol
	Formation
Distribution	Tuod, Misamis Oriental; Tagaolip, Sitio
	Saging; tributaries of Mologan and Alubijid
	Rivers
Age	late Late Oligocene to early Early Miocene
Thickness	300-350 m
Named by	Pacis (1966)
Named by	Pacis (1966)

Tupas (1952) originally named this rock unit Tuod Group for the exposures at Brgy. Tuod, Manticao, Misamis Oriental, but was renamed by Pacis (1966) as Tuod Formation. The unit consists of a sequence of sedimentary rocks, volcanic flows and volcanic breccias unconformably overlying the Himalyan Formation. The largest outcrop of this formation occurs in the high ridge on the western side of Misamis Oriental and Lanao. Exposures of the unit can also be found in Tagaolip and in Sitio Saging, and along the tributaries of Mologan and Alubijid rivers where they appear as windows in the Opol Formation. Clastic rocks and lenses of limestone comprise the lower portion of the unit. The upper part of the formation consists of dense layers of basalt flows with pillow structures intercalated with sedimentary rocks and basaltic breccias. The sedimentary sequence consists of conglomerate, sandstone with lenses of limestone and siltstone, thin coal beds and carbonaceous and silty shale. Basalt flows were also observed at Barangay Saging and along a logging road to Digkilaan River. A sample consists of clusters of small augite crystals enclosing saussuritized calcic plagioclase in a matrix of plagioclase, pigeonite and brownish chlorite. Veinlets of zeolite are abundant. Another sample consists of phenocrysts of augite and labradorite set in a groundmass of altered glass and probably chlorophaeite. The basaltic

breccia consists of fragments that are angular to sub-angular, vesicular, and contains quartz or calcite amygdules.

Pubellier and others (1991) assigned a late Late Oligocene to early Early Miocene age to the unit. The thickness of the Tuod ranges from approximately 300 to 350 m.

Maniki Quartz Diorite

Lithology	Quartz diorite; diorite; granodiorite,
	anuesite
Stratigraphic relations	Intrudes the Himalyan Formation
Distribution	Maniki River; sitio Batinay, Misamis
	Oriental
Age	Middle Miocene
Named by	MGB (this volume)

The Maniki Quartz Diorite is named for the exposure of quartz diorite along Maniki River in southwestern Misamis Oriental. Associated with the quartz diorite are diorite, granodiorite and andesite. The main quartz diorite stock, covering 75 km2, intrudes the Himalyan Formation and the Balongkot Limestone. Small andesitic bodies and dikes of early Late Miocene age intrude the diorite and the Himalyan. The texture of the diorite stock becomes coarse-grained towards the core.

The quartz diorite is medium to coarse-grained and consists of quartz, hornblende, andesine, biotite with secondary pyrite, chlorite, magnetite, sericite and limonite. Zoned plagioclase and hornblende are partly altered to chlorite. The granodiorite, which occurs as dikes in the schist, is lightcolored, coarse-grained and consists of sodic plagioclase, anhedral orthoclase, and serrated quartz with secondary sericite, epidote, amphibole, chlorite and zeolite.

The andesite porphyry underlies a large portion of the area. Exposures are generally porphyritic with considerable amounts of hornblende and plagioclase (andesine) phenocrysts set in a fine-grained matrix.

The textural variation of the belt is noteworthy. Massive, dark, porphyritic varieties becoming porous and fragmental with decreasing ferromagnesian minerals are the distinctive changes from the south to the north. Widespread kaolinization, silicification and pyritization were noted.

Opol Formation

Lithology	Sandstone, conglomerate, agglomerate,
Stratigraphic relations	Unconformable over the Himalyan
	Formation; conformable over the Tuod
	Formation
Distribution	Opol, Misamis Oriental; Tagaloan; Mapoto
	mountain range
Age	Late Miocene
Thickness	100-150 m

Previous Name	Opol Sandstone (Capistrano, 1946)
Renamed by	Pacis (1966)

The Opol Formation was previously named Opol Sandstone by Capistrano (1946) for the rocks exposed at Opol, southwestern Misamis Oriental. Pacis (1966) used the term Opol Formation to include the conglomerate, pebbly sandstone, pyroclastic breccia, tuffaceous sandstone and tuff in the area. It rests unconformably over the Himalyan Formation, but is conformable over the Tuod Formation. The formation is widespread on the western half of Misamis Oriental; and on the northern slopes of Mopoto mountain range facing Mindanao Sea. Exposures were also observed east of Tagaloan town.

The pebbly sandstone, which occurs as thin layers, is fine- to mediumgrained, poorly sorted and poorly cemented. The tuffaceous rocks are dark to light brown. The layers of conglomerate interbedded with these rocks are well-cemented, poorly sorted with pebbles, cobbles and even boulders of basalt, chert, diorite and metamorphic rocks set in a sandy clay and tuffaceous matrix. The unit is assigned a Late Miocene age. Its thickness ranges from 100 to 150 m.

Indahag Limestone

Lithology	Limestone; calcarenite, limy tuff
Stratigraphic relations	Not reported
Distribution	Indahag, Cagayan de Oro City; Lumbia;
	Opol; Lugait near Iligan City; Cagayan
	River, Barrio Alae, Cagayan de Oro
Age	Pliocene
Thickness	250-300 m
Named by	Capistrano (1946)

The Indahag Limestone was named by Capistrano (1946) for exposures of limestone at Indahag, Cagayan de Oro City. Large outcrops occur at Lumbia. Exposures can also be found along the seashore from Opol westward to Lugait near Iligan City; along Cagayan River and southeast of Barangay Alae, Cagayan de Oro City. The limestone is massive to well-bedded, dull white to brown and red, and coralline. Minor interbeds of clastic rocks include conglomerate, tuffaceous sandstone and shale.

Three distinct horizons are recognizable along the banks of Cagayan River, where the outcrops are thickest. Pacis (1966) noted that the lowest horizon of the section along Cagayan River is largely coralline limestone with calcisilities, calcarenites and calcirudites. The middle section consists of limestone rubble and coral fingers. Intercalated layers of coralline limestone, calcarenite and limy tuff comprise the upper horizon.

The Indahag is of Pliocene age. Its thickness ranges from 250 to 300 m.

Iponan Formation

Lithology	Conglomerate, sandstone, shale
Stratigraphic relations	Unconformably overlies the Himalyan
	Formation
Distribution	Iponan River, Misamis Oriental to Lanao
	del Norte
Age	Pliocene
Thickness	50 m
Previous name	Iponan Clastics (Pacis, 1966)
Renamed by	MGB (this volume)

The Iponan Formation was previously named Iponan Clastics by Pacis (1966) for the well-bedded conglomerates, sandstones and shales exposed along Iponan River. The rock unit extends southward and probably widens beyond Mandulog River in Lanao del Norte. The Iponan unconformably overlies the Himalyan Formation.

The conglomerate consists of rounded to sub-rounded pebbles and boulders of igneous and metamorphic rocks. Sandstone beds with average thickness of 0.3 m varies from quartz arenite to arkosic sandstone to lithic arenite. Locally, the sandstones and shales interbedded with the conglomerate are carbonaceous. It is assigned a Pliocene age and has a thickness of 50 m.

Bukidnon Formation

Lithology	Agglomerate, sandstone, conglomerate
Stratigraphic relations	Not reported
Distribution	Cagayan River, Bukidnon
Age	Pleistocene
Thickness	800 m
Named by	Pacis (1966)
Correlation	Kapatagan Group (Tupas, 1952)

The Bukidnon Formation was named by Pacis (1966) for the exposures of agglomerate, tuffaceous sandstone, pebbly sandstone and conglomerate that cover the area east of Cagayan River. The conglomerate consists predominantly of angular to sub-angular pebble- to boulder-sized clasts of volcanic rocks, schists and serpentinite. The Kapatagan Group of Tupas (1952) is probably correlative to the Bukidnon Formation.

A Pleistocene age was assigned to the formation. The thickness of the Bukidnon is approximately 800 m.

Cagayan Gravel

Lithology	Gravel, sandstone, shale
Stratigraphic relations	Unconformable over older formations
Distribution	Cagayan de Oro City; Cagayan River
Age	Pleistocene - Holocene
Thickness	100 m

Previous Name	Cagayan Terrace Gravel (Pacis, 1966)
Renamed by	MGB (this volume)
Correlation	Cabanglasan Gravel

The term Cagayan Terrace Gravel was designated by Pacis (1966) for the extensive exposures of gravel along the road from Cagayan de Oro City to the Lumbia Airport. Outcrops are found along the National Road in Cagayan de Oro City to Indahag road; from Bugo to Alae; and on the west bank of Cagayan River just before the airport.

The formation consists of intercalated gravel, sand, shale and tuffaceous sandstone. The slightly consolidated and poorly sorted gravel is composed of rounded to sub-rounded pebble- to boulder-sized igneous and metamorphic rocks. The shales and tuffaceous sandstones are slightly compacted. Molluscan shells were noted in the tuffaceous sandstone. A Pleistocene to Holocene age was assigned to the unit. Its estimated thickness is 100 m. Deposition of the Cagayan Terrace Gravel probably took place in a deltaic environment. It may be correlated with the Cabanglasan Gravel.

Mindanao Central Cordillera

Tago Schist

Lithology	Schist, slate, amphibolite, phyllite
Stratigraphic relations	In fault contact with ultramafic rocks
Distribution	Mt. Tago, Mangima Canyon, Sayre
	Highway between Manolo Fortich and
	Damay, Alae-Damilag area and vicinity of
	Mt Tagiptip in Bukidnon. Brgys. Cugman,
	Balubal and Pigsag-an, Umalag Creek,
	Cagayan and Bobonawan rivers in
	Misamis Oriental
Age	Cretaceous (?)
Named by	MGB (this volume)

The pre-Cenozoic metamorphic rocks composed of garnetiferous quartz-sericite-epidote-amphibolite, greenschists, phyllite and slate described by Pacis (1966), are the oldest rocks in the region. The largest exposure in Bukidnon underlies the western slope of Mt. Tago, bounded by Amusig and Tagaloan rivers on the northwest and southwest, respectively. In Misamis Oriental, the schist is extensively exposed along an east-west trending belt from Malasag in Brgy. Cugman to the upper reaches of Agusan River in Brgy. Balubal, Cagayan de Oro City. Other large exposures are to be found within the vicinity of Brgy. Pigsag-an, Cagayan de Oro City and the upper reaches of Cugman River. Smaller isolated bodies occur as erosional windows along Umalag Creek and Cagayan and Bobonawan rivers in Misamis Oriental and along Sayre Highway between Manolo Fortich and Damay, Mangima Canyon, and the western portion of Alae-Damilag area in the vicinity of Mt. Tagiptip in the province of Bukidnon. Most of the schists, which are intensely folded, are in fault contact with ultramafic rocks.

The garnetiferous quartz-sericite schist is fine-to medium-grained and contains sericite, quartz, plagioclase and garnet. The epidote-amphibolite schist is closely associated with the garnetiferous quartz-sericite schist.

More widely distributed are greenschists, phyllites and slates. These rocks exhibit alternating shades of green, black and dark gray, which signify former beddings. Other associated metamorphic rocks include piedmontite schist, quartzites and marbles. The Tago Schist is assigned a probable Cretaceous age.

Pantaron Ultramafic Complex

Lithology	Peridotite, gabbro, dunite, basalt,
	serpentinite
Stratigraphic relations	Constitutes basement of Mindanao
	Central Cordillera
Distribution	Pantaron Range; San Fernando,
	Bukidnon
Age	Cretaceous
Named by	MGB (this volume)

The ultramafic rocks forming the Pantaron Range dividing Bukidnon, Agusan del Sur and Davao are grouped here into a unit designated as Pantaron Ultramafic Complex. Santiago (1983) assigned a type locality in the headwaters of Balongkot Creek in San Fernando, Bukidnon.

Only peridotite and gabbro were previously identified as the constituents of this unit (BMG, 1981) with peridotite as the dominant lithology (Santiago, 1983). However, other authors have reported the occurrence of serpentinite, dunite, and basalt (Santiago, 1983). The gabbro is composed of plagioclase, olivine, diallage and a few opaque minerals (BMG, 1981). The Pantaron is presumed to have been emplaced during Cretaceous time.

Nilabsan Formation

Lithology Stratigraphic relations	Pyroclastic rocks, mudstone, sandstone Unconformably overlain by Kilapagan and Kalagutay formations
Distribution	Kalagutay River, Sita River, Davao River
Age	Late Cretaceous (?)
Thickness	3,000 m
Previous name	Nilabsan Group (MMAJ-JICA, 1973)
Renamed by	MGB (this volume)

The Nilabsan Group as designated by MMAJ-JICA (1973) is here renamed Nilabsan Formation for the rocks exposed at Kalagutay River and from upper Sita River in northern Davao del Sur to the western side of Davao River in northern Davao del Sur. The formation consists of pyroclastic rocks with intercalated dark gray mudstone and gray, fine grained sandstone. The pyroclastic rocks consist of dark green or greenish gray fine tuff, sandy tuff, lapilli tuff, tuff breccia and reddish brown fine tuff. The lithic fragments in these pyroclastics, which variably consist of porphyritic or aphyric andesite, are embedded in an argillized or glassy matrix together with chips of plagioclase and augite. The reddish brown fine tuff, characteristic of this formation, is a compact rock with traces of stratification. It consists of amphibole, plagioclase and clinopyroxene set in reddish brown volcanic glass. It sometimes contains spherulites (BMG, 1981).

The maximum thickness is estimated to reach up to 3,000 m. It is believed to date as far back as Late Cretaceous.

Umayam Limestone

Lithology	Limestone, subordinate shale
Stratigraphic relations	Unconformably overlies igneous rocks
	constituting the basement and
	conformable over Paleocene limestone
Distribution	Southwestern Agusan; Mangagoy area,
	Surigao del Sur
Age	Eocene
Thickness	610 m
Previous name	Umayam Formation (Ranneft and others,
	1960)
Renamed by	MGB (this volume)
Synonymy	Baggao Limestone (San Jose Oil Co., in
	BM Petroleum Division, 1966)

The Umayam Formation, which was previously named Umayam Formation by Ranneft and others (1960) is renamed here as Umayam Limestone for the exposures of limestone in southwestern Agusan and the Mangagoy area in Surigao del Sur The Umayam was reported to lie unconformably over igneous basement rocks, although it is conformable over outcrops of Paleocene limestones (unnamed) in Mangagoy area, Surigao del Sur (BED, 1986b). The formation consists principally of massive reefal limestone with associated evenly-bedded reef-flank limestones. The Umayam is dated Eocene with an estimated thickness of 610 m (Ranneft and others, 1960). In the Mangagoy area, it is represented by well-bedded lagoonal biocalcarenites (Agusan-Davao Consortium, 1979).

The equivalent of the Umayam along the flanks of the Pacific Cordillera is the Baggao Limestone. These limestone units may be regarded as remnants of isolated reefs that grew on submarine basement platforms (BED, 1986b).

Kilapagan Formation

Lithology	Basalt, sandstone,	mudstone, shale
Stratigraphic relations	Unconformably ove	rlies the Nilabsan
	Formation	

Distribution	Barrio Kaburacanan, Talakag Timber
	logging road in Kilapagan area
Age	Eocene – Early Oligocene
Named by	Santiago (1983)

The term Kilapagan Formation was first used by Santiago (1983) for the rocks typically exposed in Barrio Kaburacanan and along the Talakag Timber, Inc. logging road within the Kilapagan area. This formation consists of slightly metamorphosed basalt flows and clastic rocks consisting of sandstone, shale and mudstone of Eocene to Early Oligocene age (Santiago, 1983).

Kalagutay Formation

Lithology	Mudstone, sandstone, conglomerate, limestone
Stratigraphic relations	Unconformably overlies the Nilabsan Formation
Distribution	Kalagutay River, upper Sita River
Age	Late Oligocene – Early Miocene
Thickness	3,000 m
Previous name	Kalagutay Group (MMAJ-JICA, 1973)
Renamed by	MGB (1998)
Synonymy	Malayanan Formation (Santiago, 1983)

The name Kalagutay Group (MMAJ-JICA, 1973) is renamed here as Kalagutay Formation for the rocks exposed in the Kalagutay River and from upper Sita and Nilabsan rivers to the mountain area on the west side of Pulangi River near the Agusan del Sur-Bukidnon-Davao del Norte boundary. Santiago (1983) reported an equivalent unit, which he designated as **Malayanan Formation**. However, the name Kalagutay is retained here. The formation, which unconformably overlies the Nilabsan Formation, is composed of pyroclastic rocks with mudstone, sandstone, conglomerate and limestone beds. The pyroclastic rocks of the formation consist of andesitic volcanic breccia, tuff breccia, lapilli tuff, ash tuff and agglomerates with associated intercalations of andesitic to basaltic lava flows (BMG, 1981; Santiago, 1983).

The volcanic breccia typically crops out in the middle course of Sita River and in the upper reaches of Kalagutay River. It is dark green or dark gray, and in places, exhibits auto-brecciated structure. The fragments are more than 10 cm in diameter and contain phenocrysts of plagioclase, green amphibole and augite in a groundmass of plagioclase microlites and glass. Chlorite, calcite and pumpellyite in large amounts are present in the rock (BMG, 1981). The lapilli tuff, tuff breccia and ash tuff are distributed widely from the upper reaches of Nilabsan River to Malicapan River. These are dark green to dark gray strongly altered rocks, which are also distributed in the eastern side of the Davao-Pulangi Fault. The lapilli tuff along the upper reaches of Nilabsan River characteristically contains chromite and serpentinite fragments, which are probably derived from peridotite (BMG, 1981). Paleontological dating of limestone and mudstone containing foraminiferal assemblages indicate ages of Late Oligocene to Early Miocene (Pubellier and others, 1991; Quebral, 1994 in Sajona and others, 1997). Pubellier and others (1993) also reported a dating of Late Oligocene to early Middle Miocene for the thick limestone unit traced on seismic lines (Moore and Silver 1983) that overlie volcanic rocks. Likewise, andesite flows yielded radiometric K-Ar ages of 19.86 Ma and 16.32 Ma or Early Miocene (Pubellier and others, 1991; Sajona and others, 1997).

Tagbacan Formation

Lithology	Conglomerate, sandstone, shale
Stratigraphic relations	Not reported
Distribution	Tagbacan Creek, Bukidnon
Age	Middle Miocene – Late Miocene
Named by	Santiago (1983)

Well-bedded conglomerate, pebbly sandstone and fine tuffaceous sandstone and shale exposed along Tagbacan Creek were designated by Santiago (1983) as Tagbacan Formation. These rocks generally exhibit a light gray color that tarnishes to a brownish tint upon oxidation. A thrust fault defines the contact between this formation and ultramafic rock.

Santiago (1983) assigned a Middle to Late Miocene age for this lithologic unit. Correlation with the stratigraphic column of Pubellier and others (1991) yielded the same age range.

Locawan Diorite

Lithology	Diorite, andesite porphyry, pyroxenite, gabbro
Stratigraphia relationa	Intrudee Kelegutev Formation
Stratigraphic relations	intrudes Ralagulay Formation
Distribution	Nirobsan, Locawan, Tigua rivers
Age	Late Miocene
Named by	MGB (this volume)

Diorite, along with pyroxenite and gabbro constitutes an igneous composite body from the upper Nirobsan River to Locawan and Tigua rivers. The mutual relations among these rocks suggest that the emplacement of the diorite was preceded by the formation of pyroxenite and gabbro. These rocks were originally designated as Ultramafics and Diorite in BMG (1981) and are here renamed as Locawan Diorite. Radiometric K-Ar dating of a gabbro sample gave 11 Ma or Late Miocene age (BMG, 1981). Santiago (1983) also noted the occurrence of andesite porphyry body in Malaybalay, Bukidnon, which could represent a facies of the diorite. The diorite and andesite porphyry intrude the older rocks, particularly the Kalagutay Formation (BMG, 1981; Santiago, 1983).

The diorite, which occupies the southern and western parts of the composite mass, is a melanocratic holocrystalline rock. It consists of plagioclase, potash feldspar augite and biotite. Magnetite, sphene and apatite are the accessory minerals (BMG, 1981).

Around Barangays Simay and Langasihan in Malaybalay, an andesite porphyry body and porphyritic dikes also intrude the Kalagutay Formation. These are generally composed of plagioclase and hornblende crystals set against a matrix of glass. Santiago (1983) assigns a Late Miocene age to this rock.

Lumbayao Formation

Lithology	Conglomerate, sandstone, mudstone,
	limestone
Stratigraphic relations	Unconformably overlies the Kalagutay
	Formation
Distribution	Mt. Merui, Upper Sita River, Kiulom River,
	Little Baguio near the boundary of
	Bukidnon and Davao del Norte
Age	Pliocene – Pleistocene
Thickness	1,000 m
Named by	MMAJ-JICA (1973)
Synonymy	Kapalong Formation (MMAJ-JICA, 1973)

This formation was named Lumbayao by MMAJ-JICA (1973) for the sedimentary unit composed of conglomerate with limestone pebbles, sandstone, mudstone and limestone that unconformably overlies the Kalagutay Formation. Exposures of the Lumbayao can be found at Mt. Merui, upper Sita River, Kiulom River, and Little Baguio near the boundary of Bukidnon and Davao del Norte.

The basal conglomerate of the Lumbayao directly overlies the volcanic rocks of the Kalagutay Formation in Kumawas Creek. The sandstone is tuffaceous in character, creamy white in color and sometimes grayish when fresh. It is generally interbedded with shale. Limestone acts as capping over the older andesite porphyry intrusive body. There appears to be two types: the first is a hard, massive, crystalline unit that is white to dirty white, and sometimes bluish and pinkish; and the second is a fossiliferous coralline type that occurs as a thick interbed with the clastic sedimentary rocks.

The Kapalong Formation, which was designated by MMAJ-JICA (1973) and defined by BMG (1981), as a "molasse-type deposit consisting of conglomerate, sandstone, and siltstone with thin limestone beds at its base," is considered here as the equivalent of the Lumbayao Formation. BMG (1981) assigned a Pliocene - Pleistocene age for the Kapalong, and Pleistocene for the Lumbayao. However, Santiago (1983) gave the Lumbayao a Pliocene age. Here, the Lumbayao is assigned a Pliocene to Pleistocene age. The aggregate thickness of the Lumbayao, including the Kapalong, is about 1,000 m.

Malambo Andesite

Lithology	Andesite flows, breccia
Stratigraphic relations	Not reported
Distribution	Tigua River, Bukidnon
Age	Pleistocene

Previous Name	Malambo Formation (MMAJ – JICA, 1973)
Renamed by	MGB (this volume)

Hornblende andesite lava flows and breccias exposed in the upper reaches of Tigua River were designated as Malambo Formation by MMAJ-JICA (1973) and renamed here as Malambo Andesite. The unit is correlatable with the andesite flow breccias found around Mt. Apo. It is probably Pleistocene in age.

Koronadal Formation

Lithology	Sandstone, mudstone, pyroclastic rocks,
	basalt, andesite
Stratigraphic relations	Unconformable over older formations
Distribution	Koronadal and Allah valleys; slopes of
	Mounts Apo and Matutum
Age	Pleistocene
Thickness	500 m
Previous name	Carmen Clastics and Pyroclastics
	(Froehlich and Melendres, 1960)
Renamed by	MGB (this volume)

This formation was named earlier by Froehlich and Melendres (1960) as Carmen Clastics and Pyroclastics for the exposures at Carmen, North Cotabato. It is here renamed Koronadal Formation to avoid confusion with another Carmen Formation located in Bohol province. The formation occurs as lenticular belts covering the gentle slopes of Mounts Apo, Parker and Matutum. It also crops out at the fringes of the Allah and Koronadal Valleys. The rocks comprising the formation are chiefly shallow marine deposits of poorly consolidated tuffaceous sandstone and mudstone intercalated with lenses of conglomerate, agglomerate, basalt and andesite. The formation attains a thickness of 500 m. A Pleistocene age is assigned to the formation.

Cabanglasan Gravel

Lithology	Conglomerate, sandstone, siltstone, tuff
Stratigraphic relations	Not reported
Distribution	Cabanglasan, Bukidnon
Age	Late Pleistocene – Holocene
Previous Name	Cabanglasan Terrace Gravel (Santiago,
	1983)
Renamed by	MGB (this volume)
Correlation	Cagayan Gravel

A Late Pleistocene to Holocene assemblage of loosely consolidated conglomeratic and sandstone gravels with minor lenses of carbonaceous silty sediments and tuff outcrops, which cover a large area of the Cabanglasan synclinal trough was designated as Cabanglasan Terrace Gravel by Santiago (1983). The Gravel consists of cobble- to pebble-sized fragments of andesite porphyry, thin-bedded sediments, tuff, ferruginous sediments and abundant ultramafic rocks. The Cabanglasan may be correlated with the Cagayan Gravel.

Central Mindanao Volcanic Zone

A number of active and inactive volcanoes that date back to Pliocene are disposed along a north-northwesterly belt from Camiguin Island (Hibok-Hibok Volcano) down south to Mt. Parker in South Cotabato. Some of the more prominent volcanic formations and complexes are described below.

Mambuaya Andesite

Lithology	Basaltic andesite
Distribution	Mambuaya, Misamis Oriental; Talakag,
	Bukidnon
Age	Pliocene – Pleistocene
Previous Name	Mambuaya Volcanics (Pacis (1966)
Renamed by	MGB (this volume)

The Mambuaya Andesite was previously named Mambuaya Volcanics by Pacis (1966) for the exposures of volcanic rocks at Mambuaya, Misamis Oriental on the west side of Cagayan River. The largest exposure is narrow and elongated. It can be traced for several kilometers southward to Talakag where it apparently widens. The Mambuaya consists largely of basaltic andesite. Phenocrysts consist of clinopyroxene and plagioclase with occasional olivine. These rocks are fine to medium-grained and locally exhibit columnar jointing and abundant vesicles. Originally, Pacis (1966) included the volcanic rocks underlying active volcanoes as part of the Mambuaya. However, these active volcanoes, such as, Ragang, Calayo and Hibok-Hibok, are treated separately here.

Lanao Volcanic Complex

Lithology	Basalt, andesite, pyroclastic rocks
Distribution	Lanao del Norte and Lanao del Sur
Age	Pliocene – Pleistocene
Named by	MGB (this volume)

The Lanao Volcanic Complex consists of a cluster of volcanoes with associated volcanic lakes in Lanao del Norte and Lanao del Sur. The volcanoes, which are all inactive, include Mt. Gadungan, Dos Hermanos Peaks, Mt. Cabugao, Mt. Iniaoan, Lake Nunungan, Mt. Catmon, Mt. Sagada, Mt. Puerai and Gurain Mountains. Radiometric K-Ar dating of a sample of basaltic andesite taken near the northern rim of Lake Lanao gave an age of 2.31 Ma, while that of basalt from the northern slope of Mt. Puerai gave an age of 0.16 Ma (Sajona and others, 1997). The Lanao Volcanic Complex is assigned an age range of Pliocene – Pleistocene on the basis of the above information.

Ragang Volcanic Complex

Lithology	Andesite, pyroclastic rocks
Distribution	North Cotabato, Lanao del Sur
Age	Pliocene - Recent

Named by

MGB (this volume)

Ragang Volcano occupies the northeast end of a series of relatively young volcanic cones at the boundary of Lanao del Sur and North Cotabato. These volcanic cones include Kitabud Mountain, Makaturing, Maranat, Mariyug, Salagabanog, and Magampao. The eruptive vent of Ragang is rimmed by three peaks with a deep hollow at the center (PHIVOLCS, 1981). From the southeast of this crater, jagged lava flow rocks radiate for about one kilometer. All around the cones and craters, scattered products of past eruptions are roughly sorted according to their sizes: boulders near the cones and cinders, lapilli and ashes farther away. Jets of sulfurous vapors issue from vents in the crater and from one of the cones. Eruptions of Ragang were reported in 1834, 1840, 1858, 1865, 1871 and 1873 and 1915 (PHIVOLCS, 1981).

Mt. Makaturing in Butig, Lanao del Sur is a stratovolcano whose eruption in 1840, 1856 and 1871 were vulcanian in nature. The volcano is presently solfataric. A sample of andesite flow from Kitabud Mountain gave a radiometric K-Ar age of 0.46 Ma (Sajona and others, 1997).

Parker Volcanic Complex

Lithology	Andesite, dacite, basalt, agglomerate,	
	pyroclastic flows	
Stratigraphic relations	Unconformable over Siloay Formation	
Distribution	South Cotabato	
Age	Pliocene - Recent	
Previous Name	Mt. Parker Formation (Santos and	
	Baptista, 1963)	
Renamed by	MGB (this volume)	

At the southeast portion of the Cotabato Cordillera is Mt. Parker volcano, which is part of the cluster of volcanoes that includes Mt. Busa and Mt. Malibao. The core of Mt. Parker is a plug of gray porphyritic andesite. The volcanic flow rocks of Mt. Parker predominantly consist of pyroxene- and quartz-bearing hornblende andesite (Delfin and others, 1997). Olivine basalt lava is rare. At the summit is a crater lake called Maughan Lake. Along the flanks are deeply dissected piles of agglomerates, ash flows and other pyroclastic rocks with subordinate volcanic flows representing the eruptive products of the volcano. Pumiceous pyroclastic flows and lahars form gentle slopes that extend more than 20 km from the volcanic cone. The principal clast of the tuff breccias constituting the pyroclastic flows is dacitic pumice. Hornblende andesite clasts occur in subordinate amounts. At various horizons, thin beds of highly tuffaceous shales and/or fine-grained sandstone are found interbedded with the pyroclastic pile. A dacite dome south of the crater probably represents the post-caldera phase. A dacitic plug north of the volcano could also be attributed to the activity of Mt. Parker. Sulfur deposits and thermal spring activities occur at various places on the slopes of Mt. Parker.

Radiometric K-Ar dating of fresh boulders from the northwestern flank of the volcano gave ages of 4.37 Ma and 0.07 Ma, equivalent to Early Pliocene and Pleistocene, respectively (Sajona and others, 1997). On the other hand, ¹⁴C dating reveal radiocarbon-age groupings of 23 Ka – 27 Ka, 3.8 Ka, ~600 ybp and ~300 ybp (Delfin and others, 1997). Historical accounts indicate that Mt. Parker might have erupted as late as the year 1641 (Delfin and others, 1997).

Apo Volcanic Complex

Lithology	Basalt, andesite, pyroclastic rocks
Distribution	Davao
Age	Pleistocene
Named by	MGB (this volume)

Volcanic flows and pyroclastic rocks, chiefly agglomerates and tuffs, underlie the broad slopes of Apo, Boribing, Talomo and Sibulan mountains. Mt. Apo consists of basaltic flows cut and overlain by more recent andesites in the northeastern portion. The agglomerates consist chiefly of fragments of basaltic andesite and pyroxene andesite cemented by a tuffaceous matrix. Beds of ash tuff are horizontal to moderately dipping. Flows of andesite porphyry are found at the municipality of Sta. Cruz, Davao del Sur and at Barrio Sirawan in Davao City. Numerous solfataras are localized along a crevasse in the southern part running from elevation 2,400 masl to the top (Comvol, 1981). Radiometric K-Ar dating of a sample of high-K basaltic andesite gave an age of 0.62 Ma (Sajona and others, 1997).

Malindang Volcanic Complex

Lithology	Basalt, andesite, dacite, pyroclastic rocks
Distribution	Misamis Occidental
Age	Pleistocene
Named by	MGB (this volume)

Malindang Volcanic Complex in Misamis Occidental consists of Mt. Malindang, North Peak and Mt. Ampiro to its north. These are characterized by volcanic flow rocks in their summit areas with pyroclastic rocks at their flanks. The volcanic flow rocks of Malindang include shoshonitic basalt and basaltic andesite. Radiometric K-Ar dating of samples of basalt and basaltic andesite gave ages of 0.40 Ma and 0.64 Ma, respectively (Sajona and others, 1997). Volcanic flow rocks at Ampiro that were identified by Sajona and others (1997) consist of shoshonitic basalt, basaltic andesite, high-K andesite and dacite. The ages of these rocks as determined from radiometric K-Ar dating range from 0.70 Ma for the dacite to 0.29 Ma for the high-K andesite (Sajona and others, 1997). The age of the shoshonite (0.43 Ma) is nearly the same as that for a similar sample from Malindang (0.40 Ma).

Katanglad Volcanic Complex

Lithology	Basalt, andesite, dacite, pyroclastic rocks
Distribution	Bukidnon
Age	Pleistocene

Named by MGB (this volume)

Mt. Katanglad and Mt. Kalatungan to its south are the more notable of a cluster of volcanic edifices in northern Bukidnon area. Other volcanic centers in the area include Pudung, Kilakron, Nanluyaw and Kidonging. A few adventive domes of andesite and dacite are also present. Radiometric K-Ar dating of three basalt samples gave ages of 0.40 Ma, 0.27Ma and 0.25 Ma. On the other hand, a sample of shoshonitic basalt gave a K-Ar age of 0.52 Ma, while a dacite sample from an adventive dome was dated < zero, that is to say, <100 Ka (Sajona and others, 1997).

Matutum Volcanic Complex

Lithology	Andesite, dacite, pyroclastic rocks	
Distribution	Mt. Matutum, south-central Cotabato	
Age	Pleistocene - Recent	
Thickness	> 1,000 m	
Named by	MGB (this volume)	

Mt. Matutum is a stratovolcano in south-central Cotabato, which stands 2,380 m high. Its summit crater is surrounded by hills and knobs of hornblende andesite and dacite flows. Voluminous pyroclastic materials blanket the southern and western portions of the edifice. The thickness of the volcanic rocks and intercalated clastic rocks is over 1,000 m. Radiometric K-Ar ages of isolated plugs around the volcano range in age from 1.5 to 0.85 Ma (Sajona and others, 1997). Comparably, samples from the flanks of the volcano gave radiometric K-Ar ages of 1.83 to 0.17 Ma (Sajona and others, 1997). On the other hand, dacite from the summit yielded a K-Ar age of 0.00 Ma (<100,000 years) and a charred wood in pyroclastic rock gave a radiocarbon ¹⁴C age of 2Ka (Sajona and others, 1997). Mt. Matutum is presently inactive, although there is an unconfirmed report that the volcano emitted smoke in 1911. The Complex is assigned an age of Pleistocene to Recent.

Camiguin Volcanic Complex

Lithology	Basalt, andesite, dacite, pyroclastic rocks
Distribution	Camiguin Island, Misamis Oriental
Age	Pleistocene - Recent
Named by	MGB (this volume)

The Camiguin Volcanic Complex is a composite volcano located at the northwestern end of Camiguin Island, an island province off the north coast of Mindanao. The complex consists mainly of Hibok-Hibok, Mambajao, Vulcan and Butay. The summit of Hibok-Hibok is formed of loose ejecta with several craterlets at or near the summit, some in the form of shallow lakes. The complex consists predominantly of olivine-bearing andesite and subordinate dacite. Phenocrysts of the andesite consists of augite, little hypersthene, and olivine although hornblende is also present in some exposures. Field evidence suggests that volcanism started at Mt. Butay in the south and propagated northward to Mambajao, Hibok-Hibok and Vulcan (Sajona and others, 1997). Radiometric K-Ar dating of a sample of basaltic andesite from Mt. Butay was dated 0.34 Ma, while an andesitic

flow from Mt. Mambajao gave a zero age (< 100 Ka) (Sajona and others, 1997).

The first recorded eruption of Hibok-Hibok was in 1827. This was followed by similar activity in 1862. Its eruption in 1871 was accompanied by the formation of an adventive dome 3.5 km from Hibok-Hibok. After four years of activity, the adventive lava dome reached a height of 457 m with a base measuring nearly 1.6 km in diameter, henceforth called Vulcan (PHIVOLCS, 1981, 1991). Of the five most prominent volcanoes in the island, Hibok-Hibok has been the most active recently. Its most recent activity was a series of Pelean type eruptions that lasted from 1948 to 1953. The eruption in 1948 was characterized by glowing avalanche (*nuées ardentes*) of highly heated ash, volcanic breccia and gases. The lava, which were extruded after the blasts, consists of blocky, grayish, porphyritic andesites with numerous ferromagnesian and plagioclase phenocrysts (PHIVOLCS, 1981, 1991).

Mt. Kihangad / Balingoan in Misamis Oriental, just south of Camiguin Island, is underlain by basalt and andesite, which were probably products of volcanic eruptions that occurred sometime in the Pleistocene past when Camiguin was already active. Radiometric K-Ar dating of a sample of andesite flow from Kihangad gave an age of 0.14 Ma. Samples of basalt flows gave ages of 0.65 Ma and 0.36 Ma (Sajona and others, 1997).

Musuan Volcano

Lithology	Andesite, tuff		
Distribution	Valencia, Bukidnon		
Age	Pleistocene – Recent		

Musuan or Calayo Volcano in Valencia, Bukidnon is an isolated tuff cone amidst a relatively flat, agriculturally rich terrain. Steam eruptions in 1886 or 1887 and strong solfataric emission in 1891 are some of the volcano's recorded activities (PHIVOLCS, 1995). Several inactive volcanoes to its southeast could be related to Musuan. These include Tangulang, Malambo and Talemo with elevations of 1,879, 1,200 and 900 meters masl, respectively. These volcanoes progressively decrease in height towards the north up to Musuan, which stands only 646 masl, suggesting that volcanic activity might have propagated northwards. Radiometric K-Ar dating of a basaltic andesite sample on the flanks of Tangulang gave an age of 1.15 Ma (Sajona and others, 1997).

AGUSAN – DAVAO BASIN (SG 23)

The stratigraphy of the Agusan-Davao Basin is simplified in this edition. In the first edition, formations belonging to the neighboring cordilleras have been included in the basin stratigraphy. Here, formations belonging to the Central Mindanao Volcanic Arc and the Pacific Cordillera on the western and eastern flanks, respectively, are not considered part of the basins except perhaps as basement.

PERIOD	EPOCH HOLOCENE	STAGE	Ма	AGUSAN BASIN		
5	HOLOCENE			AGOONIT BHOIL	DAVAO BASIN	DAVAO GULF -SAMAL ISLAND
,				Alluvial, paludal & lacustrine deposits	Tigatto Terrace Gravel	
,		4	0.0117		Bunawan Limestone	Samal Limestone
	PLEISTOCENE	3	0.126	Wawa Formation	min	Currie concercio
		2	1.81		Mandog Formation	
-		1	2.59		Mawab Sandstone	
Щ	PLIOCENE	2	3.60			Tagbobo Conglomerate
<u> </u>		1	5.33			
8			2.05	Adgaoan Formation	Masuhi Limestone	
¥			7.25			
		<u> </u>	11.61		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
	MIOCENE	2	13.65			
			15.97		Upian Limestone	
		20.43		Kabagtican Formation		
			23.03			
		2	20.00			
	OLIGOCENE	1	28.4			
-		<u> </u>	33.9			
ш		4	37.2			
Z		3				
00	EOCENE	2	40.4			
Ŭ.		~	48.6			
AL		1				
-		3	55.8			
	PALEOCENE	2	00.7			
		1	65.5			
and	K2		00.0			
- AL	К1		99.6			
JURASSIC			145.5			

 Table 2.27 Stratigraphic column of Agusan-Davao Basin

For the Agusan Basin, the Umayam Formation of San Jose Oil Company (in BM Petroleum Division, 1966) is included in the Central Pacific Cordillera. The Umayam and its equivalent in the east, the Baggao Limestone, may be considered remnants of isolated reefs that grew on submarine basement highs on both sides of the respective Cordilleras that flank the basin (BED, 1986b). The Umayam Formation and other Eocene limestone units are described by Ranneft and others (1960) as erosional outliers on the flanks of the Pacific Cordillera. The succeeding Bislig Formation of BED (1986b) is considered a transgressive Late-Oligocene-Early Miocene sequence that predates the basinal sequence and belongs to the Pacific Cordillera grouping. The Bislig includes the Mangagoy, Mekoupe and Pamaypayan formations of Vergara and Spencer (1957), which are considered different facies of a time-transgressive formation (BED, 1986b). The deposition of the Bislig Formation is associated by BED (1986b) with a westward transgressing shoreline in, which the conglomerate and sandstone facies, coupled with the occurrence of petrified wood, represent terrestrial environment of deposition. On the other hand, the coal-bearing carbonaceous mudstones represent an intertidal swamp environment and the limestone facies corresponds to marine lagoonal environment (BED, 1986b).

For the Davao Basin, the Palaeozoic (?) metamorphic rocks, Mesozoic volcanic and sedimentary rocks, Paleocene to Eocene conglomerate, sandstone and limestone, and Miocene limestone with clastics and basalt flows, quartz diorite and andesite porphyry of Malicdem and Peña (1965) are included in the Pacific Cordillera stratigraphy.

In this volume, therefore, the Agusan-Davao Basin is considered to have formed during Late Miocene.

Agusan Basin

Adgaoan Formation

Lithology	Turbidite, conglomerate, limestone
Stratigraphic relations	Formation and other Pleistocene deposits
Type locality	Barangay Ampayon, Prosperidad, Agusan
	del Sur, along the Zigzag portion of the
	Butuan-Prosperidad highway
Distribution	Las Nieves, Guadalupe Anticlines,
	Prosperidad area; western coast of
	Butuan Bay down to the west of Davao
	Gulf
Age	Late Miocene to late Pliocene
Thickness	2,300 m (maximum)
Named by	San Jose Oil Company (in BM Petroleum
	Division, 1966)

The Adgaoan Formation was named by San Jose Oil Company (BM Petroleum Division, 1966) for the sedimentary sequence typified by exposures at Brgy. Ampayon, Prosperidad, Agusan del Sur. A clear angular unconformity separates the Adgaoan from the Wawa Formation and other Pleistocene deposits (Quebral, 1994). Exposures of the Adgaoan can be traced along an elongate zone from the western coast of Butuan Bay to the west of Davao Gulf (BED, 1986b). Aside from the Carmen area along the Butuan-Cagayan de Oro highway, this formation outcrops within the Guadalupe and Las Nieves anticlines. A section across the Las Nieves Anticline reveals a clastic series with a lower turbiditic portion and an upper conglomeratic portion.

Three facies of the formation is recognized by BED (1986b), namely, marine clastic facies, limestone facies and non-marine clastic facies. The well-bedded lower turbiditic sequence consists of sandstones, shales with layers of detrital limestones and conglomerates. The conglomerates are heterogeneous with well-rounded clasts of andesites, ultramafic rocks, limestone and dacite. These grade into thin to medium bedded coarse sandstones. Sandstones and shales, which are important components in the series on account of their thickness, are calcareous and often contain shell fragments.

The conglomerates in the upper portion of the sequence are resistant to erosion and form well developed cuestas. Although stratified, the bedding is seldom clear. The conglomerates are usually thick bedded and heterogeneous. They are poorly sorted and contain large angular to wellrounded blocks of andesite, basalt, diorite, limestone and chert in a matrix of gravel and coarse sands of similar composition. Coarse volcanic breccias are intercalated with the conglomerates. Towards the base, the conglomerate beds are less thick but more defined and there is a larger percentage of intercalated coarse sandstones. The clasts are more rounded and often include mollusk shell fragments.

The limestone facies consists largely of massive coralline limestones intercalated with marls, shales and conglomerates. The non-marine facies is composed of sandstones, shales and conglomerates, which occasionally contain carbonized wood.

As a result of numerous and more precise nannofossil age determinations, this formation is reassigned a late Miocene (NN11) to late Pliocene (NN16) age (Quebral, 1994), based on the following assemblage: *Discoaster brouweri, Discoaster icarus, Discoaster pentaradiatus* and *Discoaster variabilis.*

San Jose Oil Company (in BM Petroleum Division, 1966) estimates a thickness of over 2,000 m for the Adgaoan Formation. Outcrop thicknesses of the Adgaoan as reported by BED (1986b) vary from 420 m to 1,600 m. On the other hand, a maximum thickness of more than 2,300 m is indicated from the Tuganay-1 well data (BED, 1986b).

The **Sayon Formation** of Victoriano and Gutierrez (1980) in the Bislig-Lianga area probably corresponds in part to the Adgaoan Formation. It consists of greenish gray sandstone and dark gray lignitic siltstones, which grade upward into light gray to green intertidal calcareous silty sandstones with abundant bivalves, gastropods, corals and other calcareous detrita (BED, 1986b). It is Pliocene in age and has a maximum estimated thickness of 100 m.

Wawa Formation

Lithology	Lower sandstone member and upper
	carbonate member.
Stratigraphic relations	Unconformably overlies the Adgaoan
	Formation
Type locality	Prosperidad, Agusan del Sur
Distribution	Prosperidad, Bunawan, Talacogon,
Age	Early Pleistocene to Late Pleistocene
Named by	San Jose Oil Company (in BM Petroleum
	Division, 1966)

The Wawa Formation was named by geologists of San Jose Oil Company for the exposures along Wawa River in Prosperidad, Agusan del Sur. As observed along Wawa gorge, this formation consists of a lower sandstone member and an upper carbonate member. A clear angular unconformity separates the Wawa from the underlying Adgaoan Formation.

Sandstones of the lower member are fine grained and argillaceous and rich in fossils such as pelecypods, gastropods and echinoderm spines. The carbonate member consists of an upper reefal limestone and a lower portion made up of detrital limestone or coral breccia and marls. At Talacogon, over the Guadalupe Anticline, the formation consists of thinand well-bedded sandstones, shales and diatomite-bearing mollusks and echinoderms (Quebral, 1994).

A regional angular unconformity clearly separates the undeformed early to late Pleistocene (NN19) from the folded late Miocene to late Pliocene (NN15-16) beds. In Talacogon, this unconformity is clearly uplifted by as much as 100 m (Quebral, 1994).

A possible equivalent of the lower clastic member is the **Liuanan Sandstone** of San Jose Oil Company (in BM Petroleum Division, 1966), described as a Pleistocene fluviatile sequence of loose and crossbedded sands with gravel lenses outcropping along Liuanan River on the basin's western flank. Its thickness, as measured by San Jose Oil Company, is around 300 m.

This formation was previously considered to be Middle Miocene. However, its age has been revised to Early Pleistocene (NN19) to Late Pleistocene (NN20-21) based on the presence of the nannofossils in the sandstones and marls, such as: *Cyclococcolithus leptoporus, Discolithina japonica, Gephyrocapsa ericsonii, Gephyrocapsa oceanica, Helicosphaera carteri, Pseudomiliana lacunosa, Syracosphaera pulchra and Umbilicosphaera mirabilis in the sands and marls. This Pleistocene age is confirmed by the foraminifera Operculintonesa sp. cf. and O. barthschi <i>Cushman* from the limestone.

The lower clastic member and upper limestone member of the Wawa Formation probably correspond, respectively, to the **Mandog Sandstone** (Casasola, 1956) in the Davao Basin and **Gamut Limestone** (Victoriano and Gutierrez, 1980) in the Bislig-Lianga area.

Recent Deposits

Recent deposits - alluvial, paludal or lacustrine - occupy a large portion of the basin. West of the Philippine Fault are uplifted fluviatile deposits while the area east of the fault is generally swampy with scattered lakes (Quebral, 1994).

Davao Basin

Kabagtican Formation

Lithology Stratigraphic relations	Sandstone, shale, volcaniclastic rocks
Stratigraphic relations	
	sequence
Distribution	Asuncion, Nabunturan, Mt. Caunabayan,
	Davao del Norte
Age	Early Miocene
Thickness	>150-200 m
Named by	Casasola (1956)

Although Casasola (1956) introduced the term Kabagtican Formation, no type locality is given. The term is therefore retained but is used to represent well-defined rhythmic interbeds of indurated thin sandstones and shales of Early Miocene age in the core of the Kilagden Anticline in Asuncion, Davao del Norte. The eastern flank of this fold is displaced in a left lateral sense by the Philippine Fault and is now found at Mt. Caunabayan.

The Kabagtican likewise outcrops at the core of the Nabunturan Anticline as altered volcaniclastic rocks found stratigraphically beneath the vertical cliff-forming Early Miocene limestone along the highway in Nabunturan.

Casasola (1956) gives a thickness of 150 to 200 m for the Kabagtican Formation although it is possible that the base of the formation was not observed. The formation does not form part of the basinal sequence. It is, instead, part of the underlying basement.

Casasola (1956) assigns a Pliocene age for the Kabagtican Formation along the basin's western flank. However, the outcrops he describes elsewhere along the Davao-Agusan Highway, was dated Early Miocene by Quebral (1994), who correlates the Kabagtican with the upper, bedded portion of the Oligo-Miocene arc, found throughout the Pacific Cordillera beneath the limestone capping.

The volcaniclastic series at the core of the Kilagden Anticline has been dated Early Miocene (NN3) based on the following nannofossil assemblage: *Cyclicargolithus abisectus, Cyclicargolithus floridamus, Cyclococcolithus leptoporus, Discoaster deflandrei, Discoaster desueta, Helicosphaera carteri, Helicosphaera euphratis, Sphenolithus belemnos, Sphenolithus heteromorphus and Sphenolithus moriformis* (Quebral, 1994).

Upian Limestone

Lithology	Limestone
Stratigraphic relations	Unconformably overlies the Kabagtican
	Formation; constitutes part of the
	basement; unconformably overlain by the
	Masuhi Formation
Type locality	Nabunturan, Davao del Norte
Distribution	Nabunturan, Mawab and Asuncion, Davao
	del Norte
Age	Early Miocene
Thickness	50-80 m
Author	Casasola (1956)

Casasola (1956) used the term Upian Limestone for a limestone outcropping along the basin's western flank, although no type locality is provided. The term is retained here but is used to refer to another outcrop of the same limestone in Nabunturan. The limestone outcrops within the cores of the Kilagden, Mawab and Nabunturan anticlines in Asuncion, Mawab and Nabunturan, respectively. It is readily recognized along the national highway in Nabunturan where it is found in a subvertical position and is notably cliff-forming. Northwest of Mawab, the same limestone is easily identified by its karstic expression.

Casasola (1956) gives a thickness of 50 - 80 m for the Upian Limestone although its equivalent in the Pacific Cordillera is definitely much thicker. Like the Kabagtican Formation, the Upian Limestone is not part of the basinal sequence. Seismic reflection profiles show that it forms the uppermost portion of the acoustic basement.

As in the case of the Kabagtican Formation, Casasola (1956) presumes the age of the Upian Limestone along the basin's western flank as Pliocene. Where he describes it outcropping elsewhere along the Davao-Agusan Highway, Quebral (1994) dates the limestone as Early Miocene. This limestone corresponds to the massive limestone found capping most of the Pacific Cordillera such as in the Diwalwal and Bunawan areas.

The limestone in the Nabunturan and Mawab anticlines has been dated Early Miocene based on its foraminifera content (Quebral, 1994), including the following: *Amphistegina sp., Cycloclypeus sp., Globigerinoides sp. Lepidocyclina (E.) sp. cf. L (E.) omphala Tan, Lepidocyclina (N.) angulosa Provale, Lepidocyclina (N.) sumatrensis Brady, Lepidocyclina (N.) sp., Lepidocyclina (N.) sp. cf. L. (N.) sumatrensis, Lepidocyclina sp., Miogypsinoides sp., Operculina sp. cf. O. venosa Fichtel and Mose, Operculinopides sp and Sphaerogypsina sp.*

Masuhi Formation

Lithology	Sandstone, shale, conglomerate
Stratigraphic relations	Unconformably overlies the Upian
	Limestone; unconformably overlain by the
	Mandog Sandstone
Distribution	Mawab, Davao del Norte
Age	Late Miocene - Early Pliocene
Thickness	200-250 m
Author	Casasola (1956)

Unconformable over the Early Miocene Upian Limestone is the Masuhi Formation that outcrops along the basin's western flank as well as within some folds of the Davao Basin. Masuhi Formation was used by Casasola (1956) to refer to interbedded sandstones and shales with polymictic conglomerate beds along the western flank of the basin as well as along portions of the Agusan-Davao Road west of Mawab. The term is retained in this volume but the Mawab exposures are used as a reference section. Here, rhythmically interbedded sandstones and black shales were encountered although, elsewhere in the same fold, lenses of limestone bearing conglomerate, marls and coral breccia are found. This marine sequence was dated as Late Miocene-Pliocene. A thickness of 200 - 250 m was estimated for the Masuhi Formation (Casasola, 1956). The Masuhi Formation of the Davao Basin is probably equivalent to the Adgaoan, Carmen, or Nasipit Formations of the Agusan Basin.

Mandog Sandstone

Lithology	Sandstone, shale, conglomerate
-----------	--------------------------------

Stratigraphic relations	Unconformably overlies the Masuhi
	Formation; unconformably overlain by the
	Mawab Formation
Distribution	Mandog, Davao City; Lasang and Davao
	Rivers; Mawab and Asuncion, Davao del
	Norte
Age	Early Pleistocene to Late Pleistocene
Thickness	200-250 m
Named by	Casasola (1956)
-	

Unconformably overlying the Masuhi Formation is the Mandog Sandstone (Casasola, 1956) whose type locality is Barangay Mandog, Davao City. Exposures of the Mandog may be encountered along Lasang and Davao Rivers on the western flank of the basin and the Mawab and Makgum anticlines. The first fold is located along km 58 to 68 of the national highway west of Mawab while the second fold is located north of Asuncion.

The Mandog Sandstone consists of a poorly consolidated, sequence of interbedded sandstone and shale with conglomeratic portions. The latter are crossbedded, poorly-sorted and polymictic, having igneous, sedimentary and metamorphic clasts. Casasola (1956) gives a thickness of 600 - 800 m. elsewhere, a sequence of bluish-gray, fine-grained argillaceous sandstone outcrops at the core of the Makgum Anticline in Asuncion.

The Mandog occupies the same stratigraphic position as the Mawab Formation, but where Casasola (1956) also describes the Mandog Sandstone west of Mawab between km 58 and 68, what was mapped by Quebral (1994) are coarse conglomerates with dacitic clasts in a sandy matrix and not polymictic conglomerates as described by Casasola (1956). If correlated with the Agusan Basin, the Mandog Sandstone probably corresponds to the lower clastic member of the Pleistocene Wawa Formation.

Casasola (1956) assigns a continental environment of deposition although he found it to be locally fossiliferous. At the Makgum Anticline, in Asuncion, the nannofossil content and the numerous megafossils, such as pelecypods and gastropods, in fine sediments, as well as the presence of limestone, indicate sedimentation within a shallow marine environment.

Quebral (1994) revised the age of this formation to a range of Early (NN19) to Late (NN20-21) Pleistocene based on the presence of nannofossils in the sandstones and marls at the core of the Makgum Anticline. This Pleistocene age is confirmed by foraminifers from the limestone.

Mawab Conglomerate

Lithology	Conglomerate
Stratigraphic relations	Unconformably overlies the Masuhi
	Formation
Type Locality	Mawab, Davao del Norte

Distribution	Mawab and Tagum, Davao del Norte
Age	probably Pleistocene
Named by	Quebral (1994)

Quebral (1994) describes a sequence of coarse conglomerates with dacitic clasts in a sandy matrix along the zigzag portion of the highway between Tagum and Mawab. The term Mawab Formation is introduced here to refer to this sequence. This unit rests unconformably on the Masuhi Formation and is unconformably overlain by Pleistocene limestone, as shown by exposures along the Mawab, Nabunturan and Monkayo anticlines.

The formation seems to be equivalent to the Mandog Sandstone of Casasola (1956). However, between kms 58 and 68, where polymictic conglomerate of the Mandog Sandstone is described by Casasola (1956), what was mapped by Quebral (1994) are coarse conglomerates with dacitic clasts in a sandy matrix that belong to the Mawab Conglomerate.

Although no fossil age dates were obtained, these conglomerates are stratigraphically located between the Late Miocene-Pliocene sedimentary rocks and Pleistocene limestone, both of which were deposited under marine conditions (Quebral, 1994).

Bunawan Limestone

Lithology	Coralline limestone and coral breccia
Stratigraphic relations	Unconformable over the Mandog
	Sandstone
Distribution	Bunawan, Matina in Davao City
Age	Late Pleistocene (?)
Thickness	70-80 m
Named by	MGB (this volume)

Casasola (1956) describes the presence of raised Quaternary coral reefs in Bunawan, Matina in Davao City, designated here as Bunawan Limestone. These are highly porous coralline limestone and coral breccia, which probably are unconformable on the Pleistocene Mandog Sandstone. The thickness of the limestone attains a maximum of 80 m from barrios Budbod to Bunawan (Casasola, 1956).

Foraminifers in the limestone from Bunawan indicate a probable Late Pleistocene age for the formation. Similar limestone exposures were recognized along the Mawab (near Tagum) and Makgum (along Buan River, Asuncion) anticlines (Quebral, 1994).

Tigatto Terrace Gravel

Lithology	Sand, gravel, lahar and volcanic ash
Stratigraphic relations	Unconformable over older formations
Distribution	Davao City, Nabunturan
Age	Holocene (?)
Named by	Casasola (1956)

The Tigatto Terrace Gravel was named by Banogon (1975) for the poorly stratified gravel and sand deposits occurring at elevations 30 - 150 m at Tigatto, Davao City. The gravel consists mostly of pebbles and cobbles derived from Mts. Apo, Talomo and Boribing. The Tigatto may be correlated with the Pleistocene Apo and Talomo volcanics and pyroclastics of Casasola (1956).

Unaltered and undeformed lahar deposits in Nabunturan could be equivalent to the Tigatto. These consist of well-rounded gravel and boulders of dacite in a sandy matrix. These deposits are channeled and show graded- and cross-bedding. Each flow is often thick but usually topped by fine ash layers. These dacitic rocks are believed to have originated from the Lake Leonard caldera where dacitic tuffs have been dated at 1,800 years (PNOC-EDC unpublished report, 1983).

Davao Gulf and Samal Island

Tagbobo Conglomerate

Conglomerates
Unconformably overlain by Pleistocene
coral terraces
Tagbobo, Davao
Tagbobo, Davao and Samal Island
probably Pliocene
Quebral (1994)

The eastern portion of Samal Island is characterized by a discontinuous series of north-south trending ridges representing anticlines unconformably overlain by Quaternary coral terraces. The folded rocks consist of poorly consolidated coarse conglomerates rich in limestone boulders. Casasola (1956) includes this as part of the Tigatto Terrace Gravel although Quebral (1994) suggests that this might not be the case. The term Tagbobo Conglomerate is therefore adopted in this volume after the type locality, Tagbobo, on the eastern coast of Davao. The conglomerates were probably deposited in a marine environment during Pliocene time.

Samal Limestone

Lithology	Coralline limestone and coral breccia
Stratigraphic relations	Unconformable over the Tagbobo
	Conglomerate
Distribution	Samal Island, Talikud Island
Age	Pleistocene
Thickness	80 m
Previous name	Samal Reef Limestone (Banogon, 1975)
Renamed by	MGB (this volume)

Uplifted Pleistocene coral terraces that forms the capping of Samal Island and the neighboring Talikud Island was designated as Samal Reef Limestone by Banogon (1975). The formation consists mainly of highly porous coralline limestone and coral breccia. The Limestone rests unconformably over the Tagbobo Conglomerate. The maximum thickness of the Samal reaches 80 m (Casasola, 1956; BED, 1986b). The Samal is equivalent to the Bunawan Limestone.

MINDANAO PACIFIC CORDILLERA (SG 24)

The Mindanao Pacific Cordillera is principally a magmatic arc terrane with an ophiolitic segment in the north, subdivided into three sections, namely, (1) Northern Pacific Cordillera; (2) Central Pacific Cordillera; and (3) Southern Pacific Cordillera.

MINDANAO PACIFIC CORDILLERA			ILLERA			
PERIOD	EPOCH	STAGE	Ma	NORTHERN PACIFIC CORDILLERA	CENTRAL PACIFIC CORDILLERA	SOUTHERN PACIFIC CORDILLERA
	HOLOCENE					Amacan Volcanic Complex
NEOGENE	PLEISTOCENE	4 3 2 1	0.0117 0.126 0.78 1.81	Maniayao Andesite Hinaligan Limestone Placer Conglomerate Formation Bad-as Dacite	Hinatuan Limestone	Manay Formation
	PLIOCENE	2	2.59	Ipil Andesite		
		3	7.25	Tugunan Formation		Antuinnee Linestees
	MIOCENE	2	13.65	Mabubay Engention	Rosario Limestone	Agrougation criticatione
			20.43	Bacuag Formation	Bislig Formation	Cateel Quartz Dionte
	OLIGOCENE	2	28.4	Asiga Diorite	Diwata Diorite	
PALEOGENE		4	33.9	Mandalog Formation	Anoling Andesite	
	EOCENE	3 2 1	40.4 48.6		Buggao Limestone	Tagabakid Formation
	PALEOCENE	3 2 1	55.8 58.7 61.7			Barcelona Formation
40 ³⁵	К2		00.0	Dinagat Ophiolite Complex		
Contra Co	K1		99.6			
JURASSIC			145.5			

Table 2.28 Stratigraphic column of Mindanao Pacific Cordillera

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Northern Pacific Cordillera and Masapelid Island

Dinagat Ophiolite

Lithology	Amphibolite, peridotite, pyroxenite, dunite,
	gabbro, serpentinite
Stratigraphic relations	Basement rocks in thrust contact with
	amphibolites and other metamorphic rocks
Type Locality	Dinagat Island
Distribution	Pacific Cordillera, Malimono Ridge
Age	Cretaceous (?)
Previous name	Ultramafic rocks (Santos-Yñigo, 1944)
Renamed by	MGB (this volume)

Santos-Yñigo (1944) and Santos and others (1962) described mafic to ultramafic rocks outcropping in the northern Pacific Cordillera and Malimono Ridge. The rocks include peridotite, pyroxenite, dunite, serpentinite and gabbro. These rocks may be correlated with similar rocks in the Dinagat group of Islands, which are designated as Dinagat Ophiolite (see 2.3.1.1.2). These are often found as basement rocks in thrust contact with amphibolites and other metamorphic rocks.

The **Humandum Serpentinite** of UNDP (1984) is probably part of the Ophiolite Complex. The **Pangulanganan Basalt** of UNDP (1984) could also be part of the Dinagat Ophiolite that has been dismembered. It consists of pillow basalts and minor basalt breccia found along Cabadbaran River and its tributary, Pagulanganan Creek at Agusan del Norte.

Sohoton Greenschist

Lithology	Greenschist, phyllite and low-grade metamorphic sedimentary and volcanic
Stratigraphic relations	rocks with marble interbeds Unconformable over basement rocks consisting of Dinagat Ophiolite and Nueva Estrella Schist; unconformably overlain by
Distribution	the Madanlog Formation western coast of Surigao peninsula; Northern Pacific Cordillera
Age	Cretaceous
Previous name	Sohoton Formation (Santos-Yñigo, 1944)
Renamed by	BMG (1987)

The Sohoton Greenschist as mapped by Bureau of Mines and Geosciences (BMG, Jagupit and Alegria quadrangles, 1987), consists of color-banded phyllites and minor marble overlying massive greenstone, greenschists and metaconglomerate. The name was derived from the Sohoton Formation of Santos-Yñigo (1944) in reference to а metasedimentary and metavolcanic sequence near Sitio Sohoton, Malimono along the western coast of the Surigao Peninsula. The metasedimentary rocks include marble, conglomerate, sandstone and shale subjected to low-grade metamorphism. At the type locality, the conglomerate is highly indurated and foliated with poorly sorted angular to sub-rounded pebbles and cobbles. The interbedded sandstone and shale are dark gray and highly indurated. The marble occurs as irregular lenses within the clastic sequence. Schistose dark gray marly limestone near Anao-aon is also considered part of Sohoton. The Concepcion Greenschist of UNDP (1984) is probably equivalent to the Sohoton Formation and the greenschists discussed above. A late Cretaceous age is assigned based on its fossil content (Quebral, 1994).

Madanlog Formation

Lithology

Conglomerate, sandstone and shale with limestone lenses

Stratigraphic relations	Unconformable over older rocks,
	unconformably overlain by the Bacuag
	Formation
Distribution	Mt. Madanlog, Rizal, Surigao City
Age	Late Eocene
Thickness	~ 500 m
Named by	Santos-Yñigo (1944)

The Madanlog Formation was used by Santos-Yñigo (1944) to refer to rocks at Mt. Madanlog, its type locality, and scattered patches in Surigao del Norte. The formation consists of interbedded conglomerate, sandstone, shale and limestone. At Mt. Madanlog, the conglomerate is dark gray and poorly sorted with well-cemented sub-angular to sub-rounded clasts of serpentinite. Quebral (1994) describes a dark gray to greenish gray serpentine sandstone with blocks of ultramafic rocks and algal limestone at Rizal, west of Surigao City, and along Cabadbaran River.

The Madanlog Formation is unconformable over the metamorphic and ophiolitic basement. It is, in turn, unconformably overlain by the Bacuag Formation. It has been consistently dated as late Eocene based on its foraminiferal content by many workers (Santos-Yñigo, 1944; Santos and others, 1962; UNDP, 1984; Quebral, 1994). The Madanlog Formation corresponds to the **Nabanog Formation** of UNDP (1984). It was deposited on a shallow marine environment and estimated to be 500 m thick.

Bacuag Formation

Lithology	Conglomerate, sandstone, mudstone, limestone with intercalated basalt flows and pyroclastic rocks
Stratigraphic relations	Unconformable over the Madanlog
	Formation; conformably overlain by the
	Mabuhay Formation and Timamana
	Limestone
Distribution	Siana Mine, Tubod, Amislog, Bacuag,
	Surigao del Norte;
Age	Late Oligocene – Early Miocene
Thickness	~ 1,500 m
Previous name	Bacuag Series (Santos-Yñigo, 1944)
Renamed by	Santos and others (1962) as Bacuag
-	Formation

The term Bacuag was first applied by Santos-Yñigo (1944) for the rocks at Bacuag. It was named Bacuag Series but Santos and others (1962) designated it as a formation. It is also exposed at the former Siana Mine, Tubod, Amuslog and the Placer-Bacuag road. The unit consists of clastic rocks and basalt flows, sometimes with pillow structures, and agglomerates. The clastic rocks consist of conglomerate, sandstone and shale with limestone lenses. The conglomerate is poorly bedded, dark gray, medium- to coarse-grained with poorly sorted angular pebbles, cobbles and boulders of basaltic composition. The sandstone is dark gray, generally well-bedded and well-cemented. The shale is dark to bluish gray, also well-

bedded with coal stringers. The limestone lenses are buff to light gray, commonly argillaceous.

Northeast of Barrio Bacuag, UNDP (1987) noted basalt flows overlain by beds of calcisilities and calcirudites that attain a thickness of 100 m. Above these beds, conglomerate with clasts of basalt that attain boulder sizes and coralline limestone with abundant shells pass into wackes and volcanic conglomerate. In the northeast, the formation is represented mostly by pillow basalts with thin interbeds of mudstones and limestones. Other limestone exposures have been observed at Danau and scattered localities.

The exposure at Siana Mine, called **Siana Beds** by Santos-Yñigo (1944), may be considered as a reference section representing the lower portion of the Bacuag Formation. The lithology at the Siana pit consists of basalt flows, basaltic pyroclastics, feldspathic sandstones, laminated sandstones, green shales and white nodular limestone. Also present are light gray to black, massive limestone with cherty lenses and greenish gray or black shale. The formation generally dips gently except in the north where dips are much steeper. The **Tigbauan Formation** of UNDP (1984) also appears to be equivalent to the Bacuag. Likewise, the **Nagtal-o Formation** of UNDP (1984) could be partly equivalent to the Bacuag Formation.

The fossil content of the limestone points to a late Oligocene to Early Miocene age (Quebral, 1994). According to UNDP (1987), most of the limestone samples studied for paleontological dating yielded Early Miocene fauna and two samples were found to contain late Oligocene to Early Miocene fossils. Radiometric K-Ar dating of basalt from the middle part of the formation gave an age of 23 ± 1.1 Ma or earliest Miocene (Aquitanian). Here, the formation is considered Late Oligocene to Early Miocene.

The stratigraphic thickness near Bacuag is around 1,100 m, although this does not include the base, and the maximum thickness could be in the vicinity of 1,500 m.

Asiga Diorite

Lithology	Hornblende diorite and biotite hornblende
	quartz diorite
Stratigraphic relations	Intrudes the Bacuag Formation
Distribution	Asiga River, Agusan del Norte;
Age	Early Miocene (?)
Named by	UNDP (1984)

UNDP (1984) provides the best description of the plutonic rocks within the Cordillera. The main diorite body lies in the middle course of the Asiga River. The **Maraat Diorite** of UNDP (1984) is a smaller intrusive body northeast of the Asiga Diorite. The Asiga and Maraat diorites, which include hornblende diorite, biotite hornblende quartz diorite and biotite quartz diorite, intrude the Bacuag Formation. It is, in turn, intruded by microdiorite and andesite porphyry dikes. The **Cabadbaran Diorite** of UNDP (1984), which intrudes ophiolitic rocks, is of the same age as the Asiga Diorite. UNDP (1984) likewise describes a small intrusive body of monzonite and syenite, which is referred to as the **Mt. Mabaho Monzonite**. The rock is readily recognized in the field by its potash feldspar content. The monzonite is intrusive into the Humandum Serpentinite, Concepcion Greenschist and probably part of the Tigbauan Formation of UNDP (1984), which is equivalent to the Bacuag Formation.

UNDP (1984) assigns a Late Oligocene age for the diorites. Considering that the diorites intrude the Bacuag, a probable Early Miocene age is postulated for the diorite intrusions.

Mabuhay Formation

Lithology	Sandstone and mudstone with minor
	limestone and conglomerate
Stratigraphic relations	Conformable over Bacuag Formation;
	conformably overlain by the Timamana
	Formation
Distribution	Libas River southwest of Motherlode Mine;
	Taganaan
Age	Early – Middle Miocene
Thickness	700 m
Named by	Santos-Yñigo (1944)

Conformably overlying the Bacuag Formation is the Early-Middle Miocene sedimentary sequence designated by Santos-Yñigo (1944) as Mabuhay Formation. As described by Santos-Yñigo (1944), the formation consists of interbedded shale, sandstone, occasional lenses of conglomerate, thin beds of limestone, coal and manganese. It covers largely the northeastern part of Surigao del Norte. The formation is bounded on the west by the Surigao River, on the south by Taganaan River. The shale is gray to brown, thin bedded, finely laminated, easily breaks into slabs and becomes limy upsection. The sandstone is greenish gray, medium- to fine-grained and indurated.

This formation is probably equivalent to the **Motherlode Turbidite Formation** of UNDP (1987). The base of the formation as described by UNDP (1987) is characterized by mudstones with thin siltstones and wackes on a thin limestone bed, which lies on a 3 – 10 m thick calcisilitie boulder conglomerate. This is underlain by purple marls, calcisilities and limestones assigned to the Bacuag Formation. Turbiditic sequences in exposures along Libas River are also described by UNDP (1987). A unit designated as **Taganaan Marl**, which attains a thickness of 200 m, is regarded by UNDP (1987) as a member of this formation. This member yielded fossils of Early to Middle Miocene age. The total thickness of the formation is estimated to be 700 m (UNDP, 1987).

Alipao Andesite

Lithology	Hornblende andesite
Stratigraphic relations	Intrudes Bacuag Formation
Distribution	Alipao and Siana, Surigao del Norte

Age	Middle Miocene
Named by	UNDP (1987)

The Alipao Andesite was named by UNDP (1987) for the hornblende andesite plugs in the vicinities of Alipao and Siana Mine pit, Surigao del Norte. The Alipao is typically porphyritic, with plagioclase phenocrysts reaching up to 2 cm long and small hornblende needles in an aphanitic to finely crystalline groundmass (UNDP, 1987). These andesites also host epithermal mineralization in the Alipao area.

Radiometric whole rock dating of a sample of andesite porphyry yielded an age of 13.0 ± 0.6 Ma or early Middle Miocene.

Timamana Limestone

Massive coralline limestone
Unconformable over Bacuag and Mabuhay
Formations
Timamana, Tubod, Surigao del Norte
Middle Miocene
250 m
Santos-Yñigo (1944)

The Timamana Limestone was named by Santos-Yñigo (1944) for the rocks at its type locality at Timamana, Tubod, Surigao del Norte. It extends as a continuous belt from Timamana to the Surigao-Agusan border and may also extend to Surigao del Sur, virtually capping the entire northern Pacific Cordillera. According to UNDP (1987), the main body of limestone situated east of Timamana lies unconformably over the Bacuag Formation.

The Timamana Limestone corresponds to the **Kitcharao Limestone** of Teves and others (1951), and to the Rosario Formation and Agtuuganon Limestone of the central and southern Pacific Cordillera, respectively. Santos and others (1962) consider the limestone to be Middle to Late Miocene in age. Based on the presence of *Globorotalia peripheronda* Blow and Banner in the shaly horizons, BMG (1981) pegged the age of the formation at Middle Miocene, which is adopted in this volume. UNDP (1987) reports conflicting age dates, from Early Miocene to Pliocene. Quebral (1994), on the other hand, reports late Oligocene to Early Miocene dating for the limestone based on its foraminiferal and nannofossil contents. The thickness as estimated by UNDP (1987) is about 250 m.

Tugunan Formation

Lithology	Conglomerate, sandstone and mudston
Stratigraphic relations	Unconformable over Bacuag and Mabuhay
	Formations and Timamana Limestone
Distribution	Sitio Tugunan, hills around Lake Mainit,
	Surigao del Norte; Asiga River,
	Cabadbaran River, Calamba Creek, Camp
	Arega, Anticala and Andana River
Age	Late Miocene to Late Pliocene

Thickness	300 m
Named by	Santos-Yñigo (1944)

Santos-Yñigo (1944) named the rocks in Sitio Tugunan and at Tugunan River, Surigao del Norte as Tugunan Formation. These also occur as patches and cover the low rolling hills north of Lake Mainit. The formation is composed of folded conglomerate, sandstones and mudstones. The conglomerate with pebbles and cobbles of serpentinite and volcanic rocks are well compacted. The well-bedded and grayish green sandstones are interbedded with mudstones. The mudstones, which make up most of the formation, are well-bedded and light greenish gray. This sequence is unconformable over the Timamana Limestone.

Quebral (1994) also describes a turbiditic sequence belonging to this formation. It is found along the Asiga River, Cabadbaran River, Calamba Creek, Camp Arega, Anticala and Andana River. This clastic sequence consists of rhythmic interbeds of sandstone-siltstone-shale with minor beds of conglomerate and limestone lenses. Bedding planes are well defined and graded bedding is observed in the sandstone. The conglomerates are polymictic with sandy horizons. Poorly sorted and poorly rounded clasts include late Oligocene to early Middle Miocene limestone, fine clastic rocks, volcanic and ophiolitic rocks. The formation appears to have been deposited under lacustrine conditions.

A Late Miocene to Pliocene age was assigned by Santos-Yñigo (1944) to the Tugunan, but Santos and others (1962) dated it Pliocene. Quebral (1994) dated this sequence through nannofossils as Late Miocene (NN11) to late Pliocene (NN15-16). The Tugunan is estimated to be about 300 m thick.

The **Mabuhay Clastics** of UNDP (1987) at Mabuhay, Placer and Sison, Surigao del Norte, probably corresponds to the Tugunan Formation. UNDP (1987) recognized five lithologic facies, namely: Kambilibid boulder beds southeast of the Motherlode Mine; West Siana calcareous rocks in the west wall of Siana pit that lie on the basalts of the Bacuag Formation; Briggs pyroclastics at the Briggs and Reno pits of Placer Mine, Mapaso and Motherlode mines and western part of Siana Mine; Placer conglomerates in the road section south of Placer; and andesite flows, which are too small to be mapped. The Placer conglomerate facies is regarded by UNDP (1987) as part of the Placer Conglomerate of Santos and others (1962) that apparently postdates the mineralization.

The Tugunan also corresponds to the **Jagupit Formation** of UNDP (1984) at Agusan del Norte and the **Nasipit Formation** of Teves and others (1951) at Agusan del Sur.

Ipil Andesite

Lithology	Andesite
Stratigraphic relations	Unconformable over pre-Pliocene deposits
Distribution	Ipil, Surigao del Norte, Malimono Range
Age	Early - Late Pliocene
Named by	Santos-Yñigo (1944)

The Andesite Group of Santos and others (1962) in Surigao del Norte includes the Ipil Andesite, the Mabuhay Andesite and its acidic phase – the Bad-as Dacite – and the Maniayao Andesite. This group is equivalent to the Andesite Series of Santos-Yñigo (1944) in the Surigao Gold District. In this volume, the various volcanic units are discussed separately.

The Ipil Andesite (Santos-Yñigo, 1944) is named after its type locality in the town of Ipil. It underlies portions of the main northern Pacific Cordillera and Malimono Ridge. The Ipil Andesite is typically light-colored or greenish gray, mottled green, brown and black. It becomes whitish gray when argillized. It is porphyritic and consists of plagioclase, hornblende and biotite with minor augite. A sample from Malimono Ridge provided a radiometric age of 2.31 \pm 0.24 Ma corresponding to a Late Pliocene age (Quebral, 1994).

The Mabuhay Andesite, often associated with gold mineralization, could be a mineralized and hydrothermally altered equivalent of the lpil Andesite. It is found in the northern Pacific Cordillera along the eastern coast of Surigao Peninsula. Varieties are fine-grained andesite, andesite porphyry and agglomeratic andesite. Hydrothermally altered andesite in the Mabuhay, Mapaso and Siana areas constitutes the greater part of the Mabuhay Andesite. It varies from white to yellowish brown or gray. Argillized Mabuhay Andesite is usually white. The fine-grained andesite constitutes the unaltered part of the unit. It is generally gray and porphyritic. Phenocrysts are plagioclase and rare needle-shaped hornblende. It is distinguished from the Ipil Andesite by the absence of biotite. The andesitic fragmental rock is distributed in Masapelid Island, Mapaso, East Mindanao Mine, Mindanao Motherlode, eastern Surigao and Nabago areas and Sitio Banban, Taganaan. This unit is known under various names: Mabuhay Breccia in the Mindanao Mother Lode; Blue Agglomerate or Tinupa Agglomerate in East Mindanao; Breccia-conglomerate of Kemmer (1953); and Andesite Breccia of Santos-Yñigo (1944). The rock is dark gray and composed mainly of angular andesite fragments embedded in an andesite matrix. The Mabuhay Andesite is probably equivalent to the Alegria Andesite Porphyry of UNDP (1984). A sample from the Mabuhay mines was radiometrically dated 4.54 ± 0.57 Ma equivalent to Early Pliocene (Zanclean) age.

The **Naga Andesite, Hill 169** and **Hill 259** hornblende andesites are Pliocene andesitic units mapped by UNDP (1987), which could also be equivalent to the Ipil Andesite. Radiometric K-Ar dating of samples of Naga Andesite and Hill 259 Hornblende Andesite Porphyry indicated ages of 2.3 \pm 1.2 Ma and 3.18 \pm 0.27 Ma (UNDP, 1987).

Bad-as Dacite

Lithology	Dacite
Stratigraphic relations	Intrudes older deposits
Distribution	Barangay Bad-as and Placer area,
	Surigao del Norte; Masapelid Island
Age	Late Pliocene
Named by	Santos and others (1962)

The Bad-as Dacite (Santos and others, 1962) occurs in limited outcrops near Barangays Bad-as and Placer area. It consists of phenocrysts of quartz, biotite and plagioclase in a pale gray groundmass. It differs from the Ipil Andesite in its quartz content and relatively larger plagioclase phenocrysts.

Maniayao Andesite

Lithology	Andesite
Stratigraphic relations	Intrudes or unconformably overlies pre-
	Pleistocene deposits
Distribution	Mt. Maniayao, Surigao del Norte
Age	Pleistocene
Thickness	> 300 m
Named by	Santos and others (1962)
-	

The volcanic edifice at Mt. Maniayao is located along the Philippine Fault north of Lake Mainit between the main Cordillera and the Malimono Ridge. Several magmatic episodes are indicated by the domes and andesitic and dacitic flows and pyroclastic deposits designated as Maniayao Volcanics (Santos-Yñigo, 1944), **Paco Andesite** (UNDP, 1987) and **Paco Volcanics** (Tebar and Pagado, 1989). Radiometric dating obtained from an andesite sample indicate a Pleistocene age based on whole rock dating of 1.08 \pm 0.061 Ma, while the feldspar phenocrysts gave a dating of 1.781 \pm 0.091 Ma (Sajona, 1997).

As described by UNDP (1987), the andesites of Maniayao show subequal amounts of biotite and hornblende together with plagioclase phenocrysts. The andesites are at least a few meters thick and in places attain a total thickness of more than 300 m (UNDP, 1987). Radiometric K-Ar dating of two samples of andesite by UNDP (1987) at Tugunan and Ipil indicated ages of 0.3 ±Ma and 0.9 ±0.2 Ma, respectively.

UNDP (1987) also describes the Paco Andesite as an extinct volcano with a conical peak at 524 masl north of Brgy. Paco in Surigao del Norte. The cone is surrounded by gently dipping andesitic flows and lahars.

Mainit Formation

Lithology	Conglomerate, sandstone with shale
	lenses
Stratigraphic relations	Unconformable over Tugunan Formation
	and Maniayao Andesite
Distribution	northern area around Lake Mainit, Surigao
	del Norte
Age	Pleistocene
Thickness	400 m
Named by	Santos and others (1962)

Santos and others (1962) named the conglomerate, sandstone and lenses of shale that are widespread north of Lake Mainit as the Mainit Formation. The conglomerate is massive and slightly compacted. The sandstone is flat bedded with lenses of light gray shale. The Mainit is unconformable over the Tugunan Formation and Maniayao Andesite. It is about 400 m thick and considered to be Pleistocene in age.

Hinatigan Limestone

Lithology	Limestone, marl, calcareous wacke,
	siltstone
Stratigraphic relations	Not reported
Distribution	Hinatigan, Surigao del Norte
Age	Pleistocene
Named by	MGB (2005)
Previous Name	Hinatigan Marl member (UNDP, 1987)

A small outcrop of marl at Hinatigan was earlier named Hinatigan Marl by UNDP (1987), which was considered a member of the Timamana Limestone. As described by UNDP (1987), the Hinatigan consists of calcareous siltstones and calcareous volcanic wacke that appear to occupy the lower part of a limestone unit. Small corals and bivalves are notable along gently dipping to horizontal bedding planes. Above the marl is massive cream-colored limestone, which was interpreted by UNDP (1987) as part of the Middle Miocene Timamana Limestone. However, a sample of the Hinatigan Marl yielded probable Pliocene to recent fauna. Here, the Hinatigan, together with the overlying massive limestone, is interpreted as part of a separate and later limestone formation that could be coeval with the Pleistocene Siargao Limestone named after the island up north. The **Diwata Limestone** of Teves and others (1951) in Agusan del Norte could be equivalent to this Hinatigan.

Placer Conglomerate

Lithology	Conglomerate with lenses of sandstone
	and mudstone
Distribution	Coastal area around Surigao del Norte
	and neighboring islands
Age	Pleistocene
Thickness	100 m
Named by	Santos-Yñigo (1944)

Santos-Yñigo (1944) named the conglomerate with lenses of shale and sandstone in Placer, Surigao del Norte as Placer Conglomerate. Clasts of the conglomerate range from angular to sub-angular and granule to boulder sizes. Sorting is poor and bedding becomes apparent only where there are lenses of sandstone and shale. The formation is of Pleistocene age and is 100 m thick.

Central Pacific Cordillera

Anoling Andesite

Lithology	Andesite and pyroclastic rocks
Stratigraphic relations	Constitutes the basement rocks
Distribution	San Francisco, Anoling, Rosario-Banahaw
--------------	---
	area, Agusan del Sur
Age	Eocene (?)
Named by	MGB (this volume)

Portions of San Francisco, Anoling and Rosario-Banahaw areas are underlain by andesitic volcanic flows and pyroclastic basement believed to be of Eocene age. These rocks are often hydrothermally altered and mineralized with gold. This unit is intruded by diorite and is capped by massive limestone, probably corresponding to the Middle Miocene Rosario Formation.

Baggao Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over igneous basement
Distribution	Agusan del Sur
Age	Eocene
Named by	San Jose Oil Co. (in BM Petroleum
-	Division, 1966)

The Baggao Limestone was named by geologists of San Jose Oil Co. (in BM Petroleum Division, 1966) for exposures in Baggao, Agusan del Sur. It is unconformable over the igneous basement of the Central Pacific Cordillera. The Baggao consists largely of massive irregularly bedded limestone with occasional interbeds of shale. The formation is the equivalent in the Pacific Cordillera of the Umayam Limestone in the Mindanao Central Cordillera. It is dated Eocene with an undetermined thickness. These limestones may be regarded as remnants of isolated reefs that grew on submarine basement platforms on both sides of the respective Cordilleras that flank the Agusan-Davao Basin (BED, 1986b). The Baggao may also be correlated with the limestone constituent of the Eocene Tagabakid Formation of Southern Pacific Cordillera.

Diwata Diorite

Lithology	Diorite
Stratigraphic relations	Intrudes Anoling Andesite
Distribution	Mt. Diwata, San Francisco, Agusan del
	Sur
Age	Early Oligocene
Named by	MGB (this volume)

This intrusive body is here designated as Diwata Diorite based on the description by Quebral (1994) of coarse-grained diorite underlying Mount Diwata in San Francisco, Agusan del Sur. This diorite was radiometrically dated 31.79 ± 0.78 Ma or Early Oligocene (Sajona and others, 1997). The diorite also outcrops in the vicinity of Banahaw mine in the Rosario massif.

Bislig Formation

Lithology	Conglomerate, sandstone, mudstone and
	limestone

Stratigraphic relations	Unconformable over volcanic basement
	and Baggao Limestone
Distribution	Bislig Bay area, Surigao del Sur
Age	Late Oligocene – Early Miocene
Thickness	680 m (maximum)
Named by	MMAJ-JICA (1973)
Synonymy	Mekoupe, Mangagoy, Pamaypayan,
	Saugan Formations

The Bislig Formation was named by MMAJ-JICA (1973) for the sequence of conglomerate, sandstone, shale, limestone, pyroclastic rocks and basaltic lava flows at the upper Bislig River, Surigao del Sur. It rests unconformably over the Eocene Baggao Limestone and andesites. As described by MMAJ-JICA (1973), the conglomerate is thin-bedded to massive with sub-angular to rounded pebbles of volcanic rocks. The poorly sorted sandstone is thick-bedded to massive and the limestone is dark gray and coralline. The Bislig is exposed widely along the tributaries of Bislig River and the headwaters of Panusugon and Cateel rivers. Fossils indicate a Late Oligocene to Early Miocene age.

BED (1986b), proposed to redefine Bislig as a formation consisting of three facies that could be related to a westward transgressing shoreline. The conglomerate and sandstone facies with associated occurrence of petrified wood represents the terrestrial environment of deposition, whereas the coal-bearing carbonaceous mudstones represent an intertidal swamp environment and the limestone facies corresponds to marine lagoonal environment (BED, 1986b).

Viewed in this context, the Mekoupe Formation of Alberding (1939) and Mangagoy and Pamaypayan formations of Vergara and Spencer (1957).are considered equivalent units characterized by lower clastic sequence capped by limestone. Victoriano and Gutierrez (1980) recognized the two distinct lithologies in these formations and proposed to distinguish the clastic unit as Anahawan Formation and the limestone as Mangagoy Formation. The clastic sequence in the above units is dated Late Oligocene, while the limestone is dated Early Miocene. The maximum thickness of the formation around Bislig Bay is 680 m. The Bislig Formation predates the onset of formation of the Agusan-Davao Basin.

The Mangagoy Formation was originally named for the sedimentary sequence at Mangagoy, Bislig, Surigao del Sur. In the Rosario-Banahaw mine area, the Mangagoy consists of a sequence of dark gray conglomerate, dark gray, thin-bedded sandstone and shale (Vergara and Spencer, 1957). These authors describe a thick and massive coralline limestone comprising the top of the formation. The Mangagoy, which was dated Late Oligocene, probably corresponds to the Mabuhay Formation of the northern Pacific Cordillera.

The term **Mekoupe Formation** was first applied by Alberding (1939) to a sequence exposed along Mekoupe Creek in Sitio Mekoupe in Lingig. The Mekoupe Formation consists of sandstone, mudstone, shale, coal, conglomerate and limestone. Sandstones are the dominant lithology. These are dark gray, very poorly sorted and thick bedded to massive with occasional conglomerate lenses. Petrified logs are often embedded within the clastic rocks as exposed along Mekoupe Creek. The mudstones are black to dark gray and contain large amounts of carbonized plant remains and mollusk fragments and thin coal lenses. Most shales grade to sandstones and are gray to light gray in color. Beds of coralline limestone are dark gray, hard, massive and directly overlie the coal beds. These are usually 1 to 1.5 m thick but may reach as much as 15 m in thickness. Vergara and Spencer (1957) report a thickness of 510 m for the Mekoupe Formation.

The **Pamaypayan Formation** is described by Vergara and Spencer (1957) as a 500 meter-thick sequence of interbedded conglomerate, sandstone, shale, coal and coralline limestone outcropping in Pamaypayan. Petrified logs are reported to be common. As described, there seems to be no major difference between the Mekoupe and Pamaypayan formations and even Vergara and Spencer (1957) admit little difference between the sandstone of the Mekoupe and Pamaypayan formations.

The **Saugan Formation** of San Jose Oil Company (in BM Petroleum Division, 1966), named for exposures along Saugan Creek east of Bunawan in southeastern Agusan del Sur, may also be equivalent to the Bislig Formation. It consists of a sequence of alternating gray shale and clayey sandstones with interbeds of gray, thin-bedded limestone and coal. It is dated Early Miocene based on foraminifera and estimated to be 300 m thick at the type locality.

Rosario Limestone

Lithology	Massive coralline limestone
Stratigraphic relations	Conformable over the Bislig Formation
Distribution	Rosario-Banahaw mine area, Lianga Bay
	area
Age	early Middle Miocene
Named by	Quebral (1994)

This formation was named by Quebral (1994) for the limestone exposure in the Rosario-Banahaw mine area. The Rosario lies conformably over the Bislig Formation at Mangagoy. The limestone represents the thick and massive limestone of early Middle Miocene age capping a large portion of the Pacific Cordillera, including the Rosario massif. This limestone can also be observed in the Lianga Bay area. Quebral (1994) shows that what has been mapped earlier as an extensive Pleistocene limestone is actually early Middle Miocene limestone capped at certain locations by uplifted Pleistocene limestone.

This limestone may be correlated with the Timamana Limestone of the northern Pacific Cordillera and the Agtuuganon Formation of the southern Pacific Cordillera.

Hinatuan Limestone

Lithology	Limestone
Stratigraphic relations	Overlies Rosario Limestone

Distribution	Hinatuan, Surigao del Sur
Age	Pleistocene
Named by	Quebral (1994)

This formation was named by Quebral (1994) for the Pleistocene limestones in the Hinatuan, Surigao del Sur and Tagbina areas south of Lianga Bay. In Hinatuan, a micritic and highly fossiliferous flat-lying limestone is found in a quarry along the road leading to Hinatuan. This limestone was paleontologically dated Pleistocene. Along the same road were found unconsolidated beds of entire mollusk shells. The formation directly sits above the Rosario Limestone, which seems to be more extensive. In Tagbina, a series of en echelon ridges, probably representing the summits of tilted blocks, is underlain by unconsolidated coral breccia.

Southern Pacific Cordillera

The basement of the Pacific Cordillera is manifested by occasional windows of metamorphic and ultramafic rocks, including amphibolite schists in New Bataan and serpentinite along the western side of the Maragusan Valley. These could be correlated with the Pujada Ophiolite. Malicdem and Peña (1966) also described serpentinites and serpentinized ultramafic rocks and amphibolite schists along fault zones in the Masara area in Davao. Immediately north of the Calapagan-Marayag Valley are slates. In the Taragona area, metasedimentary rocks consist of well-indurated sandstones with bioturbation and slump features. Cretaceous limestones were recognized in Hijo River and Mati. Samples of gray colored limestones from the Hijo River and from Mati contain Late Cretaceous (Senonian to Campanian) foraminiferal assemblage (Quebral, 1994). No formal names have been proposed for these rock units.

Barcelona Formation

Basalt flows, agglomerate, breccia, clastic
rocks
Not reported
Eastern coast from Bislig to Lingig,
Surigao del Sur
Cretaceous-Paleocene (?)
Barcelona Basalt (Vergara and Spencer,
1957)
MGB (this volume)

The term Barcelona Basalt was used by Vergara and Spencer (1957) while MMAJ-JICA (1974) used the term Barcelona Group for the volcanic and sedimentary suite in the Bislig-Lingig coastal area. In this volume, the term Barcelona Formation is introduced. Vergara and Spencer (1957) described the unit exposed along the eastern coast from Bislig to Lingig as consisting of basalt flows with intercalated agglomerates, breccias and highly indurated clastic sedimentary rocks. The presence of columnar and pillow structures were noted. The age of this formation is poorly constrained and may range from Cretaceous to Paleogene. It might be equivalent to the Bacuag Formation in the north.

Tagabakid Formation

Lithology	Sandstone, mudstone and reefal limestone
Stratigraphic relations	Unconformable over metamorphic rocks
Distribution	Mati, Tagabakid, Hitangan and Taragona
	areas, Davao Oriental
Age	Eocene
Named by	MGB (this volume)

The term Tagabakid Formation is introduced in this volume for the exposures at the headwaters of Baguan River and along the Mati-Taragona Road near Tagabakid, which were described by Quebral (1994). These are unconformable over metamorphic basement and consist of a lower flysch member and upper limestone member. The lower clastic member starts with rhythmic intercalations of thin beds of fine sandstone and mudstones. It contains more mudstones and marls towards the top until it passes into the upper member represented by massive reefal limestone.

The interbedded sandstones and mudstones were dated Early (NP12-13) to Middle (NP17) Eocene based on nannofossils. This age is consistent with an upper Middle Eocene to Late Eocene (Priabonian) age for the marls and massive limestone respectively, based on foraminifera (Quebral, 1994).

Eocene limestones have also been dated in Bislig and Hijo River. At the Hijo Mine along Hijo River in Davao del Norte, the recrystallized limestone, which hosts gold mineralization, has been paleontologically dated as Eocene (Quebral, 1994).

Cateel Quartz Diorite

Lithology	Quartz diorite
Stratigraphic relations	Intrudes Barcelona Formation
Distribution	Upper reaches of Caraga and Cateel
	rivers, Masara mine area; Maragusan
	area, North Davao
Age	Early - Middle Miocene
Named by	MGB (this volume)

In the southern Pacific Cordillera, the upper reaches of the Caraga and Cateel Rivers cut across a batholith of coarse-grained quartz diorite, which intrudes the Barcelona Formation. The intrusive rock consists mainly of plagioclase, hornblende, biotite and quartz and is generally leucocratic, medium grained and hypidiomorphic granular. Other phases are melanocratic, fine grained and porphyritic.

Quartz diorite bodies outcrop in the Masara mine area in Mabini, Davao del Norte where they are associated with copper and iron deposits (Malicdem and Peña, 1966). The rocks are fine- to medium- grained, porphyritic and consist essentially of andesine, hornblende and quartz. In the Maragusan area, the quartz diorite is notably foliated. In the North Davao area, drill holes intercepted 18 m of diorite. Volcanism has been dated radiometrically to extend to Miocene although diorite actually intruding the Late Oligocene to lower Middle Miocene limestone in the field has not yet been documented. Skarn deposits have been reported although it is not certain whether the protolith is the Agtuuganon Limestone or older Eocene or Late Cretaceous limestones.

Agtuuganon Limestone

Lithology	Coralline limestone
Stratigraphic relations	Unconformably overlain by Taragona
	Conglomerate
Distribution	Mt. Agtuuganon; Cateel River, Davao del
	Norte; Monkayo, Compostela Valley
Age	Early Miocene – Middle Miocene
Thickness	~ 800 m
Previous name	Agtuuganon Formation (MMAJ-JICA,
	1973)
Renamed by	MGB (this volume)

The term Agtuuganon Formation was used by MMAJ-JICA (1973) to refer to an 800 m thick coralline limestone occupying Mt. Agtuuganon in Davao del Norte (Compostela Valley). It consists of a lower bedded portion and an upper massive limestone member.

This massive limestone, which occupies the 1,660 meter high Mt. Agtuuganon, had been previously dated as Pleistocene by MMAJ-JICA (1973). Based on later foraminiferal dating (Quebral, 2004), the age of the Agtuuganon is here amended to early Middle Miocene (Langhian) whereas marls and calcareous shales associated with the limestone indicate Early Miocene (NN3) or Burdigalian to Middle Miocene (NN6) or Serravalian ages based on nannofossils (Quebral, 1994).

The term **Dacongbanwa Formation** was likewise used by the MMAJ-JICA (1973) to refer to the massive Middle Miocene coralline limestone at the north-western slope of Mount Agtuuganon. A review of their descriptions shows that the Dacongbanwa and Agtuuganon Formations refer to the same limestone.

The Agtuuganon Limestone may be correlated with the Timamana Limestone of the northern Pacific Cordillera.

Taragona Conglomerate

Lithology	Conglomerate
Stratigraphic relations	Unconformable over Agtuuganon
	Limestone and overlain unconformably by
	the Manay Formation
Distribution	Mouth of Baguan River in Taragona,
	Davao del Norte
Age	Late Pliocene – Early Pleistocene
Thickness	200 m
Named by	Quebral (1994)

The unit designated here as Taragona Conglomerate was described by Quebral (1994) in reference to massive cliff-forming conglomerates best exposed near the mouth of the Baguan River in Taragona. These conglomerates are highly resistant to erosion and therefore form ridges around Mayo Bay. These coarse conglomerates are massive. They are heterogeneous in size and composition consisting of well- rounded clasts of ultramafic rocks, gabbros, basalt, diabase, andesite porphyry, diorites, limestone and clastic sedimentary rocks (Quebral, 1994). These conglomerates are unconformable on the underlying Agtuuganon Limestone and are in turn unconformably overlain by the Manay Formation. The formation is estimated to be 200 m thick.

Although undated, the Taragona Conglomerate contains clasts bearing Late Pliocene (NN17) nannofossils. It is unconformably overlain by Early (NN19) to Late Pleistocene (NN20-21) sands and limestone (Quebral, 1994).

Manay Formation

Lithology	Lower sandstone and upper limestone
Stratigraphic relations	Unconformable over Taragona
Distribution	Pacific Coast from Manay to south of
Age	Cateel River Early – Late Pleistocene
Named by	Quebral (1994)

The Manay Formation was introduced by Quebral (1994) to refer to a Pleistocene sequence defined by a lower sandstone member and an upper limestone member. Fine sandstones rich in mollusk and echinoderm fragments characterize the lower clastic member. The formation unconformably overlies the Taragona Conglomerate. The uplifted Pleistocene reefal limestone is readily recognized along the Pacific coast, from Manay to south of the Cateel River, due to its young morphological expression. In Manay, for example, which is taken as the type locality, it is expressed as well developed cuestas (Quebral, 1994).

The lower sandstone member has been dated as early (NN19) to late Pleistocene (NN20-21) based on nannofossils while the upper limestone member has been dated as late Pleistocene based on foraminifera (Quebral, 1994). The environment of deposition is evidently shallow marine.

Amacan Volcanic Complex

Lithology	Andesitic to dacitic domes, plugs, flows, pyroclastic rocks
Stratigraphic relations Distribution Age	Intrudes and overlies pre-Pleistocene units Amacan mine area, Lake Leonard, Davao Holocene
Named by	MGB (this volume)

The Amacan Volcanic Complex refers to the Holocene volcanic deposits in the vicinity of Lake Leonard in Davao, where the Amacan Mine of North Davao Mining Corporation is located. Aside from Maniayao Volcano in Surigao, it is the only area in eastern Mindanao affected by Pleistocene-Holocene volcanism. This volcanic activity is manifested as domes, plugs flows and pyroclastic rocks of andesitic to dacitic composition. A thin pyroclastic blanket of breccias, lapilli tuffs and ash tuffs drapes an irregular erosional surface around the lake area. A sample of carbonized wood from the volcanic ash around the Lake Leonard area gave a ¹⁴C date of 1,800 years (PNOC-EDC unpublished internal report, 1983).

DAGUMA RANGE (SG 25)

Salbuyon Schist

Lithology	Piedmontite schist, quartzofeldspathic
	schist, quartz-chlorite-sericite schist,
	amphibolite schist
Stratigraphic relations	Unconformably overlain by the Kiamba
	Formation
Distribution	Salbuyon and Apno creeks, southeastern
	part of the Cotabato Cordillera (Daguma
	Range)
Age	Cretaceous (?)
Previous Name	Salbuyon Formation (Santos and Baptista,
	1963)
Renamed by	MGB (this volume)

The formation was named for exposures of metamorphic rocks at Salbuyon and Apno creeks in the southeastern part of the Daguma Range. These comprise the oldest rocks in southern Cotabato Cordillera, consisting mainly of crystalline schists of various subfacies resulting from the regional metamorphism of older volcanic and sedimentary rocks. The schists are partly traceable along the southeastern core of the Cotabato Cordillera, primarily along Salbuyon and Apno creeks. The formation is composed principally of piedmontite schist, quartzofeldspathic schist and quartz-chlorite-sericite schist. The more predominant piedmontite schist is massive to well-foliated and is closely associated with quartz-chloritesericite schist. Amphibolite schist, consisting mainly of hornblende and minor amounts of plagioclase, are not as common as the other types but are often encountered as float in the Siguil-Kamanga ridge and valleys. The amphibolites have distinct alignment of euhedral amphiboles without any segregation banding.

At the type locality, the formation is unconformably overlain by younger formations such as Kiamba Formation, Siguil Formation and Kamanga Limestone. The formation, as correlated with similar occurrences elsewhere in Mindanao, is believed to be of Cretaceous age.

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	DAGUMA RANGE
	HOLOCENE		0.0447	Matulas Gravel
	PLEISTOCENE	4 Late 3 Middle - 2 1 Early	0.0117 0.126 0.78 1.81	Kamanga Limestone
ENE	PLIOCENE	2 Late 1 Early	2.59 3.60	
MIOCENE		3 Late	7.25	Siguil Formation Allah Formation
	2 Middle-	13.65	Tual Quartz Diorite	
		1 Early	20.43	Nakal Formation Cablacan Formation
	OLIGOCENE	2 Late	23.03 28.4	Maganoy Formation
	-	1 Early	33.9	Daguma Diorite
B B B EOCENE	4 Late 3 Middle – 2	37.2 40.4		
PA		1 Early	40.0 55.8	
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7	Kiamba Formation
CEOUS	Upper	Late	99.6	Salbuyon Schist
CRETA	Lower	Early	55.5	
JURASSIC	Upper	3 Late	145.5	
	Middle	2 Middle	175.6	
	Lower	1 Early	199.6	

Table 2.29 Stratigraphic column for Daguma Range

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

The foliation, which runs parallel to the initial structural grain of the area, trends more or less to the northwest and dips moderately to the southwest. It conforms to the configuration of the present fold system.

Kiamba Formation

Lithology	Volcanic flows and breccias; graywacke, chert
Stratigraphic relations	Unconformable over Salbuyon Schist and overlain unconformably by the Cablacan
Distribution	Formation Kiamba Point: Tual River, Kansan River,
	Kapati Creek at Kiamba; Siloay River; Banga River in South Cotabato

Age	Late Cretaceous – Early Eocene
Previous Name	Siloay Formation (Francisco and Comsti,
	1950)
Renamed by	MGB (this volume)

The Kiamba Formation was previously named **Siloay Formation** for the conglomerate and limestone beds at the headwaters of Siloay River, South Cotabato. This was later redefined by Santos and Baptista (1963) to refer to metavolcanic and metasedimentary rocks along narrow west trending belts on the southwest coast range of the Cotabato Cordillera. A sequence of volcanic and sedimentary rocks around Kiamba, South Cotabato, which corresponds to this formation, was described by Malicdem and Peña (1964). They did not assign a name to the unit, but referred to it only as pre-Miocene Volcanics. To avoid confusion with the original definition of the Siloay (Francisco and Comsti, 1950) as a sedimentary unit, the formation is here renamed Kiamba Formation.

The Kiamba Formation consists principally of massive lava flows and flow breccias with subordinate wackes and conglomeratic sandstones. These rocks crop out along Tual River and Kapati Creek and their tributaries, as well as Kansan River in Kiamba, South Cotabato. The lower part of the formation is apparently dominated by massive andesite intercalated with basalt flows with occasional flow breccias. The upper part of the formation seems to consist dominantly of flow breccias with minor flows and wackes. At the upper Banga River, the upper horizon of the formation is a fragmental flow of basaltic derivation. The flow breccias are characterized by reddish to brown to gray cobble to pebble sized volcanic fragments in a greenish matrix. The volcanic fragments are commonly vesicular, amygdaloidal and porphyritic.

At Bacud Point, at the foot of Buko Mountain just west of Kiamba, an exposure of pillow lavas is conformably overlain by thin beds of wackes intercalated with volcanic breccia. The fragments of the breccias here reach boulder sizes, up to a meter along their lengths.

The sedimentary rocks, which are more dominant towards the top of the formation, consist mainly of wackes and mudstones. Conglomeratic wackes contain sub-angular volcanic clasts. Bedded ferruginous cherts are found in several horizons of the formation. The thickness of individual beds varies from a few centimeters to about half a meter.

The formation rests unconformably over the Salbuyon Schist and intruded by the Daguma Diorite. A sample of andesite flow from an outcrop several kilometers northwest of Kiamba gave a radiometric K-Ar age of 59.18 Ma with a large uncertainty of \pm 10.99 Ma, probably caused by alteration (Sajona and others, 1997). The age of the formation is therefore bracketed within a range of Late Cretaceous – Early Eocene.

Daguma Diorite

Lithology	Hornblende diorite
Stratigraphic relations	Intrudes Salbuyon Schist and Kiamba
	Formation

Distribution	Kiamba, Maasin and Bagumbayan, South Cotabato
Age	Early Oligocene
Named by	MGB (this volume)

A batholithic mass of diorite, more or less elongated in shape, intrudes older formations along portions of the Daguma Range. Exposures of the diorite underlying large areas include those at Mt. Busa, Balakan Mountain and Lumuyon. Smaller diorite stocks crop out near the headwaters of Allah River along Mataam, Basag and Luol-il creeks as well as in Kiamba, South Cotabato. The diorite generally intrudes the Kiamba Formation, and to a lesser extent, the Salbuyon Schist.

The typical diorite is medium- to coarse-grained with euhedral hornblende and plagioclase up to 5 mm across. Few specimens of the diorite exhibit crude banding of plagioclase and ferromagnesian minerals. While the main mass is essentially equigranular, some porphyritic textures with megaphenocrysts of ferromagnesian minerals in a matrix of finer gray feldspars are also present. It is generally mottled, massive and well-jointed.

Radiometric K-Ar dating of two samples at Maasin (near Kiamba), South Cotabato gave ages of 29.28 Ma and 31.95 Ma, equivalent to Early Oligocene (Sajona and others, 1997).

Maganoy Formation

Lithology	Limestone, conglomerate, sandstone
Stratigraphic relations	Conformable over the Kiamba Formation
Distribution	Maganoy River, Akir-akir Mountain, south-
	central Maguindanao
Age	Late Oligocene – Early Miocene
Thickness	~ 600 m
Named by	Froehlich and Melendres (1960)

The Maganoy Formation was named by Froehlich and Melendres (1960) for the sedimentary sequence along Maganoy River, south-central Maguindanao. The formation rests unconformably over the volcanic basement, probably corresponding to the Kiamba Formation. The Maganoy consists of dark gray to black fossiliferous limestone, pebble and cobble conglomerates, and greenish gray pebbly and orbitoidal sandstones. The formation underlies the Akir-Akir Mountain west of Cotabato Valley. Fossils indicate a Late Oligocene to Early Miocene age. Its estimated thickness is around 600 m (BMG, 1981).

Nakal Formation

Lithology	Limestone, conglomerate, sandstone
Stratigraphic relations	Conformable over the Maganoy Formation
	and underlies the Patut Formation
Distribution	Nakal Creek, Roxas range; western and
	northern margins of Cotabato Basin
Age	Early Miocene
Thickness	~ 1,500 m

Named by Froehlich and Melendres (1960)

The Nakal Formation was named by Froehlich and Melendres (1960) for the rocks along Nakal Creek, which cuts the Matulas Anticline. The formation lies conformably over the Maganoy Formation and below the Patut Formation. Outcrops may be found along the Roxas Range and the northern and western margins of the Cotabato Basin. The Nakal consists of graywacke and conglomerate interbedded with shale and mudstone, as well as thin beds of fossiliferous limestone. Fossils indicate an Early Miocene age. Its estimated thickness is around 1,500 m (BMG, 1981).

Limestones that appear to occupy horizons near the base of the Nakal are **Head Allah Limestone** at the south central part of the basin and the **Tigbauan Limestone** in the northern portion. The Head Allah Limestone was named by Froelich and Melendres (1960) for the dense massive limestone exposures at Sitio Head Allah, Cotabato. It is exposed in the upper Big Lun River, Pangyan and Malbag rivers, Kambas creek, Mt. Latian and on the eastern shore of Lake Kapanglao. The Limestone overlies volcanic agglomerate at Big Lun River and appears to occupy horizons near the base of the Early Miocene Nakal Formation at the south-central part of the Cotabato Basin. Subsurface drilling indicates a thickness of about 450 m (BED, 1986). On the other hand, the thickness of the Tigbauan is about 100 m.

Cablacan Formation

Lithology	Andesite, dacite, conglomerate, minor
	sandstone, chert, marble
Stratigraphic relations	Unconformable over Kiamba Formation
Distribution	Cablacan and Kamanga rivers; Kiamba,
	South Cotabato
Age	Early Miocene
Thickness	> 800 m
Named by	Santos and Baptista (1963)

The Cablacan Formation was named by Santos and Baptista (1963) for the thick sequence of conglomerate, graywacke, quartzite and schistose marble, which is best exposed along the upper Kamanga and Cablacan rivers in South Cotabato. The formation unconformably overlies the Kiamba Formation. Around Kiamba, volcanic and pyroclastic rocks constitute part of this formation. The formation may be subdivided into a lower volcanic member and an upper sedimentary member.

The volcanic rocks were described by Malicdem and Peña (1963) as volcanic flows and flow breccias. The sizes of breccia fragments are generally cobble to pebble sizes although bigger fragments have been noted at Matingao River. The volcanic flows consist principally of andesites, although dacitic rocks were also observed. In Tual area, altered dacitic tuff and ignimbrite are associated with fossiliferous calcarenite. Thin bedded sedimentary rocks associated with the volcanic rocks include sandstone, shale and limestone.

The upper sedimentary member consists of sandstones, shale and limestone with intercalated pyroxene-bearing andesite flows. The basal section is dominantly made up of limestone with lenses of calcareous lithic wackes and reddish brown shale. In Labo locality, the limestone contains abundant megafossils and coral fingers while the wackes are conglomeratic with andesite clasts attaining boulder proportions. The middle section of this unit consists of thinly-bedded sandstone, shale and limestone. The upper section of this sedimentary member is predominantly made up of massive to thickly bedded wackes and calcareous wackes. The calcareous wackes sometimes contain rounded pebbles and cobbles of limestone. At Kamanga and Cablacan rivers, clast-supported limestone pebble conglomerate forms a fairly thick portion of the sequence. In places, thin beds of quartzite and less altered sandstone are interbedded with the conglomerate. Chemical analyses of the guartzite reveal as much as 80% to 90% silica. Slates and ferruginous red cherts, occurring as prominent peaks north of Kamanga River, are found near the upper strata of the conglomerate. They are banded and highly contorted. The uppermost member of the formation includes marbleized limestone with crude planar schistosity accentuated by thin sheets of chlorite-sericite. The occurrence of these schistose rocks is apparently related to local shear zones.

Radiometric K-Ar dating of volcanic and volcanogenic rocks overlying Early Oligocene diorite near Maasin gave an age of 16.73 Ma, equivalent to Early Miocene (Sajona and others, 1997). Andesite and dacitic flows overlying the Kiamba Formation gave radiometric K-Ar whole rock dating of 18.3 Ma and feldspar dating of 17.7 Ma, also equivalent to Early Miocene. Similarly, an age of Early Miocene was obtained from paleontologic dating of samples of fossiliferous limestone from several localities around Kiamba (Malicdem and Peña, 1963). However, a limestone sample from the upper portion of the sedimentary member gave an age of Early Miocene – Middle Miocene (Malicdem and Peña, 1963).

Tual Quartz Diorite

Lithology	Quartz diorite
Stratigraphic relations	Intrudes Kiamba Formation and Cablacan
	Formation
Distribution	Tual River, Kapati, Lagonsay, Kiamba,
	South Cotabato
Age	Middle Miocene
Named by	MGB (this volume)

The Tual Quartz Diorite occurs as stocks intruding the Kiamba Formation and Cablacan Formation in a few localities in Kiamba, South Cotabato. The biggest stock, measuring 2 km long with a maximum width of 750 m, is exposed along the upper reaches of Tual River. The quartz diorite is generally light gray and medium grained. It consists principally of plagioclase with subordinate amounts of hornblende and quartz. In some outcrops, biotite is also present and could be more abundant than amphibole.

At Labo locality in Kiamba, a body of fine grained quartz diorite porphyry with surface dimensions of 1.75 km by 0.65 km probably

represents a facies of the Tual Quartz Diorite. The quartz diorite, which intrudes the Cablacan Formation, has an altered andesitic to dacitic shell.

A number of iron and copper prospects in several localities in Kiamba are associated with the intrusion of the quartz diorite bodies. On the basis of intrusive relationships, the quartz diorite is assigned a Middle Miocene age.

Tampanan Limestone

Lithology	Conglomerate, minor sandstone, chert,
	marble
Stratigraphic Relations	Unconformable over the Kiamba
	Formation and Daguma Diorite
Distribution	Sitio Tampanan, Siguil River, Allah River,
	Siloay and Clinan rivers, Polomolok, South
	Cotabato
Age	Middle to Late Miocene (?)
Thickness	760 m
Previous name	Siloay Limestone (Francisco and Comsti,
	1952)
Renamed by	Santos and Baptista (1963)

The Tampanan Limestone was named by Santos and Baptista (1963) for the limestone at Sitio Tampanan near the middle reaches of Siguil River, south of Lake Maughan, South Cotabato. Remnants of the same limestone were encountered at the upper Allah River toward Mt. Busa. It is white to gray, rubbly limestone that lies unconformably over the Kiamba Formation and Daguma Diorite.

This formation is probably equivalent to the **Siloay Limestone** of Francisco and Comsti (1950). As described by Francisco and Comsti (1950), the basal portion of the formation is a conglomerate consisting of basaltic clasts in a calcareous matrix containing fossils. The limestone is typically coralline and honey-combed with cavities. In places, the limestone is well-bedded and arenaceous. Francisco and Comsti (1952) estimate the thickness of the formation at around 760 m. The age is given as Middle Miocene to Late Miocene.

Siguil Formation

Lithology	Conglomerate, sandstone, shale,
	limestone
Stratigraphic relations	Unconformable over the Tampanan
	Limestone
Distribution	Siguil River, South Cotabato
Age	Late Miocene
Named by	Santos and Baptista (1963)
-	

The Siguil Formation was named by Santos and Baptista (1963) for the sedimentary sequence along Siguil River in South Cotabato west of Sarangani Bay. The formation is a sequence of both clastic rocks and limestone that apparently rests unconformably on the older formations and overlaps the Tampanan limestone along an elongated but narrow basin. The formation is areally distributed along a basin described by the meandering Siguil River, representing the southern facies of an extensive basinal sedimentary accumulation.

Interbedded tuffaceous conglomerate, sandstone and shale comprise the clastic members of the formation. The conglomerate is generally medium- to thickly- bedded, cemented mainly by calcareous clay with colors that range from gray to buff.

Capping the whole sequence of clastic sedimentary rocks is massive white to flesh colored coralline limestone. The area underlain by the limestone is characterized by karstic topography with steep gorges in contrast to the rolling terrain underlain by the clastic members. The limestone is thickest at Sitio San Marcos, along Siguil River, in part unconformably overlying the Salbuyon Schist. The base of the limestone is tuffaceous marl about a meter thick, which form the transition zone from the clastic members underneath.

Paleontological dating of the limestone indicates a probable Late Miocene age for the formation.

Allah Formation

Lithology	Sandstone, chert, limestone
Stratigraphich relations	Not reported
Distribution	Allah River Valley
Age	Late Miocene
Named by	Santos and Baptista (1963)

The Allah Formation was named by Santos and Baptista (1963) for the clastic rocks and limestone along the basin defined by the Allah River and its tributaries, representing the northern facies of a similar sequence - the **Siguil Formation** - in the southern part of the area. Both have the same lithologic characteristics with only slight variation in facies.

Tuffaceous sandstone and shale comprise the clastic deposits in the upper reaches of the Allah River tributaries. The sandstone and shale interbeds are generally light gray in contrast to the predominating buff color of the clastic rocks of the Siguil Formation.

The upper member of the formation is flesh-colored massive limestone. In places, the limestone mass is sandy with impurities of clay and iron oxides. Foraminifera and other microscopic organisms present in the limestone matrix indicate a Late Miocene age. It was probably deposited in open basin of relatively shallow depth. The formation is tightly folded along the western flank of the Allah River Valley.

Kamanga Limestone

Lithology	Reef limestone
Stratigraphic relations	Unconformable over the Parker Volcanic
	Complex

Distribution	Kamanga – Siguil area, South Cotabato
Age	Pleistocene
Named by	Santos and Baptista (1963)

The Kamanga Limestone was named by Santos and Baptista (1963) for the recently uplifted reef limestone adjoining the Kamanga-Siguil area, along the western coast of Sarangani Bay. It appears to rest unconformably over the pyroclastic rocks of the Parker Volcanic Complex and the Salbuyon Schist.

The basal portion of the Kamanga Limestone consists of conglomerate layers derived from rocks of the Parker Volcanic Complex. From the impure marl in the lower horizon, the limestone grades upward to purely coralline type. The limestone was noted to contain marine flora and molluscan shells in several localities. The bioclastic-biohermal aggregates are white to flesh in color, generally vuggy, and are partly sandy and tuffaceous. Bedding is poor or almost absent. The limestone is probably of Pleistocene age.

Similar smaller limestone bodies were encountered on the flanks of the northern axis of Matulas Range and at the Bianan-Nufol area.

Matulas Gravel

Lithology	Gravel
Stratigraphic relations	Unconformable over older formations
Distribution	Marbel-Banga highway, north of Matulas
	Range
Age	Holocene
Named by	MGB (2004)

Terrace gravel deposits of Holocene age are found along the Marbel-Banga highway, north of Matulas Range. The deposits are topographically expressed by moderately-elevated rolling, sparselyvegetated hills along the eastern margin of the Cotabato Basin. The gravel deposits of Matulas Range consist of fluviatile detrita of various compositions merging with the alluvium of the lowlands. The sub-rounded to rounded pebbles and cobbles include a heterogeneous assemblage of the older rocks in the area. Bedding is poor or entirely lacking in the area.

COTABATO BASIN (SG 26)

The discussion that follows is limited to the basinal sequence. Thus, the discussions on the Late Oligocene-Early Miocene Maganoy Formation and the Early Miocene Nakal Formation are included in the Daguma Range section. The assumption of a basin configuration for the Cotabato Valley area probably commenced in the latter part of Early Miocene and the basin began to receive clastic debris from the surrounding highlands in the west during the Middle Miocene.

GEOLOGY OF THE PHILIPPINES

PERIOD	EPOCH	AGE	Ма	COTABATO BASIN	SARANGGANI PENINSULA
	HOLOCENE		0.0447		Balut Volcano
SENE	PLEISTOCENE	4 Late 3 Middle - 2 1 Early	0.0117	Omanay Marl Kilada Formation	Gumasa Formation
	PLIOCENE	2 Late 1 Early	3.60 5.33	Marbel Formation	
NEOG		3 Late	7.25	Dinganen Formation	Buayan Formation Sulop Formation
	MIOCENE	2 Middle-	11.61		Glan Formation
			15.97	Patut Formation	Pangyan Formation
		1 Early	20.43		Latian Limestone
	OLIGOCENE	2 Late 1 Early	23.03		
LEOGENE	EOCENE	4 Late	33.9		
		3 Middle - 2	40.4		
P/		1 Early	55.8		
	PALEOCENE	3 Late 2 Middle 1 Early	58.7 61.7		
CEOUS	Upper	Late	00.6		
CRETAG	Lower	Early	33.0		
JURASSIC	Upper	3 Late	145.5		
	Middle	2 Middle	175.6		
	Lower	1 Early	199.6		

Table 2.30 Stratigraphic column for Cotabato Basin and Saranggani Peninsula

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

Patut Formation

Conglomerate, sandstone, mudstone,
limestone
Conformable above the Nakal Formation
Patut Creek, western North Cotabato
Middle Miocene
900 m – 1,150 m
Patut Sandstone and Conglomerate
(Corby and others, 1951)
Froehlich and Melendres (1960)

The Patut Sandstone and Conglomerate was named by Corby and others (1951) for the sedimentary sequence along Patut Creek, a tributary of Simuay River in western North Cotabato, which was later described by Froehlich and Melendres (1960). The Patut conformably overlies the Nakal Formation and is conformably overlain by the Dinganen Formation.

Froehlich and Melendres (1960) subdivided the formation into two facies: the near-shore marine and terrestrial beds in the northern part of Cotabato Valley and the offshore marine Saul Creek facies in the south-central part of the valley. At the type locality, the formation consists of cobble conglomerate and thick bedded medium- to coarse-grained graywacke with occasional interbeds of bluish gray carbonaceous mudstone. The conglomerate is massive and largely occupies the lower part of the sequence. On the other hand, the Saul Creek facies consists of interbedded siltstone, mudstone and medium grained sandstone with a basal lenticular porous reefal limestone.

The Patut is dated Middle Miocene with a thickness of 900 m in the south and 1150 m in the north.

Dinganen Formation

Lithology	Mudstone, claystone, tuffaceous sandstone
Stratigraphic relations	Conformable over the Patut Formation
Distribution	Dinganen Creek, North Cotabato; south-
	central and southern part of North
	Cotabato
Age	Late Miocene
Thickness	~ 2,000 m
Previous name	Dinganen Blue Shale (Corby and others,
	1951)
Renamed by	Froelich and Melendres (1960)

This formation was previously named Dinganen Blue Shale by Corby and others (1951) in reference to the rocks along Dinganen Creek, a tributary of the Simuay River in North Cotabato. Froelich and Melendres (1960) first described the formation, which consists of blue to gray mudstone, claystone and tuffaceous sandstone. The formation also crops out in the south-central and southern part of North Cotabato. It has marine affiliations on the north but becomes non-marine towards the south. On the north, the formation is dominantly mudstone and claystone. On the south, the sandstone becomes conglomeratic and lenses of boulder conglomerate become frequent in the mudstone and siltstone sequence. It is dated Late Miocene with an estimated maximum thickness of 2,000 m.

Nicaan Formation

Lithology	Mudstone, sandstone, conglomerate,
	agglomerate, minor limestone and marl
Stratigraphic relations	Conformable over the Dinganen Formation
Distribution	Nicaan River, northern part of Cotabato
	Valley

Age	Late Miocene - Pliocene
Thickness	1,700 m
Named by	Froehlich and Melendres (1960)

The Nicaan Formation was named by Froehlich and Melendres (1960) for the thick, dominantly marine clastic rocks along Nicaan River in northern Cotabato Valley area. The Nicaan Formation is divided into a lower fine clastic member and an upper coarse clastic member. The lower member is composed dominantly of shallow marine interbeds of thinly-bedded, blue-gray fossiliferous mudstone, blue-gray to dark gray locally tuffaceous sandstone, siltstone, pebble conglomerate, and agglomerate with occasional intercalations of impure limestone and marl. The upper member is made up of non-marine, conglomeratic, cross-bedded sandstone with minor amounts of blue gray sandstone and siltstone.

Based on paleontological studies, the Nicaan is dated Late Miocene to Pliocene (BED, 1986b). The thickness of the whole formation is approximately 1,700 m. The lower member has an estimated thickness of 1,200 m, although it is estimated to be only 300 - 400 m thick in the south. The upper member has been estimated to be 300 - 500 m thick (BED, 1986b).

The Nicaan is equivalent to the Maibu Mudstone and Sandstone and the Dimuluk Conglomerate in the south (BED, 1986b).

Marbel Formation

Limestone, marl, mudstone, sandstone,
conglomerate
Not reported
Marbel, South Cotabato
Pliocene
> 1,200 m
Froehlich and Melendres (1960)

The Marbel Formation was named by Froelich and Melendres (1960) after the Pliocene sequence of biohermal limestone, marl, mudstone, sandstone and local beds of volcanic conglomerates exposed at Marbel, South Cotabato. On the north, the formation is represented by at least two distinct lithologies, namely: the **San Mateo Mudstone** consisting predominantly of tuffaceous mudstone interbedded with marl, limestone, tuffaceous sandstone and pebble conglomerate; and the biohermal **Awang-Table Limestone**. The formation is over 1,200 m thick in the area south of Mt. Matutum in central South Cotabato. The depositional environment of the Marbel is shallow marine to fluviatile.

Kilada Formation

Lithology	Sandstone, calcareous siltstone,
	conglomerate
Stratigraphic relations	Not reported
Distribution	Barangay Kilada, M'lang, North Cotabato
Age	Pleistocene

Thickness	100 m	
Named by	Froelich and Melendres	(1960)

The Kilada Formation was named by Froelich and Melendres (1960) for the Pleistocene rocks exposed at Barangay Kilada, M'lang, North Cotabato. It is also represented in the low hills around Marbel area. The formation is a relatively thin interbedded sequence of fluviatile to lacustrine deposits of buff to gray, poorly consolidated, fine-grained sandstone; calcareous siltstone; and cross-bedded conglomerate. Its maximum thickness is about 100 m.

Omanay Marl

Lithology	Marl
Distribution	Omanay, North Cotabato
Age	Pleistocene
Thickness	35 m
Named by	MGB (this volume)

The Omanay Marl was named after Omanay in northern North Cotabato. The marl is greenish cream with abundant small foraminifera and contains perfectly preserved oyster beds. It was dated Pleistocene and has a thickness of 35 m.

SARANGGANI PENINSULA (SG 28)

In the first edition of the Geology of the Philippines (BMG, 1981), the Saranggani Ridge is discussed together with the Mindanao Central Cordillera. However, Pubellier and others (1990, 1991) show that the Central Cordillera has a Philippine arc affiliation while the Saranggani Ridge is related to the Sangihe arc. These are therefore two different terranes, thus necessitating a separate discussion.

Malita Formation

Lithology	Volcanic and volcaniclastic rocks
Stratigraphic relations	Capped by limestone
Age	Early Miocene (?)
Named by	MGB (this volume)

Occasional windows through Late Miocene volcanic rocks along Malita River expose slightly metamorphosed volcanic and volcaniclastic sequence capped by limestone (Pubellier and others, 1990). This unit is poorly described and is best known through core logs recovered from drill holes by the Philippine National Oil Company (PNOC). The limestone capping has been dated as Early to lowermost Middle Miocene (Langhian) based on its foraminiferal content (Pubellier and others, 1991). The unit is probably Early Miocene.

Latian Limestone

Lithology Limestone Stratigraphic relations Unconformable over volcanic agglomerate

Distribution	Upper Big Lun; Pangyan and Malbag
	Rivers, Kambas Creek, Mt. Latian, eastern
	shore of Lake Kapanglao
Age	Early Miocene
Thickness	16 m
Named by	MGB (this volume)

Froehlich and Melendres (1960) applied the name Head Allah Limestone in Daguma Range west of Cotabato Valley for the Early Miocene limestone in Saranggani. It is here named Latian Limestone for the exposure at Mt. Latian. The formation also crops out at Big Lun, Pangyan and Malbag rivers, Kambas Creek, and the eastern shore of Lake Kapanglao. It lies unconformably above volcanic agglomerate, probably belonging to the Malita Formation. The limestone is dense and in places contains megafossils. Fossils indicate an Early Miocene age for the limestone. The thickness is 16 m at Big Lun River. Sarangani-1 well data indicate that the thickness could reach 450 m (BED, 1986b).

Pangyan Formation

Lithology	Sandstone, shale
Stratigraphic relations	Conformable over Latian Limestone;
	overlain by Glan Formation
Distribution	Upper Big Lun River; Barrio Lawa; Margus
	and Pangyan Rivers
Age	late Early Miocene – early Middle Miocene
Thickness	~ 300 m
Previous Name	Nakal Formation (Froehlich and
	Melendres, 1960)
Named by	MGB (this volume)

This formation was previously considered by BED (1986b) to be identical to the Nakal Formation of Froehlich and Melendres (1960) west of Cotabato Valley. It is here renamed Pangyan Formation for exposures along Pangyan River. The formation lies conformably over the Latian Limestone and is conformably overlain by the Glan Formation. The Pangyan consists of interbedded arkosic sandstone and calcareous thinlybedded shale with intercalations of siltstone. Aside from Pangyan River, the formation also crops out at Upper Big Lun and Margus rivers and Barrio Lawa. Based on stratigraphic position, the Pangyan is assigned a late Early Miocene to early Middle Miocene age. It has an estimated thickness of 300 m along the Big Lun River (BED, 1986b).

Glan Formation

Lithology	Mudstone, siltstone, sandstone
Stratigraphic relations	Conformable over the Pangyan Formation
Distribution	Upper Glan and Big Lun rivers
Age	Middle Miocene
Thickness	~ 915 m
Named by	MGB (this volume)

The Glan Formation refers to exposures of clastic rocks at Upper Glan River. This unit was described in BED (1986b) but its name was not indicated. It lies conformably over the Pangyan Formation and is unconformably overlain by the Buayan Formation. It is typically exposed at Big Lun River as well as Upper Glan River. The Glan consists of folded sequence of dark gray, thinly-bedded mudstone, siltstone and sandstone, which are occasionally calcareous and carbonaceous. It is dated Middle Miocene and has an estimated thickness of 915 m along the Big Lun River section (BED, 1986b).

Sulop Formation

Lithology	Andesite, pyroclastic rocks, sandstone
	with shale partings
Stratigraphic relations	Unconformably overlain by Buayan
	Formation
Distribution	Malalag-Malita area
Age	Late Miocene
Named by	Milanes (1981)

The Sulop Formation was named by Milanes (1981) for the exposures of volcanic and sedimentary rocks around the Malalag-Malita area. In this volume, the formation is redefined to include the Andesite Intrusives and Mal Clastics of the same author. The Sulop Formation is overlain unconformably by the Buayan Formation. The Sulop consists of weathered andesitic flows and intrusions, pyroclastic rocks and well-bedded upper clastic sequence. The formation outcrops in the Malalag-Malita area and comprises the bulk of Saranggani Ridge.

Exposed along the Malalag-Malita road are the volcanic flows dominantly composed of porphyritic andesite. They are highly weathered and are generally dark brown to black. Agglomerates of the same composition almost always intercalate with the volcanic flows. These volcanic rocks are also exposed in Kinangan Creek, along a logging road going to Talagutong.

The clastic rocks consist of highly indurated graywackes and shale. These conspicuously outcrop along a roadcut southwest of Malita and at the headwaters of Sanghay, Pangyan and Buca creeks. The graywackes are medium- to coarse-grained, medium bedded, tuffaceous and exhibit spheroidal weathering. The shale is brown to reddish brown, thinly to moderately bedded, fine-grained and tuffaceous. It is highly fractured and devoid of fossils. The shales show signs of bioturbation suggesting shallow marine deposition (Pubellier and others, 1990; Quebral, 1994).

The upper volcaniclastic portion, which is found steeply dipping along the eastern flank of Saranggani Ridge, is probably equivalent to the Mal Clastics of Milanes (1981) that dips gently along the western flank of the ridge. This clastic sequence apparently occupies different flanks of the Saranggani Anticlinorium.

Potassic calc-alkaline and esite samples from Malita River yielded radiometric K-Ar dating of 10.64 ± 0.22 Ma (Pubellier and others, 1990;

Quebral, 1994). Sajona and others (1997) provided additional dating of 7.70 ± 0.18 Ma on a calc-alkaline dacite sample. These all correspond to Late Miocene age (Tortonian).

Buayan Formation

Lithology	Mudstone, siltstone, sandstone,
	conglomerate, marl, tuff
Stratigraphic relations	Unconformable over the Glan Formation
	and Sulop Formation
Distribution	Barangays San Vicente, Gumasa,
	Mananda; Glan River, Small and Big Lun
	rivers; Sulop-Gen. Santos road; Malita;
	Kiblawan; Malungon Valley; Matan-ao;
	Magsaysay
Age	Late Miocene – Early Pliocene
Thickness	600 m
Named by	Punay and others (1972)

The formation was named by Punay and others (1972) for exposures along the road to Brgy. San Vicente, 7 km east of Glan municipality. It is unconformable over the Sulop Formation and Glan Formation. Aside from the exposure at San Vicente, it is also exposed along Glan River up to Barangay Calsip, along Small and Big Lun rivers, and the coastal area near barangays Gumasa and Mananda. Probably equivalent to the Buayan is the clastic sequence described by Pubellier and others (1990) and Quebral (1994) along the Sulop-Gen.Santos Road. This sequence, which unconformably rests on the underlying Sulop Formation, outcrops along the western flank of the Saranggani Ridge and constitutes the sedimentary basin riding piggyback fashion on the ridge.

At the type locality in San Vicente, the Buayan consists of mudstone with intercalations of calcareous and fossiliferous siltstone and sandstone. At the Small and Big Lun rivers, pebble and cobble conglomerates are interbedded with the mudstone and sandstone. As observed along the Sulop-Gen. Santos road, the clastic sequence consists of conglomerates, conglomeratic sandstones, marls and tuffs. The conglomerates and conglomeratic sandstones are polymictic with well-rounded clasts of andesites, indurated shales and sandstone, and limestone. Although channelling is observed within the conglomerates, marly samples from the channel fill yielded nannofossils, which were dated latest Miocene (NN11) to earliest Pliocene (Pubellier and others, 1990; Quebral, 1994). The estimated thickness of the Buayan is around 600 m.

Gumasa Formation

Lithology	Limestone, sandstone, shale,
Stratigraphic relations	Unconformable over the Buayan
Gualgraphic relations	Formation
Distribution	Coastal areas from Malapatan in the north to Mananda in the south and northeastern

	part of Sarangani Bay; Latian and Dimulok
	rivers
Age	Pliocene - Pleistocene
Thickness	~ 400 m
Previous name	Gumasa Limestone (Punay and others, 1972)
Renamed by	BED (1986b)

The Gumasa Formation was previously named Gumasa Limestone by Punay and others (1972) but was renamed by BED (1986b) to include the clastic rocks that are coeval with the limestone. The limestone and the clastic rocks of the Gumasa have unconformable relations with the underlying Buayan Formation. The limestone exposures of the Gumasa are confined to the coastal areas from Malapatan in the north to Mananda in the south and the low hills on the northeastern part of Sarangani Bay. The low dipping limestone is coralline, marly, cavernous and contains abundant megafossils. The clastic rocks, consisting chiefly of sandstones, shales and conglomerates, may be found along Latian and Dimulok rivers of the peninsula. The sandstone is usually fine-grained, friable and contains limestone interbeds and abundant megafossils. Along Latian River, wellbedded tuffaceous pebble-to cobble- conglomerates predominate over the finer-grained clastic rocks. The formation is dated Pliocene - Pleistocene. The thickness of the formation, as estimated from sections at barangays Tango and Gumasa, is around 400 m.

The Kiblawan Limestone of Milanes (1981) is probably equivalent to the limestone of Gumasa Formation. The Kiblawan occupies the higher elevations along the western parts of Magsaysay, Kiblawan and barangays Lapla and Roxas in Sulop. Milanes (1981) describes the Kiblawan Limestone as coralline and porous, often marly, and without any apparent bedding. It is also massive in some places.

The Matan-ao Clastics of Milanes (1981) may also correspond to the clastic rocks of the Gumasa. The Matan-ao underlies the relatively flat lands in Matan-ao and Magsaysay and the narrow north-south trending Malungon Valley. Along the Malungon Valley, the Matan-ao Clastics consists of poorly consolidated and poorly sorted, flat-lying sandstones, shales and conglomerates with reworked tuffs and occasional terrace gravel (Milanes, 1981).

Towards Bald Dome Ridge, Quebral (1994) dated a detrital series consisting of graywackes and sandstones with a turbiditic character towards its lower portion and of marls and microconglomerates towards the upper portion, as Late Miocene based on nannofossils. Higher into the sequence, the nannofossil assemblage of a sequence of conglomerates, sandstones, shales and limestone was dated late Pleistocene (NN20). The nannofossil faunal assemblage indicates that the area had been under marine conditions until late Pleistocene time and that sea regression is a recent event.

Balut Volcano

Balut Volcano constitutes Balut Island south of Saranggani Peninsula representing the northernmost volcano of the present day Sangihe arc. It stands 1,800 above the seafloor but only 883 m is above sea level (Comvol, 1981). Products from this inactive volcano are basaltic.

PUJADA PENINSULA (SG 28)

The southern Pacific Cordillera consists of several massifs in tectonic contact with one another, which may be affiliated either with the Philippine arc or the Pujada Ophiolite (Quebral, 1994). In the first edition of the Geology of the Philippines (BMG, 1981), formations related to the Philippine arc have been included in the stratigraphy of the Pujada Peninsula. In this volume, these have been confined in the discussion on the respective sections of the Pacific Cordillera.

Pujada Ophiolite

Lithology	Amphibolite, dunite, peridotite, gabbro,
Stratigraphic relations	Overlain by the Tagabakid and Sigaboy
0 /	Formations
Distribution	Pujada Peninsula; New Bataan,
	Compostela Valley, Maragusan Valley
Age	Cretaceous
Named by	Villamor and others (1984)

The west dipping Pujada Ophiolite includes the Ansuwang Amphibolite, Magpapangi Greenschist, Surop Peridotite, Nagas Peridotite, Matalao Gabbro, Lumao Diabase, Kalunasan Basalt and Iba Formation of Villamor and others (1984), which are described separately below.

• Ansuwang Amphibolite

Lithology	Amphibolite
Stratigraphic relations	Below the Surop Ultramafic Complex and
	thrusted over the Kalunasan Basalt
Distribution	Ansuwang Creek; Tagbibi; Malibago
Named by	Villamor and others (1984)

The Ansuwang Amphibolite was named by Villamor and others (1984), for the amphibolite along Ansuwang Creek, a tributary of Luzon River. It is a narrow elongated body with a maximum width of 300 m. The amphibolite body along Tagabibi Creek has a maximum width of 1 km and a length of 3.5 km. The mineral assemblages of the amphibolites include plagioclasechlorite-epidote-hornblende, plagioclase-hornblende and chlorite-epidotehornblende-anthophyllite. Garnet amphibolite was noted in the vicinity of Sitio Gabinanan in the southeastern portion of the peninsula.

PERIOD	EPOCH	AGE	Ма	PUJADA PENINSULA
	HOLOCENE		0.0117	
	PLEISTOCENE	4 Late	0.0117 0.126 0.78	Maco Limestone
		1 Early	1.81 2.59	Sigaboy Formation
		1 Early	3.60 5.33	
ENE		3 Late	7.25	
NEOG	MIOCENE	2 Middle-	11.61 13.65	
			15.97	
		1 Early	20.43	
	OLIGOCENE	2 Late	28.4	
		1 Early 4 Late	33.9	
TEOGENE	EOCENE	3 Middle - 2	37.2 40.4	Sanghay Formation
PA		1 Early	40.0 55.9	
	PALEOCENE	3 Late 2 Middle 1 Early	55.8 58.7 61.7	
CEOUS	Upper	Late	99.6	Iba Formation Pujada Ophiolite
CRETA	Lower	Early	145.5	

 Table 2.31 Stratigraphic column for Pujada Peninsula

Geologic Time Scale adopted from International Commission on Stratigraphy (2009)

The amphibolites are structurally below the Surop Peridotite and thrusted over the Kalunasan Basalt and the greenschists. Field relationships show that the amphibolites tend to be in contact with, or proximal to, peridotites. The amphibolites then grade into the more distal greenschists, which in turn grade into basalt. Apparently, the amphibolites represent the metamorphic sole of the ophiolite and the schists are the lower grade metamorphosed portions of the mafic and ultramafic rocks constituting the ophiolite. The Bitaogan Amphibolite is equivalent to the Ansuwang.

• Magpapangi Greenschist

Lithology	Actinolite schist, chlorite schist, antigorite schist
Stratigraphic relations	Thrusted over the Surop Peridotite
Distribution	Magpapangi; Tagugpo
Named by	Villamor and others (1984)

The Magpapangi Greenschist was named by Villamor and others (1984) for the schists occurring in the southern portion of Pujada Peninsula. The main body, which is thrusted over the Surop Peridotite, has a maximum width of 2 km and can be traced for 16 km along its length. The greenschist in the southern portion of the peninsula consists mainly of albite-epidote-actinolite and guartz-albite-chlorite-epidote. Tremoliteactinolite-antigorite schist is confined near the contact with the Surop Peridotite. On the other hand, the greenschists in the central portion of the peninsula consist of epidote-chlorite-antophyllite schist, antigorite-hematiteactinolite schist, guartz-calcite-dolomite schist, and epidote-carbonatechlorite schist. These varieties of schists occur within a narrow zone measuring 200 m. The greenschists grade into amphibolite to the west and basalt to the east. The schists, therefore, appear to be the lower grade metamorphic facies of the mafic and ultramafic rocks constituting the ophiolite. Schistosity consistently trends NW-SE and dips moderately to the southwest.

In the central portion of the peninsula, a narrow metamorphic belt, 50 m to 200 m wide, designated as **Tagugpo Schist**, is confined between the Surop Peridotite and Kalunasan Basalt. Its contact with the Surop Peridotite is defined by a zone of amphibolite. This metamorphic belt includes epidote-chlorite-antophyllite schist, antigorite-hematite-actinolite schist, low-grade calc schist, and low-grade epidote-carbonate-chlorite schist. This grade into amphibolite schist to the west and metabasalt to the east.

• Surop Peridotite

Lithology Stratigraphic relations	Harzburgite, Iherzolite, dunite, serpentinite Above the Ansuwang Amphibolite; thrusted against the Kalunasan Basalt;
	overlain by Sigaboy Clastics
Distribution	Surop River; Ilihan and Andap creeks
Previous Name	Surop Ultramafics (Villamor and others, 1984)
Renamed by	MGB (this volume)

The Surop Peridotite was previously named Surop Ultramafics by Villamor and others (1984) for the peridotite exposures at Surop River and

its tributaries. The ultramafic body constituting the Surop is approximately 30 km in length and 5 km in width. This body, which is layered and folded, can be traced from Lantawan Point on the eastern side of the peninsula to the north where it pinches out in the upper reaches of Ilihan and Andap creeks. The Surop consists mainly of harzburgite, dunite and Iherzolite. These rocks are serpentinized in varying degrees. In places, it is thrusted against the Kalunasan Basalt in which the thrust zone is characterized by the development of amphibolite and greenschists at the sole of the peridotite. The Surop is unconformably overlain by the Sigaboy Clastics.

• Nagas Peridotite

e;
Gabbro
Jpper
ək
others,

The Nagas Peridotite was named Nagas Ultramafics by Villamor and others (1984) for the peridotite exposure at Nagas Point. The ultramafic body constituting the Nagas extends for more than 30 km to the north (Barangay Jericho) with a maximum width of about 6 km. Outcrops are also found in Masanlud Creek to the east and Upper Aniwan River to the west. Serpentinized peridotites, the dominant lithology, are often sheared and brecciated and criss-crossed by magnesite veinlets. Intense weathering results in a lateritic profile. A gradational contact with the Matalao Gabbro is described by Villamor and others (1984). The transition zone between the Nagas and the Matalao Gabbro is characterized by a peridotite-gabbro complex, which is best exposed along Nagas Creek and upper Aniwan Creek and its tributaries. The Nagas is regarded by Villamor and others (1984) as part of the cumulate complex of the Pujada Ophiolite.

Matalao Gabbro

Lithology	Norite, olivine norite, gabbro, minor
Stratigraphic relations	Gradational with underlying peridotites, cut
	by diabase dikes at the upper portion of
	massive gabbro
Distribution	Matalao
Named by	Villamor and others (1984)

The Matalao Gabbro of Villamor and others (1984) defines a northwest belt with a length of 17 km and a width of 2-4 km. It consists mainly of norite with minor troctolite, pyroxene gabbro and anorthosite. The Matalao includes both massive and layered gabbros. Its contact with the Nagas is characterized by a transition zone of peridotite-gabbro complex.

• Lumao Diabase

Lithology	Diabase with associated basalt and
	gabbro dikes
Stratigraphic relations	Thrusted over the Surop Peridotite
Distribution	Luzon River, Lumao Creek; Kawayan,
	Sukalip Palaypay and Lungag creeks
Age	Cretaceous
Named by	Villamor and others (1984)

The Lumao Diabase of Villamor and others (1984) consists mainly of an outcrop that can be traced for 7 km with a width ranging from 50 to 600 m. It is widely exposed along the upper stretches of Luzon River to Lumao Creek. The Lumao Diabase also occurs as dikes within the Kalunasan Basalt although some exposures show gradational contacts. Other outcrops are found along Kawayan, Sukalip and Palaypay creeks. The Lumao Diabase represents the sheeted dike complex of the Pujada Ophiolite.

In association with the Lumao Diabase are cross cutting dikes of hydrothermally altered basalt, diabase and gabbro designated informally by Villamor and others (1984) as Lungag Dike Complex for the exposures at Lungag Creek and the upper reaches of Luzon River. Diabase is the dominant lithology of the complex. The upper portion is made up of hydrothermally metamorphosed diabase and basalt. The lower portion of the Lungag Dike Complex extends to the upper portion of the Matalao gabbro. The Complex can be traced along a north-northwest direction for about 19 km with a width ranging from 200 m to 3 km. The thickness of the dikes ranges from a few centimeters to a meter. Dike contacts are sharp and characterized by chilled margins. The dikes trend NE-SW and dip steeply to the southeast.

• Kalunasan Basalt

Lithology	Basalt
Stratigraphic relations	Overthrusted by the Surop Peridotite
Distribution	Kalunasan
Named by	Villamor and others (1984)

The Kalunasan Basalt of Villamor and others (1984) consists of highly chloritized and epidotized basalt. Most of the exposures are massive, although relict pillow structures have been recognized in some areas. The upper portion of the Kalunasan Basalt, near its thrust contact with the overlying Surop Peridotite, is sheared and brecciated. The Kalunasan probably represents the volcanic carapace of the Pujada Ophiolite.

Iba Formation

Lithology	Basalt, argillite, limestone, chert, clastic
	rocks
Stratigraphic relations	Overlain by the Sanghay Formation
Distribution	Barangays Iba and Lampasan, Mati,
	Davao Oriental, Dawan, Davao Oriental;

Mayu-Makumbol area; Bitanagon River;
Badas Road; Lupon-Mati road, Davao
Oriental
Late Cretaceous
~ 1,500 m (est.)
Villamor and others (1984)
Dawan Sediments (Melendres and Comsti,
1951)

The Iba Formation was named by Villamor and others (1984) for the exposures of pillow basalt intercalated with siliceous red argillites and crystalline limestone with lenses of red chert at Brgy. Iba, Mati, Davao Oriental. This unit is also well exposed along the Lupon-Mati Road as a sequence of hydrothermally altered pillow basalts and sheet flows, cherts, red pelagic mudstones and limestones. This unit, together with overlying well-bedded graywackes, is characterized by west verging thrusts and reverse faults as well as folds overturned or recumbent to the west. The pillow basalts and pelagic sedimentary rocks constitute the Iba Formation while the graywackes constitute the Sanghay Formation (Villamor and others, 1984). The Iba Formation is equivalent to the Dawan Sediments of Melendres and Comsti (1951). The thickness of the formation along Badas Road is 610 m although it could attain a thickness of 1,500 m based on projections.

Although the Iba Formation might be construed as representing the upper portion of the Pujada Ophiolite, the red cherts and red pelagic mudstones and limestone were not observed to lie over the Pujada Ophiolite in Pujada Peninsula itself where the Sigaboy Formation rests directly on the ophiolite. However, the same red cherts and red pelagic mudstones and limestones outcrop along the Hijo River where it has been described by Malicdem and Peña (1966) and Culala (1987)

Quebral (1994) dated the red cherts and red pelagic mudstones and limestones as Late Cretaceous based on its foraminiferal content (Campanian to Maastrichtian) and radiolarian assemblage (Coniacian to Campanian).

Basiaw Limestone

Lithology	Limestone
Stratigraphic relations	Unconformable over Kalunasan Basalt
Distribution	Kamanuan, Lungag, Kalunasan creeks
Age	Eocene (?)
Named by	Villamor and others (1984)

The Basiaw Limestone occurs as thin lenticular bodies defining a narrow NNW-SSE belt 9 km long and 50 to 150 m wide. It can be traced from a tributary of Kamanuan Creek in the south and along the junction of Palaypay and Panunsungan Creeks in the north. Patches occur along the upper Lungag and Kalunasan Creeks.

The limestone is found either in massive outcrops or as scattered blocks along the creeks and ridge tops. The latter occurrence is more

common. The rocks are generally recrystallized, marbleized or schistose. An outcrop along upper Lungag Creek shows an alternating sequence of thin layers of marbleized limestone, schistose limestone, dark gray limestone, light-colored limestone and calcareous schist. On the abandoned Davencor logging road along the ridge between Barangays Tiblawan and Kabuaya, banded calcareous mylonite grades into a chloritic schistose rock then to slightly metamorphosed basalt.

The Basiaw Limestone is unconformable over the Kalunasan Basalt and is thrusted from the west by the Surop Peridotite, Magpapangi Greenschist and Ansuwang Amphibolite. It is generally barren of fossils or organic remains although a float was dated Eocene (Villamor and others, 1984).

Sanghay Formation

Lithology	Graywacke, mudstone
Stratigraphic relations	Overlies the Iba Formation
Distribution	Barangay Sanghay, Mati, Davao Oriental;
	Lupon-Mati Road; Guanguan Peninsula;
	Gogon Hill; Magtalinga, Talisay
Age	Eocene
Thickness	~ 500 m
Named by	Villamor and others (1984)

The Sanghay Formation was named by Villamor and others (1984) for the well-bedded graywackes and mudstone exposed at Brgy. Sanghay, Mati, Davao Oriental. These well-bedded graywackes are associated with pillow basalts and pelagic sediments of the Iba Formation along the Lupon-Mati Road. The graywackes overlie the late Cretaceous pelagic sedimentary rocks that are thought to represent the ophiolite's sedimentary cover. The thickness of the formation as estimated at Guanguan peninsula is about 500 m.

Well-bedded graywackes constituting the massif between Davao Gulf and Hijo River may be equivalent to the Sanghay Formation. The base of this sequence, consisting of refolded red cherts and red pelagic mudstones and limestones of the Iba Formation, outcrops along the Hijo River where it has been described by Malicdem and Peña (1966) and Culala (1987). This massif actually represents a north-south anticline, which has been thrust westwards. The thrust corresponds to a break in slope, which separates a narrow coastal plain from the Cordillera. In the field, along Lahi River and Magapalway Creek, this break corresponds to a narrow zone of ductile shear. Towards Maco, this thrust seems to be sealed by the late Pleistocene limestone (Quebral, 1994).

Sigaboy Formation

Lithology	Conglomerate, sandstone, mudstone
Stratigraphic relations	Unconformable over the Pujada Ophiolite
Distribution	Sigaboy, Davao Oriental
Age	Late Pliocene – Early Pleistocene

Previous name	Sigaboy Clastics (Villamor and others,
	1984)
Renamed by	MGB-XI (1992)

The Sigaboy Formation refers to a thick conglomeratic sequence found along the western coast of Pujada Peninsula directly overlying unconformably the Pujada Ophiolite. The formation was originally named Sigaboy Clastics by Villamor and others (1984) and later renamed Sigaboy Formation by MGB-XI (1992). The type locality is Sigaboy, which has been renamed Governor Generoso. The conglomerates are notably absent above the thick sequence of well-bedded graywackes north of the Pujada Peninsula. In Maco, for instance, the graywackes are directly overlain by the late Pleistocene Maco Limestone.

The thick bedded conglomerates of Sigaboy are highly resistant to erosion, thereby forming well developed cuestas. The conglomerates are poorly sorted and contain boulders of peridotite, serpentinite, gabbro, diabase, basalt, amphibolite, greenschist, marble and limestone. Towards the top, sandstones and mudstones become more common and the conglomerates become finer-grained and contain more clasts of basalts, hyaloclastites, dacite, scoria, pumice and tuff in a tuffaceous matrix.

The Sigaboy Formation is equivalent to the Buso and Altar Formation of Melendres and Comsti (1951). Based on a late Pliocene (NN18) dating by Quebral (1994) of a nannofossil-bearing limestone clast, the formation is dated as probable Late Pliocene – Early Pleistocene.

Maco Limestone

Limestone
Unconformable over the Sanghay
Formation
Maco, Davao
Late Pleistocene
MGB (this volume)

This formation is named Maco Limestone on the basis of the description by Quebral (1994) for the Late Pleistocene limestone, which outcrops near the coast in Maco, Davao. This limestone has a limited areal extent in Maco and is not observed to rest on the Sigaboy Formation at Pujada Peninsula. In Maco, it is found as an unconsolidated coral breccia, which dips gently to the west towards Davao Gulf. It unconformably overlies a thick series of well-bedded graywackes, which is equivalent to the Sanghay Formation that overlies late Cretaceous cherts and pillow basalts along the Lupon-Mati road.

The shallow marine Maco Limestone was dated by Quebral (1994) as late Pleistocene (NN20-21) based on its nannofossil assemblage.

GEOLOGY OF THE PHILIPPINES

REFERENCES

- Abbate, E., Bortolotti, V. and Passerini, P., 1970. Olistostromes and olistoliths. *Sedimentary Geology*, **4**, 521-557.
- Acharya, H.K., 1980. Seismic slip on the Philippine Fault and its tectonic implications. *Geology*, 8, 40-42.
- Acharya, H.K., Ferguson, J.F. and Isaac, V., 1979. Microearthquake surveys in the Central and Northern Philippines. *Bull. Seismo. Soc. Am.*, 69 (6), 1889-1902.
- Acharya, H.K. and Aggarwal, Y.P., 1980. Seismicity and tectonics of the Philippine Islands. *J. Geophys. Res.*, 85 (B6), 3239-3250.
- Adams, G.I., 1910. Geologic reconnaissance of southwestern Luzon. *Phil. J. Science.* **A-5**, 57-116.
- Adams, G.I., 1909, The marble and schist formations of Romblon Island. Phil. J. Sci. **4**, 87-8927.
- Agadier, M.A. and Maac, Y.O., 1987. Late Neogene microfossils of northeastern Mindoro, Bureau of Mines and Geosciences, 10 p., unpublished.
- Agadier-Zepeda, M.A., Tumanda, F.P., Revilla, A.P., 1992. The Paleogene-Neogene sequences of SW Mindoro Island, Philippines: stratigraphy and events. *Mines and Geosciences Bureau*, 96 p., unpublished.
- Aguilar, M.Y., 1995. Neogene stratigraphy and paleontology of the Calubian Peninsula, northwest Leyte, Philippines. Master's Thesis, Doctoral Program. Inst. Geosci. Univ. Tsukuba, Tsukuba, Japan, 135 p.
- Agusan-Davao Consortium, 1979. Agusan-Davao Basin Evaluation. 35 p, unpublished.
- Alberding, H., 1939. Coal resources of Lingig, Bislig District, Surigao. Bureau of Mines, 39 p., unpublished
- Alberding, H., 1939. Report on the coal resources of the Polillo District.-*Phil. Bureau of Mines,* unpublished.
- Alcaraz, A.P., 1947. The structural lines of the Philippines. *The Philippine Geologist*, 1, 2, 13-17.
- Alincastre, R.S., 1983. Geology of eastern Bacon-Manito Geothermal Project. *PNOC-EDC*, 45 p, unpublished.
- Allen, C.R., 1962. Circum-Pacific faulting in the Philippines-Taiwan region. J. Geophys. Res., 67 (12), 4795-4812.
- Allen, C.R., 1975. Geological criteria for evaluating seismicity. *Geol. Soc. Am. Bull.*, 86, 1041-1057.
- Alvir, A.D., 1928. Synopsis of lectures in physiography, Part II, Manila Technology Cooperative Co.,
- Alvir, A. D., 1929. A geological study of the Angat-Novaliches region: *Phil. J. Sci*ence, **40** (3).
- Alvir, A.D., 1950, Is the Paracale granite or granodiorite of Tertiary age? Some fundamental objections. *Phil. Geologist*, **4** (3), 24-35.
- Amato, F.L., 1965. Stratigraphic paleontology in the Philippines. *Phil. Geologist*, **19** (1), 1-24.

- Amiscaray, E. A., 1987, Permian fusulinids and other microfossils from northwestern Palawan, *Bureau of Mines and Geosciences*, unpublished.
- Amiscaray, E. A. and Quiel, C.M., 1983, Geology and stratigraphy of Cuyo Island Group, *Bureau of Mines and Geosciences*, unpublished.
- Amiscaray, E.A. and Quiel, C.M., 1987, Paleontology and stratigraphy of Abinay and nearby area, Negros Oriental. *Bureau of Mines and Geosciences*, unpublished.
- Amiscaray, E. A. and Tan, M. N., 1984, *Orbitolina* from Tuburan, Cebu. *Bureau of Mines and Geosciences*, unpublished.
- Amiscaray, E. A. and Tumanda, F. P., 1990, Paleozoic and Mesozoic limestones of Calamian Island Group: its role in the tectonic development of the north Palawan Complex, Philippines. *Report No. 5 of the IGCP Project 224: Pre-Jurassic evolution of Eastern Asia*, 81-95.
- Amoco (Amoco Philippines Petroleum Co.), 1981. *Geologic Map of Agusan-Davao Basin* (Map No. GL-05), unpublished.
- Andal, D. R. and Caagusan, N. L., 1967, Geology of the iron deposits of northern Mindoro: Proceedings of the Second Geological Convention and First Symposium on the Geology of the Mineral Resources of the Philippines and Neighboring Countries, 1, 109-120.
- Andal, D.R., Esguerra, J.S., Hashimoto, W., Reyes, B.P. and Sato, T., 1968. The Jurassic Mansalay Formation, southern Mindoro, Philippines. Geology and Paleontology of Southeast Asia, 4, 179-197.
- Andal, P. P., 1966, A report on the discovery of Fusulinids: *Phil. Geologist*, **20** (1), 14-22.
- Ang, V., Milanes, F.S.J. and Dumaoal, B.P., 1979. Progress report on the reconnaissance geologic mapping and stream sediment sampling of Las Nuevas Quadrangle, Agusan Province. - *Philippine Bureau* of *Mines and Geosciences Region X*, unpublished.
- Angeles, C.A., Jr., 1980. Reconnaissance geological survey and mineral canvassing of Romblon Island Group, Bureau of Mines and Geosciences Region IV, unpublished.
- Angelier, J. and Huchon, P., 1986. Tectonic record of convergence changes in a collision area: The Boso and Miura peninsulas, Central Japan. *Earth Planet. Sci. Lett.*, 81, 397-408.
- Angelier, J., Barrier, E. and Chu, H.T., 1986. Plate collision and paleostress trajectories in a fold-thrust belt: the Foothills of Taiwan. *Tectonophysics*, 125, 161-178.
- Angelier, J., Bergerat, F., Chu, H.T. and Lee, T.Q., 1990. Tectonic analyses and the evolution of a curved collision belt: the Hsuëehshan Range, northern Taiwan. *Tectonophysics*, 183 (1-4), 77-98.
- Antonio, I.S. ,1961. Geologic report on PEC 68, 73 and 102, northern Bondoc Peninsula, Luzon, Philippines. 4th Calendar Year: Republic Development Corporation (REDECO), unpublished.
- Antonio, L. R., 1963. Preliminary Report on the Geology of East Central Zamboanga, Mindanao: *Philippine Bureau of Mines*, unpublished.
- Antonio, L. R., 1967. Geology of Santa Ines iron deposits, Antipolo, Rizal. *Proceedings of the 2nd Geological Convention and 1st Symposium on the Geology and Mineral resources of the Philippines and Neighboring Countries, Manila, January 11-14, 1967,* **1**, 121-136.

- Antonio, L. R., 1972, Geology and Mineral Resources of East-Central Zamboanga Peninsula, Mindanao, Philippines: *Philippine Bureau of Mines*, unpublished.
- Arco, R.C., 1962. Geologic reconnaissance and mineral resources of Bohol province, *Philippine, Bureau of Mines Report of Investigation*, 68 p., unpublished.
- Arco, R. C., 1967, Memorandum report on the geologic investigation of Aznar Mining and Development Company mineral claims at Barrio Bulacao, Cebu City and Sitio Santo Nino, Barrio Bantique, Isabel, Leyte del Norte. *Bureau of Mines and Geosciences*, unpublished.
- Arribas, A., JR., Hedenquist, J. W., Itaya, T., Garcia, J. S., JR., 1994. Timing of intrusion and related porphyry and high-sulfidation Cu-Au mineralization at Lepanto-FSE, Philippines (Abstract). J. Geol. Soc. Japan, 44, p. 266.
- Arcilla, C.A., 1983. Geology and mineral resources of the Montalban Quadrangle, Luzon, Philippines. 188 p., unpublished.
- Arcilla, C.A., 1991. *Lithology, age and structure of the Angat Ophiolite, Luzon, Philippine Islands.* Masters Thesis, Univ. Illinois at Chicago, 105 p.
- Arcilla, C.A., Ruelo, H.B. and Umbal, J, 1989. The Angat Ophiolite, Luzon, Philippines: lithology, structure, and problems in age interpretation. *Tectonophysics*, **168**, 127-135.
- Aurelio, M.A., 2000. Shear partitioning in an island arc setting: constraints from Philippine Fault and recent GPS Data, *Island-Arc*, Thematic Issue, 9, 585-598.
- Aurelio, M.A., 1996. A review of mechanisms of ophiolite emplacement: Philippine examples. *J. Geol. Soc. Phil.*, 51 (3/4), 87-89.
- Aurelio, M.A., 1995. Plate motions and crustal deformation deduced from space geodetic measurements for the assessment of related natural hazards in Southeast Asian regions. *Final Report:* European Community Post-Doctoral Fellowship Grant FCC No. C11*-CT-93-0164. EC Headquarters, Brussels, Belgium.
- Aurelio, M.A., 1992. Tectonique du segment central de la faille Philippine: etude structurale, cinématique et evolution géodynamique. Thèse de doctorat de l'Université de Paris 6, Université Pierre et Marie Curie, Académie de Paris, T 92-22, France, 500 p.
- Aurelio, M.A. and Almeda R.L., 1999. Active deformation and stress state in and around the Philippines: present-day crustal motion from GEODYSSEA. *In: Prog. and Abs. GPS 99* - The International Symposium on GPS. Tsukuba, Japan, 18-22 October 1999.
- Aurelio, M.A., Barrier, E., Rangin, C. and Müller, C., 1991. The Philippine Fault in the late Cenozoic evolution of the Bondoc-Masbate-N. Leyte area, Central Philippines. *J. SE Asian Earth Sci.*, 6 (3/4), 221-238.
- Aurelio M. A., Barrier, E. and Rangin, C., 1990, Polyphase tectonics in a region traversed by the Philippine Fault: a microtectonic study. J. Geol. Soc. Phil., 45, 31-49.
- Aurelio, M.A., Barrier, E., Rangin, C. and Müller, C., 1990a. The Philippine Fault: a young or an inherited feature? - *In:Int. Interdisciplinary Meeting: Orogenesis in Action*, London, G.B., 18-20 April 1990, Prog. with abs., p. 3.
- Aurelio, M.A. and Billedo, E.B., 1988. Tectonic significance of the geology and mineralization of Northern Sierra Madre. *RP-Japan Mineral Exploration Project, Technical Reports*, Manila, 101 p.
- Aurelio, M.A., Huchon, Ph., Barrier, E. and Gaulon, E.,1994. Displacement rates along the Philippine Fault estimated from slip-vectors and regional kinematics. *J. Geol. Soc. Phil.*, 49 (2), 65-77.
- Aurelio, M., Le Pichon, X., Loevenbruck, A., Pubellier, M., Vigny, C., Becker, M., Tran, D.T., and Quebral, R., 2000. Quantifying block rotation along active strike-slip boundaries in Visayas and Mindanao (Philippines) by GPS: GEODYSSEA Part III. *In: The 13th Annual Geological Convention*, Abstracts. 6-8 December 2000, Pasig City, Philippines.
- Aurelio, M.A., Rangin, C., Barrier, E. et Müller, C., 1990b. Tectonique du segment central de la Faille Philippine: un décrochement très récent. *C.R. Acad. Sci.*, 310, 403-410.
- Aurelio, M.A., Simons, W.F. Almeda, R.L. and the Philippine GPS Team, 1998a. Present-day plate motions in the Philippines from GEODYSSEA GPS Data. In: The GEODYnamics of S and SE Asia (GEODYSSEA) Project Eds. Wilson, P. and Michel, G. Scientific Technical Report STR98/14 Potsdam, Germany, December 1998.
- Aurelio, M.A., Simons W., Almeda R.L. and the EC-Philippine GPS Team, 1997. Present-day plate motions in the Philippines from GEODYSSEA data. *In: Prog. and Abs. Stratigraphy and Tectonic Evolution of Southeast Asia and the South Pacific*, Bangkok, Thailand, 19-24 August, 1997, p. 360.
- Aurelio, M.A., Walpersdorf, A., Simons W., Almeda R.L. and the EC-Philippine GPS Team, 1998b. Displacement rates and block rotation in and around the Philippines - results from GEODYSSEA data Part II. *In: Prog. and Abs. GEOSEA 98* - Ninth Regional Congress on Geology, Mineral and Energy Resources of Southeast Asia. Kuala Lumpur, Malaysia, 17-19 August, 1998, p. 238.
- Ausa, C.A. 1991. Activity Report on the Follow-up Geological Exploration Survey at Sitio Lenna, Barangay Little Baguio, Malita, Davao del Sur, *Mines and Geosciences Bureau*, Davao City, unpublished.
- Avila, E. T., Jr., 1973. Progress report of Team A on the reconnaissance geologic mapping and geochemical survey within the forest reservation of south-eastern Mindanao (Phase II-A RP-Japan Project). *Philippine Bureau of Mines*, unpublished
- Avila, E.T., 1980, Report on the geology and mineral resources of southern Batangas covering Lobo, Batangas City, Malabrigo and San Juan quadrangles: *Philippine Bureau of Mines and Geosciences Technical Information Series No. 14-80.*
- Ayson, J.N.R., 1987. Results of semi-detailed geological and geochemical survey of Pamplona sulphur area, SE Negros. UNDTCD PHI/85/001 Internal Technical Report GCR/86/11.
- Balce, G. R., 1978. *Geology and ore genesis of the porphyry copper deposits in Baguio District, Luzon Island, Philippines*. Doctoral dissertation. Tohoku University.
- Balce, G.R., 1974. Explanatory text for the tectonic map of the Philippine Archipelago. Bureau of Mines, 28 p., unpublished.
- Balce, G.R., 1970. An Introduction to the Stratigraphy of Cebu. Bureau of Mines, unpublished.
- Balce, G. R., 1964, Geology and coal resources of the Biga Area Toledo City, Cebu Island. *Bureau of Mines*, unpublished.

- Balce, G.R., Alcantara, A.P., Morante, E.M. and Almogela, D.H., 1976. Tectonic framework of the Philippine Archipelago (a review). *Bureau of Mines*, 67 p., unpublished.
- Balce, C. L. and Cabantog, A. V., 1998, Tacloban Ophiolite Massif -Basement of northeast Leyte physiographic province. *Mines and Geosciences Bureau – Region No. 8,* unpublished.
- Balce, G.R., Encina, R.Y., Momongan, A. and Lara, E., 1980 Geology of the Baguio District and its implications on the tectonic development of the Luzon Central Cordillera. *Geology and Paleontology of Southeast Asia*, **21**, 265-288 (Proc. Symposium on GPSEA, Tsukuba, Japan, October 2-9, 1978).
- Balce, G.R. and Esguerra, F.B., 1974. "Kuruko-type" ore in Sulat area, Eastern Samar, Philippines. *J. Geol. Soc. Phil.*, **28** (1) 1-36
- Balce, C.L., Leones, J.S., Dupio, A.S., Jr. and Sucgang, B.L., 1996. Geology of Northwest Leyte Basin. *Mines and Geosciences Bureau* - *Region No. 8*, unpublished.
- Banogon, P.A., 1975. Section measurements for PEC 115 (Amd2) and PEC 249 (amd) and tectonic implications of the stratigraphy of Davao Basin. *Acoje Oil Exploration & Drilling Company*, 14 p., unpublished.
- Banogon, P.A., 1974. Geological report, Bondoc Peninsula, Quezon. *Acoje Oil Exploration and Drilling Company.* Unpublished.
- Barcelona, B. M., 1981. The nature of the faults in the Philippine Fault Zone and their tectonic significance in the region, Doctoral dissertation, Tokyo University, Japan.
- Barrier, E., Huchon, Ph. and Aurelio, M.A., 1991. Philippine Fault: a key to Philippine kinematics. *Geology*, 19, 32-35.
- Barrier, E., Aurelio, M.A., Müller, C., Pubellier, M., Quebral, R.D. and Rangin, C., 1990. La faille Philippine: un exemple de grand décrochement actif à l'arrière d'une zone de subduction. *C.R. Acad. Sci.*, 311, 181-188
- Barnes, H., Jongco, C.P., Lazaga, G.C., Pilac, J.E. and Vokes, H.E., 1958. Geology and coal resources of the Argao-Dalaguete region, Cebu. *Bureau of Mines Special Project Series No. 7.*
- Basco, D.M., 1964. A contribution to the geology of southwest Palawan Group of Islands, Balabac Islands and vicinity. *Proc.* 1st National Symposium on Mineral Resources Development and 11th Mine Safety Conference, v. 2.
- Baumann, P., Latreille, M.E. and Maurizot, P., 1976: The hydrocarbon potential of the Central Luzon Basin. *Philippines Energy Development Board*, 108 p, unpublished
- Bautista, B.C., Bautista, L.P., Marcial, S.S., Melosantos, A.A. and Hadley, K.C., 1991. Instrumental monitoring of Mount Pinatubo Lahars, Philippines. *EOS Trans. AGU, 72, Fall Meeting, Abstracts*, p. 63.
- Baybayan, N.Q. and Matos, A.M., 1986. Geology of Masbate Island, Central Philippines. *Bureau of Mines and Geosciences*, 104 p., unpublished.
- BED, (Bureau of Energy Development, Philippines), 1986a. Sedimentary Basins of the Philippines, their Geology and Hydrocarbon Potential, v. 2 (Luzon Basins), 436 p.
- BED, 1986b, Sedimentary Basins of the Philippines, their Geology and Hydrocarbon Potential, v. 3 (Basins of Visayas and Mindanao), 305 p.

- BED, 1986c, Sedimentary Basins of the Philippines, their Geology and Hydrocarbon Potential, v. 4 (Basins of Sulu Sea, Palawan and Mindoro), 219 p.
- BED-JICA (Bureau of Energy Development-Japan International Cooperation Agency), 1981. Report on Buguias geothermal development, Phase I: *BED Report No. 12*, MPN.
- BEICIP (Bureau d'Etudes Industrielles et de Cooperation de l'Institute Francais de Petrole), 1976. *The Hydrocarbon Potential of the Central Luzon Basin, Philippines,* unpublished.
- Bellon H and Rangin C, 1991, Geochemistry and Isotopic Dating of Cenozoic Volcanic Arc Sequences around the Celebes and Sulu Seas, In , Silver, E.A., Rangin, C. von Breymann M.T. and others (eds), Proceedings of the Ocean Drilling Program, Scientific Results. 124, 321-338.
- Ben-Avraham, Z., Bowin, C. and Segawa, J., 1972. An extinct spreading centre in the Philippine Sea Plate. *Nature*, 240, 453-455.
- Berador, A. E. G. and Aleta, D. A., 1991, Geological exploration of chromite deposits in barangay San Antonio, Duero, Bohol. *Mines and Geosciences Development Service-DENR* 7, 12 p., unpublished.
- Billedo, E. B. 1994. Geologie de la Sierra Madre septentrionale et de l'archipel de Polillo (ceinture Mobile Est Philippine): implications geodynamiques. PhD Thesis. Institute of Geodynamics, University of Nice-Sophia Antipolis, 272 p.
- Bischke, R.E., Suppe, J. and del Pilar, R., 1988. Implications of a newly discovered branch of the Philippine Fault. In: Int'l. Symp. Geodynamic Evolution of Eastern Eurasian Margins. Abstracts. Paris, 1988, p. 29.
- Bischke, R. E., Suppe, J. and Del Pilar, R., 1990. A new branch of the Philippine Fault system as observed from aeromagnetic and seismic data. *Tectonophysics*, **183**, (1-4), 243-264.
- Blome, C.D., 1985. US Geological Survey report on referred fossils, shipment no. 0-85-100, 6 p.
- Blow, W.H., 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. *Proc.* 1st Conf. on Planktonic Microfossils, Geneva (1967). Bronnimann, P. and Renz, H.H. (eds.), Vol. 1.
- BMG (Bureau of Mines and Geosciences, Philippines), Mineral Fuels Division, 1976. A review of oil exploration and stratigraphy of sedimentary basins of the Philippines. - UN/ESCAP, CCOP Tech. Bull., **10**, 55-93.
- BMG (Bureau of Mines and Geosciences, Philippines). 1981. *Geology and Mineral Resources of the Philippines, 1(Geology).* BMG, Ministry of Natural Resources, Manila, 406 p.
- BMG, 1977. Geology and Mineral Resources of Agusan Province. *Geological Survey Division*, unpublished.
- BMG, 1987. Geologic Map of Jagupit and Alegria Quadrangles.
- BMG, 1985. Geological Map of Bangui Quadrangle
- BMG, 1985. Geological Map of Pasuquin Quadrangle
- BMG, 1984, Geologic map of Busuanga, New Busuanga quadrangles.
- BMG, 1987, Geologic map of Nasuedan, Babuyan, Caruray Tinitian and Caramay quadrangles.
- Bravo A.A., 1976. Semidetailed geological report of the Tacloban and Sta. Rita quadrangles, Bureau of Mines, unpublished.

- Bravo, A.A., Gonzales, E., Cruz, S., Raval, R., 1982. Preliminary interpretation of the marine geophysical data in Leyte Gulf, Surigao Strait and Dinagat Sound, *Bureau of Mines and Geosciences*, 18 p., unpublished.
- Briais, A., 1989. Cinématique d'ouverture de la Mer de Chine du Sud (Nanhai): implications pour la tectonique tertiaire de l'Asie. *Thèse de doctorat*, Université Pierre et Marie Curie, Paris 6, France, 239 p.
- Briais, A., Tapponier, P., Patriat, R., Lacassin, R., Leloup, H., Shaerer, U., Zhong, D. and Wang, K., 1988. The Tertiary opening of the South-China Sea Basin and other extensional basins of the Sunda Shelf: A consequence of the collision between India and Asia. *In: Int. Symp. Geodynamic Evolution of Eastern Eurasian Margins*, Abstracts. Paris, France, p. 33.
- Briais, A., Tapponier, P. and Pautot, G., 1989. Constraints of Sea Beam data on crustal fabrics and seafloor spreading in the South China Sea. *Earth Planet. Sci. Lett.*, 95, 307-320.
- Brown, G.F., 1938. Geology and coal resources of Sibuguey Peninsula, Mindanao, Philippines. *Philippine Bureau of Mines,* unpublished.
- Brown, G.F., 1950. Summary of the Geology of Malangas-Sibuguey Coalfield, Zamboanga Province, Mindanao, Philippines. *Phil. J. Science.* **79** (2)
- Bruinsma, J.W., 1983. Results of Potassium-Argon age dating on twenty rock samples from the Pinatubo, southeast Tongonan, Bacon-Manito, Southern Negros and Tongonan Leyte Area, Philippines. *Report No. 1291* prepared by Robertson Research Private Limited (Singapore), for Philippine National Oil Company, Energy Development Corporation. (Project No. S/III/834/80), 26 p.
- Buchsel, P, Kerntke, M., Wolcke, F and Hillmer, G., 1991. Geologic development of Cebu Island/Central Philippines-Group report, Central Philippines: Mapping, Mining, Modern Reefs, *Mitteilungen aus dem Geologisch-Palaontologischen Institut der Universitat Hamburg*, **71**, p.53-60.
- Bureau of Mines, 1963. *Geologic Map of the Philippines.* 1:1,000,000 *scale*, 9 sheets. Bureau of Mines, Manila.
- Bureau of Mines Petroleum Division, 1966. A Review and Assessment of Oil Exploration in the Philippines, **1**, 193 p.
- Bureau of Mines Petroleum Division, 1975. A Review of Oil Exploration and Stratigraphy of Sedimentary Basins in the Philippines, **2**, 95p.
- Burton, C.K., 1982. The geological and tectonic environment of the mineral deposits of southwest Negros, In Caguiat, A.O., Punongbayan, R.S., Domingo, R.A., Reyes, M.V. and Maceda, R.N. (eds), *Proceedings of the seminar on developing new open pit mines in the Philipp*ines, UPGAA, October 7-8, 1982, Manila,
- Burton, C.K., 1985. Geology of the Polillo Group of Islands. *Phil. Geologist*, **39**, 14-26.
- Caagusan, N.L., 1981. Late Tertiary stratigraphy, paleogeograhy and paleostructures of the Cagayan Basin, Philippines Geology and tectonics of the Luzon-Marianas region. *Phil. Seatar Committee,* Sp. Publ., 119-131.
- Caagusan, N. L., 1978. Stratigraphy of the Cagayan Valley Basin. *PNOC,* unpublished.

- Caagusan, N.L., 1977. Source material, compaction history and hydrocarbon occurrence in the Cagayan Valley Basin, Luzon, Philippines. Offshore South East Asia Conf.
- Caagusan, N.L., 1966. Petrography of the metamorphic rocks of northern Mindoro. *Bull. Inst. Filipino Geologists* **1**, 22-46.
- Cabantog, A.V. and Escalada, P.P., 1989. Geology of Tacloban Ophiolite (Abstract). Mines and Geosciences Bureau Annual National Geological Seminar, Jan. 11-13, 1989, Petrolab, Q.C.
- Cabantog, A.V. and Quiwa, N.D., 1982. Geology of massive sulfide deposits, Casandig sheet, Lawaan area, Wright, Samar Island. *Bureau of Mines and Geosciences,* unpublished.
- Cabrera, R. C., 1983. Progress report on the semi-detailed geological quadrangle mapping and mineral canvassing of southern Palawan. Bureau of Mines and Geosciences Regional Office No. 4, unpublished.
- Cabrera, R. C., 1985. Geology of Bulaloc, Canipan, Candian Point, Tarusan, Sapa and Katipunan quadrangles. *Bureau of Mines and Geosciences*, unpublished report.
- Caguiat, A.O., 1967. Geology and oil possibilities of PECs 107, 177 and 214, northeast Negros. *Anglo-Philippines Oil Corp.*, unpublished.
- Calomarde, R. I., 1987. Geology, geomorphoplogy and relief development study of Larena-Maria-Lazi-Siquijor area, Siquijor Province. *Bureau* of *Mines and Geosciences*, unpublished.
- Capistrano, P.M. 1946. Report on the geological reconnaissance of Cagayan de Oro quadrangle. *Phil Bureau of Mines,* unpublished.
- Capistrano, P.M., 1953. Geology and copper deposits of Pilar area and vicinity: *Philippine Bureau of Mines,* unpublished.
- Capistrano, P.M. & Magpantay, A.L., 1958. Geology and Mineral Resources of the Southern Segment of the Eastern Range of Panay, *Phil. Geologist*, **13** (1).
- Cardwell, R.K., Isacks, B.L., and Karig, D.E., 1980. The spatial distribution of earthquakes, focal mechanism solutions and subducted lithosphere in the Philippine and northeastern Indonesian Islands. In: Hayes, D.E. (ed.) *The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Part 1*. Am. Geophys. Union Monograph, 23, 1-35.
- Carozzi, A.V., Reyes, M.V. and Ocampo, V.P., 1976. Microfacies and Microfossils of the Miocene reef carbonates of the Philippines. *Phil. Oil Development Company, Inc. Special Publication No. 1.*
- Casasola, A.G., 1956. The petroleum and geological investigation of western Davao. *Phil. Geologist*, **10 (**3), 76-88.
- Casasola, A.G., 1956, Geological reconnaissance of southern Palawan. *Phil. Geologist.* 10 (4), 89-97.
- Castaneda, G., Momongan, A. and Luis, R. M., 1976. Reconnaissance geologic investigation of Pulangi River Damsite No. 3 in Barrio Lumbayao, Valencia, Bukidnon, Mindanao. *Bureau of Mines and Geosciences*. Unpublished.
- Castillo, P.R. and Escalada, P.P., 1979. *Geology of Southwestern Negros Island.* Phil. Bureau of Mines Technical Information Series No. 4-79, 22p.
- Catane, S. and Arpa, C.B., 1999. Recent volcanism associated with Laguna caldera, southwest Luzon, Philippines, *Abstracts*, Joint meeting on comparative studies of island arc seismicity and volcanism in the western Pacific region. *JGSP*, **54**, 70-71.2.1.9.9

- Chamot-Rooke, N., Vigny, C., Rangin, C., Walpersdorf, A., Le Pichon, X. and Huchon, P., 1997. Sundaland motion detected from Geodyssea GPS measurement, Part I: Implications for motion at Sunda Trench. *In Abs. and Progs.: GEODYSSEA Concluding Symp.*, Penang, Malaysia, 14-18 April.
- Chase, C.G., 1978. Plate kinematics: The Americas, East Africa, and the Rest of the World. *Earth Planet. Sci. Lett.*, 37, 355-368.
- Cheng, Y., 1989. Upper Paleozoic and Lower Mesozoic radiolarian assemblages from the Busuanga Islands, North Palawan Block, Philippines. *Bull. National Mus. Nat. Sci. (Taiwan)* **1**, 129-175.
- Christian, L.B., 1964. Post-Oligocene tectonic history of the Cagayan Basin, Philippines. *The Philippine Geologist*, 18 (4), 114-1147.
- Chu, H.T., 1990. Neotectonique cassante et collision plio-quaternaire à Taiwan. *Thèse de doctorat*, Université Pierre et Marie Curie, Paris 6, France, 292 p.
- Clague, D.A. and Jarrard, R.D., 1973. Tertiary Pacific plate motion deduced from Hawaiian-Emperor Chain. *Geol. Soc. Am. Bull.*, 84, 1135-1154.
- Claveria, R., Jr. 1980. Geology of Parts of Davao del Sur,, *Bureau of Mines and Geosciences, Surigao City,* unpublished.
- Cole, J., McCabe, R., Moriarty, T., Malicse, J.A., Delfin, F.G., Tebar, H and Ferrer, H.P., 1989. A preliminary Neogene paleomagnetic data set from Leyte and its relation to motion on the Philippine Fault. *Tectonophysics*, 168, 205-221.
- Comvol (Commission on Volcanology), 1981. Catalogue of Philippine Volcanoes and Solfataric Areas.
- Cooper, A.K., Scholl, D.W. and Marlow, M.S., 1976. Mesozoic magnetic lineations in the Bering Sea marginal basin. *J. Geophys. Res.*, 11, 1916-1934.
- Corby, G. W., Kleinpell, R.M., Popenoe, W.P., Merchant, R., William, H., Teves, J., Grey, R., Daleon, B., Mamaclay, F., Villongco, A., Herrera, M., Guillen, J., Hollister, J.S., Johnson, H.N., Billings, M.H., Fryxell, E.M., Taylor, E.F., Nelson, C.N., Birch, D.C., Reed, R.W. and Marquez, R., 1951. Geology and Oil Possibilities of the Philippines. *Technical Bulletin 21*, Bureau of Mines, DANR, 365 p.
- Cosico, R., Gramann, F. and Porth, H., 1989. Larger foraminifera from Visayan Basin and adjacent areas of the Philippines (Eocene through Miocene), *Geologisches Jahrbuch Reihe B, Heft* **70**. 147-206.
- Cox, A. and Engerbretson, D., 1985. Change in the motion of Pacific Plate at 5 Myr BP. *Nature*, **331**, 472-474.
- Crispin, O. A. and Fuchimoto, H., 1980. K-Ar dating of some Philippine rocks. *Geology and Paleontology of Southeast Asia*, **21**, p. 93-100.
- Cruz, A.J., 1956. Geologic reconnaissance survey of Bohol for cement raw materials. *Phil. Bureau of Mines*, unpublished.
- Cruz, A.J.. and Lingat, P.H. 1966. Geologic investigation of Buruanga Peninsula for marble. *Bureau of Mines*, 49 p., unpublished report,
- Cruz, J.B., 1987. Volcanism and associated hazards in the Philippine setting. *In: Geologic Hazards and Preparedness Systems*, Philippine Institute of Volcanology and Seismology, National Science and Technology Authority, Manila, 22-37.
- Culala, L.R., Jr., 1987. Exploration and geology of the Hijo gold project *in "Gold 87 in the Philippine Setting" Proceedings* **1**, p. 42

- Culp, B.L. and Madrid, A.P., 1967. Geology of Guimaras Island, Visayan Exploration Co., Inc., unpublished
- Curray, J.R., Emmel, F.J., Moore, D.G. and Raitt, R.W., 1982. Structure, tectonics, and geological history of the northeastern Indian Ocean. *In: A.E. NAIRN and F.G STEHLI, The Indian Ocean*, New York, Plenum Press, 6, 399-450.
- Custodio, D. G., 1973. Progress report on the traverse route of Team D in south-eastern Mindanao. *Bureau of Mines.* unpublished.
- Daligdig, J.A. 1997. Active faulting and paleoseismicity of the PFZ, north central Luzon, Philippines. *D.Sc. Diss.* Kyoto University, Japan, 155 pages.
- Daligdig, J.A., Punongbayan, R.S., Besana, G.M. and Tungol, N.M., 1997. The Marikina Valley Fault System: active faulting in Metro Manila. *PHIVOLCS Professional Paper 01*, PHIVOLCS Press, Quezon City, 20 p.
- Dario, J., 1987. Géologie et pétrologie de l'archipel Babuyan et des monts Tabungon et Cagua Nord Luzon, Philippines. *Thèse de doctorat*, Université de Bretagne Occidentale, France, 1, 233 p., 2, 147 p.
- Datuin, R. T. and Uy, F. L., 1979, Quaternary volcanism and volcanic rocks of the Philippines, unpublished.
- David, S.D. Jr., 1997. Morphologic and morphostructural analysis of southwest central Luzon, Philippines. *Postdoctoral Report*, Universite de Nice-Sophia Antipolis, Geosciences Azur (UMR 6526) Nice, France.
- David, S.D., Jr., 1994. Contributions a l'etude geodynamique ante-Neogene de la Ceinture Mobile Est Philippines, Ph.D. Thesis, University of Nice-Sophia Antipolis, 352 p.
- David, S,D., Jr., 1988. Geology of Panay Island. *Mines and Geosciences Bureau*. unpublished.
- David, P.P., 1982. Some Larger Foraminifera of Negros Occidental. *Bureau* of *Mines and Geosciences*. unpublished.
- David, P. P. and Fontaine, H., 1986. Eocene limestone offshore northeast Palawan Island, *The Philippine Geologist*, **40** (2), 36-40.
- David, S. D., Jr., Stephan J., Deleteil, J., Muller, C., Butterlin, J. 1994. The Tabgon flysch and Ragas Point olistostrome in the Caramoan Peninsula: nature, age, structure and their tectonic implication. *J. Geol. Soc. Phil.* **49** (1), 41-63.
- De Boer, J. Odom, L.A., Ragland, P.C., Snider, F.G., and Tilford, N.R., 1980. The Bataan orogene: eastward subduction, tectonic rotations and volcanism in the western Pacific. *Tectonophysics* **67**, 251-282.
- Defant, M.J., De Boer, J.Z., and Oles, D., 1988. The western Central Luzon volcanic arc, the Philippines: two arcs divided by rifting? *Tectonophysics* **145**, 305-17.
- Defant, M.J. and Drummond, M.S., 1990. Derivation of some modern arc magmas by melting of young subducted lithosphere. *Nature*, **347**, 662-664.
- Defant, M., J., Jacques, D., Maury, R., Boer, J., and Joron, J., 1989. Geochemistry and tectonic setting of the Luzon arc, Philippines: *Geol. Soc. America Bull.*, **101**, 663-672.
- Defant, M., Maury, R., Joron, J., Feigenson, M., Leterrier, J., Bellon, H., Jacques, D., and Richard, M., 1990. The geochemistry and tectonic setting of the northern section of the Luzon arc (the Philippines and Taiwan): *Tectonophysics*, **183**, 187-205.

- Defant, M.J., Maury, R.C., Ripley, E.M., Feigenson, M.D., and Jacques, D., 1991. An example of island-arc petrogenesis: Geochemistry and petrology of the southern Luzon arc, Philippines. *J. Petrol.* **32**, 455-500.
- De Guzman, R.A., 1963. Preliminary report on the geology of western Albay and portions of north-central Albay, *Phil. Bureau of Mines*. unpublished.
- De la Rosa, S. C., and others, 1978. Geology and mineral resources of Dona Remedios Trinidad municipality, Bulacan: *Phil. Bureau of Mines Regional Office IV*, unpublished.
- De Leon, M.M. and Militante-Matias, P.J. 1992. Calcareous nannofossil biostratigraphy of the western part of Tarlac province, Central Luzon Basin, *J. Geol. Soc. Phil.* **47**, 35-65.
- De Leon, M.M, Tamesis, E.V. and Militante-Matias, P.J., 1991. Calcareous nannofossil study of the Klondyke Formation section along km. posts 278-251, Marcos Highway, Baguio City - Pugo, La Union province. J. Geol. Soc. Phil., 46, (3-4), 35-49.
- De los Santos, R.B., 1982. Geology of the Southwestern Baguio District. Bureau of Mines and Geosciences Technical Information Series, Geology No. 53, 17 p.
- De los Santos, V. & Spences, F., 1957: Geology and coal resources of Central Polillo Island, Quezon. *Phil. Bureau of Mines,* unpublished.
- De los Santos, V., 1959, Preliminary report on the geology and mineral resources of central Palawan. *Phil. Geologist*, **13** (4), 104-141.
- De Villa, E. M., 1941, Contribution to the geology of Palawan: *Industrial Journal*, **12**, (5).
- Deffontaines, B. and Pubellier, M. (1990). New structural data of Agusan-Davao basin from drainage network analysis (Mindanao, southern Philippines). In: Orogenesis in Action: tectonics and processes in the west equatorial Pacific margin, London, April 18-20, 1990.
- Delfin, F.G., Jr., 1991. *Petrogenesis of Mt. Bulusan Volcanic Complex, Bicol Arc, The Philippines.* MS Thesis, University of South Florida, 124 p.
- Delfin, F.G., Jr., and Alincastre, R.S. 1988. Geology of Del Gallego (Mt. Labo) Geothermal Prospect. PNOC-EDC Internal Report, unpublished.
- Delfin, F.G., Jr., Newhall, C.G., Martinez, M.L., Salonga, N.D., Bayon, F.E.B., Trimble, D. and Solidum, R., 1997. Geological ¹⁴C and historical evidence for a 17th century eruption of Parker Volcano, Mindanao, Philippines. *J. Geol. Soc. Phil.*, **52**, 25-42.
- Delfin, F.G., Panem, C.C., and Defant, M.J., 1993. Eruptive history and petrochemistry of the Bulusan Volcanic Complex: Implications for the hydrothermal system and volcanic hazards of Mt. Bulusan, Philippines. *Geothermics*, **22**, p.417
- Dewey, J.F., 1976. Ophiolite obduction. *Tectonophysics*, 31, 93-120.
- Dickerson, R.E., 1923. The development of Baguio Plateau: a study in historical geology and physiography in the tropics, *Phil. J. Sci.* 23 (5), 413-453.
- Diegor, W.G., 1980. Geology of the Baguio Mineral District. *Bureau of Mines and Geosciences Technical Information Series No. 13-80*, Manila, 12 p.

- Diegor, W. G. and Matos, A. M., 1986, Tectonic implications of the RP-Japan Project area. Part I., *Mines and Geosciences Bureau*, 27p., unpublished
- Diegor, W. G., Momongan, P. C. and Mamaril-Diegor, E. J., 1996. The ophiolitic basement of Cebu. *J. Geol. Soc. Phil.*, **51**, (1-2), 48-60.
- Diegor, W. G., Aleta, D. A., Berado, A. E. G., Lucero, A. R., Jr., Miel, J. Z. and Aleta, J. T., 1996. Field evidence of the southeast Bohol Ophiolite Complex. *J. Geol. Soc. Phil.*, **51**, (1-2), 61-72.
- Dimalanta, C.B., Tamayo, R.A., Jr. and Ramos, E.G.L., 2004. Geophysical, geological and geochemical investigations of the arc-continent collision zone in the Romblon, Tablas and Sibuyan islands, Romblon Province, *PCIERD Project Progress Report*, unpublished.
- Divis, A.F., 1983. The geology and geochemistry of Philippine porphyry copper deposits. *In: D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Part II*, A.G.U. Monograph 27, 176-216.
- Domingo, E.G., 1977. Reconnaissance geological survey of Cabanbanan area, Cauayan, Negros Occidental. *Phil. Bureau of Mines,* unpublished.
- Drasche, Richard von, 1878. Fragments zu einer geologie der Insel Luzon (Philippinen), mit einen anhange über die Foraminiferen der tertiaren Thone von Luzon. Vienna, 99p.
- Duna, B. G., 1968. Preliminary report on the geochemical and geological survey of Masbate forest reservation: *Philippine Bureau of Mines,* unpublished report.
- Duquesnoy, Th., 1997. Contributions de la géodésie à l'étude de grands décrochements actifs associés à des zones de subduction à convergence oblique. *Thèse de docteur en sciences*, Univ. Paris XI, Orsay.
- Duquesnoy, Th., Barrier E., Kasser M., Aurelio M.A., Gaulon R., Punongbayan R.S., Rangin C. & the French-Filipino Cooperation Team. 1994. Detection of creep along the Philippine Fault: first results of geodetic measurements in Leyte Island, central Philippines: *Geophys. Res. Lett.*, 21 (11), 975-978.
- Durkee, E. F. and Pederson, S. L., 1961. Geology of northern Luzon. Am. Assoc. Pet. Geol. Bull. 5, (2), 138-168.
- Easton, W. H. and Melendres, M. M., 1959. The first Paleozoic fossil from Mindoro, Philippine Archipelago: *Nat. & Applied Sci. Bull.*, **18**, p. 229-232.
- Eguchi, T., 1984. Seismotectonics around the Mariana Trough. *Tectonophysics*, 102, 17-32.
- Encarnacion, J. and Mukasa, S.B., 1997, Age and geochemistry of an "anorogenic" crustal melt and implications for I-type granite petrogenesis. *Lithos*, **42**, 1-13.
- Encarnacion, J. P., Mukasa, S. B. and Obille, E. C. Jr., 1993. Zircon U-Pb geochronology of the Zambales and Angat ophiolites, Luzon, Philippines: evidence for an Eocene arc-back arc pair. *J. Geophys. Res.*, **98**, 19,991-20,004.
- Encina, R.Y. and Del Rosario, E., 1978. Activity report on the semi-detailed and stratigraphic studies of a portion of the Baguio Mineral District, Benguet Province. *Bureau of Mines and Geosciences,* unpublished.
- Esperidon, J.A., Milanes, F.S.J., Jacinto, M.L.J., Madrona, J.D. and Ang, V.C., 1978. Progress report on the reconnaissance geological

survey and geochemical sampling of Cabadbaran Quadrangle, Agusan del Norte. - *Philippine Bureau of Mines and Geosciences Region X,* unpublished

- ESCAP (Economic and Social Commission for Asia and the Pacific), 1978. Atlas of Stratigraphy I: Stratigraphic Correlation between Sedimentary basins of the ESCAP Region, vol. 5, *Mineral Resources Development Series, No. 44*, 58 p.
- Faure, M. and Ishida, K., 1990. The Mid-Upper Jurassic olistostrome of the west Philippines: a distinctive key-marker for the North Palawan block. *Journal of Southeast Asian Earth Sciences*, 4, (1), 61-67.
- Faure, M. and Ishida, K., 1988. The Middle-Late Jurassic Olistostrome of west Philippines. A distinctive criteria for the north Palawan Block. Universite D'Orleans, France, 26 p.
- Faure, M,, Marchadier, Y., and Rangin, C., 1989. Pre-Eocene metamorphic structure in the Mindoro-Romblon-Palawan area, west Philippines, and implications for the history of Southeast Asia. *Tectonics*, 8 (5), 963-979.
- Faustino, D.V., Yumul, G.P., Jr., De Jesus, J.V., Dimalanta, C.B., Aitchison, J.C., Zhou, M-F, Tamayo, R.A., Jr. and De Leon, M.M., 2003. Geology of southeast Bohol, central Philippines: accretion and sedimentation in a marginal basin. *Australian J. Earth Sci.*, **50**, 571-583.
- Feliciano, V. M. and Basco, D. M., 1947. Preliminary geologic report of the Mansalay district, Mindoro. *Phil. Geologist*, **1**, (3), 1-11.
- Ferguson, H.G., 1911. The geology and mineral resources of the Aroroy district, Masbate. *Phil. Jour. Sci.*, Sec. A, **6** (5).
- Fernandez, H.E. and Damasco, F.V., 1980. Gold deposition in the Baguio Gold District and its relationship to regional geology. *J. Geol. Soc. Phil.*, **34**, (3), 1-27.
- Fernandez, J.C. & Abarquez, O., 1967: Report on the regional geology of Polillo Island Group, Quezon. *Phil. Bureau of Mines*, unpublished.
- Fernandez, J. C. and Pulanco, D. H., 1964. Preliminary report on reconnaissance geology of northwestern Luzon. *Mines and Geosciences Bureau*, unpublished.
- Fernandez, J. C. and Pulanco, D. H., 1967. Reconnaissance geology of northwestern Luzon, Philippines. Proc. 2nd National Convention and First Symposium on the Geology of the Mineral Resources of the Philippines and Neighboring Countries, Geol. Soc. Phil., Jan. 11-14, 1967, 1, 35-45.
- Fernandez, J.C., Vera Cruz, B., Estupigan, P. and Abarquez, O, 1967. Preliminary report on the regional geology of Polillo Island Group, Quezon. *Phil. Bureau of Mines*, unpublished.
- Fernandez, M.V., Revilla, A.P. & David, S., Jr., 1994. Notes on the Cretaceous Carbonates in Catanduanes island and Caramoan Peninsula, Philippines. *J. Geol. Soc. Phil.*, **49** (4), 241-261.
- Fitch, T.J., 1972. Plate convergence, transcurrent faults, and internal deformation adjacent to Southeast Asia and the Western Pacific. *J. Geophys. Res.*, 77 (23), 4432-4460.
- Florendo, F.F., 1987. The tectonic framework and the Cretaceous to Cenozoic evolution of the East-Central Philippines. *Masteral Thesis in Geology*, The Graduate School of the University of Tulsa, Okla. U.S.A., 103 p.

- Florendo, F.F., 1981. Preliminary report on the geology, geotectonic development and mineralization of western Panay. *Bureau of Mines and Geosciences, Region VII*, unpublished.
- Fontaine, H., 1978. Preliminary notes on a Pre-Tertiary geological study of the Philippines, United Nations, ECAFE, CCOP News letter, 5, (1-2), 22-23.
- Fontaine, H. 1979. Note on the Geology of the Calamian Islands, North Palawan, Philippines, *ESCAP- CCOP Newsletter*, **6** (2), 40-47.
- Fontaine, H., David, P. and Tien, N., 1983. A note on the northwest Panay-Tablas area. *Bureau of Mines and Geosciences*, 14 p., unpublished.
- Foronda, V. J., 1994. Sequence stratigraphy of an Oligocene-Miocene mixed siliciclastic-carbonate system, Visayan Basin, central Cebu, Philippines. Doctoral thesis, Rheinischen Friedrich-Wilhelms-Universitat Bonn, Germany, 152 p.
- Foronda, J.M. and Schoell, W., 1987. Microfacies types of the Binangonan Formation, Antipolo-Teresa, Rizal Province. *J. Geol. Soc. Phil.*, **41**, 40-78.
- Förster, H., Oles, D., Knittel, U., Defant, M.J. and Torres, R.C., 1990. The Macolod Corridor: A rift crossing the Philippine island arc. *Tectonophysics* **183**, 256-271.
- Francisco, F.U., 1956. The pre-Tertiary rocks of Buruanga Peninsula, Panay Island, Philippines. *Proc.* 8th Pacific Sci. Congress, v. 2, 482-499.
- Francisco, F.U. and Comsti, F.A., 1952. Limestone and Guano resources of southern Cotabato and Maramag, Bukidnon, *Phil. Geologist.*, **6** (2), 26-36.
- Franco, H.E.A., Nakagawa, M, Esguerra, Jr., E., Lazo, F.B., Domingo, E.G. and Togashi, Y., 1993. Platinum-group minerals in laterite overlying the ultramafic massif in eastern Samar and Dinagat Island, Philippines. *Resource Geology Special Issue*, no. 15, 149-156.
- Froehlich, H.A. and Melendres M., 1960. Summary and geology of Cotabato, unpublished.
- Frost, J.E., 1954. Notes on the genesis of the ore-bearing structures of the Paracale District, Camarines Norte, Philippines. *Phil. Geologist*, **13** (2), 31-42.
- Fuller , M., Haston, R., Lin, J-L., Richter, B., Schmidtke, E. And Almasco, J., 1991. Tertiary paleomagnetism of regions around the South China Sea. J. SE Asia Earth Sci., 6, 161-184.
- Gamboa, M. M., 1977. A geologic report on the Tagbita silica project. Tagbita Silica Industries Corporation, Silica Sand Project, unpublished.
- Garcia, J.S., Jr., 1991. Geology and mineralization characteristics of the Mankayan Mineral District, Benguet, Philippines. *Geol. Soc. Japan Report No.* 277, 21-30.
- Garcia, J.S., Jr, and Bongolan, M. B., 1990. Developments in enargite ore search at Lepanto, Mankayan, Benguet, Philippines. *Lepanto Cons. Min. Co.,*.unpublished.
- Garcia, M.V. and Mercado, J.M.O., 1981. Geology and mineral resources of Samar and Leyte Islands. *Phil. Bureau of Mines and Geosciences,* unpublished.
- Garcia, C.L., Valenzuela, R., Arnold, E.P., Macalinag, T.G., Ambubuyog, G.F., Lance, N.T., Cordeta, J.D., Doniego, A.G., Dabi, A.C., Balce,

G.R. and Fr. Su, S.,1985 Series on Seismology : Philippines. In: Arnold, E.P. (ed.), *Southeast Asia Association of Seismology and Earthquake Engineering*, **4**, 792-743.

- Garrison, R.E., Espiritu, E.A., Horam, L.S. & Mack, L.E., 1979. Petrology, sedimentology and diagenesis of hemipelagic limestone and tuffaceous turbidites in the Aksitero Formation, Central Luzon, Philippines. US Geol. Survey Prof. Paper 1112, 16 p.
- Gealey, W. K., 1980. Ophiolite obduction mechanism In: A. Panayiotou (ed.), *Ophiolites-Proceedings of the International Ophiolite Symposium, Cyprus (1979),* Geological Survey Dept., Cyprus, 228-243,
- Geary, E. E., 1986. Tectonic significance of basement complexes and ophiolites in the Northern Philippines: Results of geological, geochronological and geochemical investigations. *Doctoral Thesis*, Cornell University, Ithaca, New York.
- Geary, E.E., Harrison, T.M. and Heizler, M., 1988. Diverse ages and origins of basement complexes, Luzon, Philippines. *Geology*, **16**, 341-344.
- Geary, E.E., Kay, R.W., Reynolds, J.C. and Kay, S.M., 1989. Geochemistry of mafic rocks from the Coto Block, Zambales Ophiolite, Philippines: Trace element evidence for two stages of crustal growth. *Tectonophysics* 168, 43-63.
- Geological Survey Section-Mines and Geosciences Regional Office X, 1981. Geology and Mineral Resources of Davao del Norte. unpublished.
- Geological Survey Section Mines and Geosciences Regional Office XI. 1992. Geology and Mineral Resources of South Cotabato, *Technical Information Series No. 5.*
- Gervasio, F. C., 1971. Geotectonic development of the Philippines. J. Geol. Soc. Phil., 25, (1) 18-38.
- Gervasio, F.C., 1970. *Geological map of Marinduque*: Philippine Bureau of Mines.
- Gervasio, F.C., 1967. Age and nature of orogenesis in the Philippines. *Tectonophysics*, 4 (1), 379-402.
- Gervasio, F.C., 1966. Age and nature of orogenesis in the Philippines. J. Geol. Soc. Philippines, 29 (4), 1-19.
- Gervasio, F. C., 1958. The geologic structure of Marinduque Province and their relation to ore localization. *Phil. Geologist*, 12 (3), 85-90.
- Geshwind, C-H., and Rutherford, M.J., 1992. Cummingtonite and the evolution of the Mt. St. Helens (Washington) magma system and experimental study. *Geology* **20**, 1011-1014.
- Giese, U., Knittel, U., Kramm, U., 1986. The Paracale Intrusion: geologic setting and petrogenesis of a trondhjemite intrusion in the Philippine Island Arc. J. Southeast Asia Earth Sci., 1 (4), 235-245.
- Gonzales, B.A., Ocampo, V.P. and Espiritu, E.A., 1971. Geology of Southeastern Nueva Ecija and Eastern Bulacan Provinces, Luzon Central Valley, *J. Geol. Soc. Phil.*, **25** (2), 1-41
- Gonzales, B. A., Martin, S. G. and Espiritu, E. A., 1978. Onshore stratigraphy of Philippine Tertiary Basins. UN-ESCAP, Mineral Resources Dev. Series No. 44, 33-44.
- Gramann, F., 1982. Micropaleontological report, Negros. unpublished.

- Gradstein, F.M., Ogg, J.G., Smith, A.G., Bleeker, W., Lourens, L.J., 2004. A new Geologic Time Scale with special reference to Precambrian and Neogene, *Episodes*, **27** (2), 83-100.
- Grey, R. R., 1954. Eccene in the Philippines. Phil. Geologist, 8, (3), 53.
- Gwinn, J.W., Melendres, M.N. and Williams, R.L., 1959. Geology and petroleum prospects of the Luzon Central Valley, Philippines. San Jose Oil Co., Inc., 32 p., unpublished,
- Haeck, G.D., 1987. The geological and tectonic history of the central portion of the southern Sierra Madre, Luzon, Philippines. PhD Thesis, Cornell Univ., NY, 294 p.
- Hamburger, M., Cardwell, R.K. and Isacks, B.L., 1983. Seismotectonics of the Northern Philippine Island arc. In:D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Sea and Islands. Part 2. A.G.U. Monograph 27, 1-22.
- Hamilton, W., 1979. Tectonics of the Indonesian region. U S Geological Survey, Professional Paper, no. 1078, 345 p.
- Hamilton, W., 1977. Subduction in the Indonesian region. In : Talwani, M. and Pitmann, W.C. III, Eds., Island arcs, deep sea trenches, and back-arc basins, *Maurice Ewing Series, 1, AGU*, Washington, D.C., p.15-31.
- Hanzawa, Shosiro and Hashimoto, Wataru, 1970. Larger Foraminifera from the Philippines, In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia*, **8**, 187-230.
- Hart, S.R., 1984. A large scale isotopic anomaly in the southern hemisphere mantle. *Nature* **309**, 753-757.
- Hashimoto, W., 1981. Geologic development of the Philippines, In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia,* **22**, 83-170.
- Hashimoto, W., 1981. Supplementary notes on the geologic development of the Philippines, In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia*, 22, 171-190.
- Hashimoto, W., 1975. Larger foraminifera from the Philippines, Part IV -Larger foraminifera from Mountain Province. In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia* 16, 127-139.
- Hashimoto, W., 1939. Stratigraphy of the Philippines. *Jubillee Publ. in Commemoration of Prof. H. Yabe's 60th Birthday,* 381-426.
- Hashimoto, W., Alcantara, P.M., Aoki, N., Balce, G.R., David, P.P., 1978. Nummulites from the Lubingan crystalline schist of Bongabon, Nueva Ecija and their significance on the geologic development of the Philippines. *Proc. Japan Acad.* **54** (11) ser. B, 1-4.
- Hashimoto, W., Aoki, N., David, P.P., Balce, G.R. and Alcantara, P.M., 1978. Discovery of Nummulites from the Lubigan Schist exposed east of Bongabon, Nueva Ecija, Philippines, and its significance in the geologic development of the Philippines. *Geology and Paleontology of Southeast Asia*, 19, 57-63.
- Hashimoto, W. and Balce, G. R., 1977. A new correlation scheme for the Philippine Cenozoic formations. *Proceedings of the First International Congress on Pacific Neogene Stratigraphy, Tokyo,* 1976, p. 119-132.
- Hashimoto, W., Kitamura, N., Balce, G.R., Matsumaru, K., Kurihara, K., and Aliate, E., 1979. Larger Foraminifera from the Philippines, Pt. X. Stratigraphic and Faunal breaks between the Maybangain and

Kinabuan Formations in the Tanay Region, Rizal, Phils., In: T. Kobayashi, R. Toriyama and W. Hashimoto. (eds.), *Geology and Paleontology of Southeast Asia*, **20**, 143-157.

- Hashimoto, W., Matsumaru, K., and Kurihara, K., 1978. Larger foraminifera from the Philippines VII. Larger foraminifera from Lutak Hill Limestone, Pandan Valley, Central Cebu, In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.) *Geology and Paleontology of Southeast Asia*, **19**, p. 73-80.
- Hashimoto, W., Matsumaru, K., Kurihara, K., David, P. P. and Balce, G. R., 1977. Larger foraminiferal assemblages useful for the correlation of the Cenozoic marine sediments in the mobile belt of the Philippines. In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia*, 18, p. 103-123
- Hashimoto, W. and Sato, T., 1973. Geological structure of northwest Palawan and its bearing on the geologic history of the Philippines.
 In: by T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), Geology and Paleontology of Southeast Asia, 13, 145-161.
- Hashimoto, W. and Sato, Tadashi, 1968. Contribution to the geology of Mindoro and neighboring islands of the Philippines, In: T. Kobayashi, R. Toriyama and W. Hashimoto (eds.), *Geology and Paleontology of Southeast Asia*, 5, pp.192-210.
- Hashimoto, W., Takizawa, S., Balce, G. R., Espiritu, E. A. and Baura, C. A., 1980. Discovery of Triassic conodonts from Malajon and Uson islands of the Calamian Island Group, Palawan Province, the Philippines and its geological significance. *Proceedings, Japan Academy*, **56**, Ser. B, 69-73.
- Hatley, A.G., 1978. Palawan oil spurs Philippine action. *Oil Gas J.*, Feb. 27, pp. 112-118.
- Hatley, A.G., 1977. The Nido reef oil discovery in the Philippines; its significance: *Paper presented in ASCOPE Conference*, Jakarta, Indonesia, October 11-13, 1977, Singapore Cities Service East Asia, Inc. 33 p.
- Hawkins, J.W., 1980. Petrology of back-arc basins and island arcs: Their possible role in the origin of ophiolites. In: A. Panayitou (ed.), *Proceedings on the Internal Symposium on Ophiolites, Cyprus, 1979,* Geological Survey Department, Nicosia, Cyprus, 244-254.
- Hawkins, J.W. and Evans, C.E., 1983. Geology of the Zambales Range, Luzon, Philippine islands: Ophiolite derived from an island arcback-arc pair. In: Hayes, D.E. (ed.) The Tectonics and Geologic Evolution of Southeast Asin Seas and Islands, Part 2. AFU Geophys. Monograph 27, 124-138.
- Hawkins, J. W., Moore, G. F., Villamor, R., Evans, C. and Wright, E., 1985. Geology of the composite terranes of east and central Mindanao, in David G. Howell (editor) Circum-Pacific Council for Energy and Mineral Resources Earth Science Series, No. 1: *Tectonostratigraphic Terranes of the Circum-Pacific Region*, Circum-Pacific Council for Energy and Mineral Resources, Houston, Texas, U.S.A.
- Hayes, D.E. and Lewis, S.D., 1984. A geophysical study of the Manila trench, Luzon, Philippines, 1. Crustal structure, gravity and regional tectonic evolution. *J. Geopgys. Res.* **89**, 9171-9195.
- Hilde, T.W.C., Uyeda, S. and Kroenke, L., 1977. Evolution of the Western Pacific and its margin. *Tectonophysics*, 38, 145-165.

- Hilde, T.W.C. and Lee, C.S., 1984. Origin and evolution of the West Philippine Basin: A new interpretation. - *Tectonophysics*, 102, 85-104.
- Hinz, K. and Schluter, H. V., 1983. Geology of the Dangerous Grounds, South China Sea and the continental margin off SW Palawan: Results of Rv Sonne cruises SO-23 and SO-27. Sachliencht zum Fonderungsvorhaben 03 R 3379.Bundesanstalt für Geowissenchaften und Röhstoffe, Hannover, 17 pp.
- Holloway, N. H., 1982. The North Palawan Block, Philippines: its relation to the Asian mainland and its role in the evolution of the South China Sea. *Geol. Soc. Malaysia Bull.*, **14**, 19-58.
- Huchon, Ph., 1985. Géodynamique de la zone de collision d'Izu et de la jonction du Japon Central Leur place dans l'évolution de la Plaque Philippine. *Thèse de Doctorat d'état*, Université Pierre et Marie Curie Paris VI, Paris, 414 p.
- Huchon, Ph., 1986. Comment on the "Kinematics of the Philippine Sea Plate." by B. Ranken, R.K. Cardwell and D.E. Karig. - *Tectonics*, Washington, D.C., 5(1), pp. 165-168.
- Hussong, D., Uyeda, S. and Scientific Party, 1981. Near the Philippines, Leg 60 Ends in Guam. *Geotimes*, U.S.A, 22(10), pp. 93-103.
- Huth, J. R., Jr., 1963, Regional Geological Survey, Visayan Area. *Mobil Company*, unpublished.
- Huth, J. R., Jr., 1962. Summary of Philippine Stratigraphy. Standard Vacuum Oil Company, unpublished.
- Ibañez, C.B, Antonio, I.S., Barnes, H., and Santos-Yñigo, L., 1956. Geology and coal resources of the Malangas-Kabasalan Region, Zamboanga del Sur. *Philippine Bureau of Mines Special Project Series Publ. No. 8*, 51p.
- Imai, A., Listanco, E.L. and Fuji, T., 1996. Highly oxidized and sulfur-rich dacitic magma of Mount Pinatubo: Implication for metallogenesis of porphyry copper mineralization in the western Luzon arc, in Newhall, C.G. and Punongbayan, R.S. (eds.) *Fire and Mud*, PHIVOLCS and Univ. Wahington, 865-874.
- Irving, E.M., 1952, Physiographic observations on Mindanao, by aerial reconnaissance, and their geological interpretation. *Phil. J. Sci.*, **81**, (2), 141-169.
- Irving, E.M., 1957. Geological history and petroleum possibilities pf the Philippines. *Bull. Am. Asso. Petro. Geol.*, 81 (2), 141-169.
- Irving, E. M., 1950. Review of Philippine basement geology and its problems: *Phil. J. Sci.*, 79, 267-307.
- Irving, E.M., 1949. Notes on the geology of Balabac Island, Palawan. *Phil. Geologist*, 3 (4), 14-22.
- Irving, E.M. and Cruz, D.P., 1950. Notes on the geology of Rapu-Rapu Islands. *Phil. Geologist*, **5** (1), 1-14.
- Irving, E. M. and Quema, J. C., 1948. Reconnaissance geology of the Burgos-Pasuquin area, Ilocos Norte: a demonstration of modern reconnaissance methods: *Phil. Geologist*, **2** (3), 1-17.
- Isozaki, Y., Amiscaray, E. A. and Rillon, A., 1988. Permian, Triassic and Jurassic bedded radiolarian cherts in North Palawan Block, Philippines: Evidence of Late Mesozoic subduction-accretion. *Rep. No. 3 IGCP Proj. 224: Pre-Jurassic Evolution of Eastern Asia,* p. 99-115.

- Jagolino, R.B. and Jandumon, M.J., 1973. Geological reconnaissance and canvassing of the economic mineral deposits in northern Panay, Western Visayas. *Bureau of Mines*, unpublished.
- Javelosa, Ricarte S., 1989. Reconnaissance Investigation of Silica Deposits in Jordan, Guimaras Island, *Philippines Bureau of Mines and Geosciences,* unpublished.
- Javelosa, R., 1994. Active Quaternary environments within the Philippine Mobile Belt. *ITC Publication No. 20, Enschede, Netherlands.*
- JICA-MMAJ, Japan International Cooperation Agency Metal Mining Agency of Japan, 1985. The mineral exploration - Mineral deposits and tectonics of two contrasting geologic environments in the Republic of the Philippines. *Report* on Southern Sierra Madre, Polilio and Bohol-Siguijor Areas.
- JICA-MMAJ, Japan International Cooperation Agency Metal Mining Agency of Japan, 1988. The mineral exploration - Mineral deposits and tectonics of two contrasting geologic environments in the Republic of the Philippines. *Report* on Palawan V-VI, Southwest Negros and Samar I-III Areas.
- JICA-MMAJ-MGB, Japan International Cooperation Agency Metal Mining Agency of Japan, Mines and Geosciences Bureau, 1985. Mineral deposits and tectonics of two contrasting geologic environments. *Terminal Report*, Japan, 121 p., incl. 2 geologic and 5 mineral deposit maps.
- Jolivet, L., 1988. Evolution tectonique et géodynamique du Japon septentrional. *Thèse de l'Habilitation à diriger des recherches*. Université Pierre et Marie Curie, Paris VI, Paris, 361p.
- Jolivet, L., Huchon, P. and Rangin, C., 1989. Tectonic setting of Western Pacific marginal basins. *Tectonophysics*, Amsterdam, 160, 23-47.
- Jumawan, F., Yumul Jr., G.P., Tamayo, Jr., R.A., 1998. Using geochemistry as a tool in determining the tectonic setting and mineralization potential of an exposed upper mantle-crust sequence: Example from the Amnay Ophiolitic Complex in Occidental Mindoro, Philippines. J. Geol. Soc. Phil., **53**, 24-48.
- Jurgan, H., 1980. Geology and hydrocarbon prospects of the Visayan Basin. Appendix III: Younger Tertiary carbonate rocks, unpublished
- Jurgan, H. and Domingo, M. A. R., 1989. Younger Tertiary limestone formations in the Visayas Basin, Philippines. *Geologisches Jahrbuch Reihe B, Heft*, **70**, 207-276.
- Kamata, H., 1999. Significance of tectonic events at 6 Ma and 2 Ma in the northern part of the Philippine Sea Plate. In Proc. Joint Meeting on Comparative Studies of Island-Arc Seismicity and Volcanism in the Western Pacific Region, Quezon City, Philippines, 16-17 February.
- Kamata, H., 1999. Volcanism and tectonics of arc-arc junction a case study of the southwest Japan arc and Ryukyu arc (Abstract). *J. Geol. Soc. Phil.*, **54**, 77-78..
- Kamata, H. and Kodama, K., 1999. Volcanic history and tectonics of the Southwest Japan Arc and the Ryukyu Arc since 2 Ma. *The Island Arc*, 8, 393-403.
- Karig, ,D.E., 1983. Accreted terranes in the northern part of the Philippine archipelago. *Tectonics*, **2**, 211-236.
- Karig, D.E., 1975. Basin genesis in the Philippine Sea. *In: S.M. WHITE, Ed., Initial Reps. D.S.D.P.* 31, U.S. Gov't. Pr. Office, 857-879.
- Karig, D.E., 1973. Plate convergence between the Philippines and the Ryukyu Islands. *Marine Geology*, 14, 153-168.

- Karig, D.E., 1971. Origin and development of marginal basins in the western Pacific. *J. Geophys. Res.*, 75, 239-254.
- Karig, D. E., Lagoe, M. B., Snow, J. K., Schweller, W. J. and Bacuta, G. C., 1986. Stratigraphy along the Cabaluan River, and geologic relations on the west flank of the Zambales Range, Luzon, Philippines. *Phil. Geologist*, 30 (3), 1-20.
- Karig, D.E. and Sharman, G.F. 1975. Subduction and accretionin trenches. *Geol. Soc. Am. Bull.*, 86, 377-389.
- Kemmer, G.H., 1953. Report on the work performance on the Surigao project for the Commonwealth of the Philippines, National Development Company. *Bureau of Mines*, unpublished.
- Keston S., 1981. Geological Relationship between Reed Bank and offshore western Palawan, Philippines. *Proceedings, GEOSEA, 1981 Manila, Philippines*, p. 829-833.
- Kimura, T., Tokuyama, A., Gonzales, B.A. and Andal, R.A., 1968. Geologic structures in the Tayabas Isthmus District, Philippines. *Cont. Geol. Paleont. Southeast Asia*, 49, 156-178.
- Knittel, U., 1985. Contributions to the petrography and geochemistry of the Polillo intrusion, Polillo Island Philippines. *Phil. Geologist*, **39**, 14-26.
- Kobayashi, K. and Nakada, M., 1978. Magnetic anomalies and tectonic evolution of the Shikoku Inter-Arc basin. *Earth Planet. Sci. Lett.*, 6, 391-402.
- Koike, Toshio, Hashimoto, Wataru and Sato, Tadashi, 1968. Fusulinidbearing limestone pebble found in the Agbahag Conglomerate, Mansalay, Oriental Mindoro, Philippines: *Geology and Paleontology of Southeast Asia*, **4**, 198-210.
- Krause, D.C., 1966. Tectonics, marine geology and bathymetry of the Celebes-Sulu sea region, *Geol. Soc. America Bull.*, **77**, 813-831.
- Kudrass, H.R., Müller, P., Kreuzer, H. and Weiss, W., 1990. Volcanic rocks and Tertiary carbonates dredged from the Cagayan ridge and the Southwest Sulu Sea, Philippines. *In: Proc. ODP, Initial Report*, Leg 124, 93-100.
- Kudrass, H.R., Wiedicke, M., Cepek, P., Kreuzer, H. and Müller, P., 1986. Mesozoic and Cainozoic rocks dredged from the South China Sea (Reed Bank Area) and Sulu Sea and their significance for plate tectonic reconstructions. *Mar. Petr. Geol.*, 3, 19-30.
- Lee, C.S. and McCabe, R., 1986. The Banda-Celebes-Sulu Basin. A trapped piece of Cretaceous-Eocene oceanic crust? *Nature*, 322 (3), 51-53.
- Lee, T.-Q., 1989. Evolution tectonique et géodynamique néogène et quaternaire de la chaîne côtière de Taiwan: apport du paléomagnétisme. *Thèse de doctorat*, Université Pierre et Marie Curie, Paris VI, 328 p.
- Lee, T.-Q., Angelier, J., Chu, H.T. and Begerat, F., 1990. Rotations in the Northern collision belt of Taiwan: preliminary results from paleomagnetism. *Tectonophysics*, 199, 109-120.
- Leith, A., 1938. Geology of the Baguio gold district. *Tech. Bull. No. 9*, Dept. of Agriculture and Commerce, Manila.
- Le Pichon, X. and Huchon, P., 1984. Pangea, geoid and convection. *Earth Planet. Sci. Lett.*, 67 (1), 123-136.
- Le Pichon, X., Huchon, P. and Barrier, E., 1985. Pangea, geoid and the evolution of the Western margin of the Pacific Ocean. *In: N. NASU*

et al., Ed., Formation of Active Ocean Margins, Terrapub, Tokyo, 3-42.

- Le Pichon, X., Chamot-Rooke, N., Vigny, C., Walpersdorf, A., Huchon, P. and Rangin, C., 1997. Sundaland motion detected from Geodyssea GPS measurement, Part II: Relative motion of Sundaland and South China blocks, implications on India/Eurasia collision and on the tectonics of Taiwan. *In Abs. and Progs.: GEODYSSEA Conclduing Symp.*, Penang, Malaysia, 14-18 April
- Letouzey, J., Sage, L. and Müller, C., 1987. Geological and structural maps of Eastern Asia, *Notice: Institute Francis du Petrol. Paris*, 73 p.
- Lewis, S.D. and Hayes, D.E., 1983. The tectonics of northward propagating subduction along Eastern Luzon, Philippine Islands. *In: D.E. HAYES, Ed., Tectonic and Geologic Evolution of Southeast Asian Seas and Islands: Part 2.* A.G.U. Monograph 27, 57-78.
- Liggayu, M.C., 1964. Reconnaissance geology and mineral resources of the Romblon group, *Phil. Bureau of Mines*, 30 p., unpublished.
- Llaban, N.Q., 1989. The geology and hydrocarbon potential of northwest Leyte. PNOC-EC, unpublished.
- Lorentz, R.A., Jr., 1984. Stratigraphy and sedimentation of Late Neogene sediments on the southwest flank of Luzon Central Cordillera, Philippines. *Phil. Geologist*, **38** (2), 1-24.
- Los Baños, C.F., Layugan, D.B., Maneja, F.C., apuada, N.A. and Delfin Jr., F.G., 1996. Geophysical model of Mt. Labo geothermal field, Southeastern Luzon. *Proceedings of the 17th Annual PNOC-EDC Geothermal Conference*, Makati, March 7-8, 1996.
- Louden, K.E., 1977. Paleomagnetism of DSDP sediments, phase shifting of magnetic anomalies and rotation of the west Philippine Basin. *J. Geophys. Res.*, 82, 2989-3002.
- Lovering, J. F., 1983. Zircon track ages from Philex Mine diorite porphyry complex and Agno diorite batholith. *Melbourne University Fission Track Laboratory Services Report to Philex Mining Corp.*, unpublished.
- Lubas, L.L., de Guzman, A.M., Revilla, A.P., Krijnen, J.P., 1998. Biostratigraphy, structural and sequence stratigraphic framework of Bondoc Peninsula. *Proc. 1998 Geological Convention, Geol. Soc. Phil (December 2-4, 1998, Pasig City).*, p 128-136.
- Ludwig, W.J., Hayes, D.E. and Ewing, J.I., 1967. The Manila Trench and West Luzon Trough - I. Bathymetry and sediment distribution. *Deep Sea Res.*, 14, 533-544.
- Maac, Y. O., 1988. Paleontologic and paleoenvironemnt studies of the Tabuk-Batong Buhay route, Kalinga-Apayao. *ITIT Project No.* 8319 (*Research on stratigraphic correlation of Cenozoic strata in oil and* gas fields Philippines) p. 20-31.
- Maac-Aguilar, Y. O., 1995. Neogene stratigraphy and paleontology of the Calubian Peninsula, NW Leyte, Philippines. M.Sc. Thesis, University of Tsukuba, Japan, 135 p.
- Maac, Y.O. and Agadier, M.A., 1988. Stratigraphic, paleontologic and sedimentologic studies of southern Palawan: its tectonic implications. *Research on stratigraphic correlation of Cenozoic strata in oil and gas fields Philippines (ITIT Project No. 8319)*, 102-133
- Maac Aguilar, Y.O. and Ylade, E.D., 1988. Stratigraphic and pal;eontologic studies of Tablas, Romblon. *Research on Stratigraphic Correlation*

of Cenozoic Strata in Oil and Gas Fields, Philippines, ITIT Project 8319, Geol. Soc. Japan, p. 44-67

- Madrona, J, 1979. Geology of the Jagupit quadrangle, Agusan del Norte. *Philippine Bureau of Mines and Geosciences Region X,* unpublished report.
- Madrona, J., Villamor, R., et al. Report on the reconnaissance geologicalgeochemical exploration survey of Magsaysay quadrangle, provinces of Agusan del Norte and Misamis Oriental. *Philippine Bureau of Mines and Geosciences Region X,* unpublished.
- Magpantay, A.L., 1959. The Geology of southern Polillo Island, Quezon. *Phil. Bureau of Mines*, unpublished.
- Malicdem, D.G., 1971. *Geological-geophysical investigation of a porphyrytype copper deposit at Camp 4, Tuba, Benguet.* Masters Thesis, University of the Philippines.
- Malicdem, D. G. and Peña, R. E., 1966. Preliminary Report on the Geology and Mineral Deposits of the Masara Mine Area, Mabini, Davao. *Bureau of Mines*, unpublished.
- Malicdem, D.G. and Peña, R., 1965. Report on the geology and ironcopper prospects of a portion of Kiamba, Cotabato. *Bureau of Mines*, unpublished.
- Malicdem, D.G., Raval, L.H., Peña, R., Garcia, M.V., and 1965. Notes on the geology of the Looc lead-zinc-silver-antimony deposits and vicinity, Nasugbu, Batangas. *Bureau of Mines*, unpublished.
- Maleterre, P., 1989. *Histoire, sedimentation, magmatique, tectonique et metallogenique d'un arc oceanique deforme en regime de transpression.* PhD Thesis, Universite de Bretagne Occidentale, Brest, 304 p.
- Maleterre, Ph., Stephan, J.F., Andreieff, P., Bellon, H., Chorowicz, J. Boirat, J.M. and Balce, G.R., 1988. The Southern Central Cordillera of Luzon: A multi-stage Upper Eocene to Pleistocene arc deformed on the Northern end of the Philippine strike-slip Fault. *In: Int. Symp. Geodynamic Evolution of Eastern Eurasian Margins.* Abstracts. Paris, France, p. 81.
- Marchadier, Y., 1988. La terminaison de la fosse de Manille en domaine continental: Etudes stratigraphique et tectonique des îles de Mindoro-Tablas, (Philippines). *Thèse de doctorat*, Université Pierre et Marie Curie, Paris 6, France, 358 p.
- Marchadier Y. and Rangin, C., 1990. Polyphase tectonics at the southern tip of the Manila trench, Mindoro-Tablas islands, Philippines. *Tectonophysics*. **183**, 273-287.
- Marchadier Y. and Rangin, C., 1989. Passage subduction-collision et tectoniques superposees a l'extremite meridionale de la fosse de Manille (Mindoro-Tablas, Philippines). *C.R. Acad. Sci. Paris, t. 308. Serie II*, 1715-1720.
- Martin, S.G., 1972. Progress report on the petroleum geological survey of southern Palawan, Bureau of Mines, unpublished.
- Martin, S. G. and Cruz, N. B. dela, 1976, Report on the geological survey of Masbate Island: *Philippine Bureau of Mines,* unpublished.
- Martinez-Villegas, M.I., Bornas, M.A.V., Abigania, M.I.T. and Listanco, E.L., 2001. Geology and geochemistry of Mayon Volcano. *J. Geol. Soc. Phil.*, **56** (3-4), 163-183.

- Mascle, A. and Biscarrat, P.A., 1978. The Sulu Sea: A marginal basin in the Southeast Asia. *Am. Asso. Petr. Geol.*, Memoir 29, Tulsa, Okla, 373-381.
- McCabe, R., Almasco, J. and Diegor, W., 1982. Geologic and paleomagnetic evidence for a possible Miocene collision in Western Panay, Central Philippines. *Geology*, 10, 325-329.
- McCabe, R., Almasco, J. and Yumul, G., 1985. Terranes of the Central Philippines. In: D.G. HOWELL, Ed., Tectonostratigraphic Terranes of the Circum-Pacific Region: Circum-Pacific Council for Energy and Mineral Resources Earth Science Series No.1, Houston, Tex., 421-435.
- McCabe, R., Kikawa, E., Cole, J.T., Malicse, A.J., Baldauf, P.E., Yumul, J. and Almasco, J., 1987. Paleomagnetic results from Luzon and the Central Philippines. *J. Geophys. Res.* 92, 555-580.
- McCaffrey, R., 1991. Earthquakes and ophiolite emplacement in the Molucca Sea collision zone, Indonesia. *Tectonics*, 10 (2), 433-453.
- McDermott, F., Defant, M.J., Hawkesworth, C.J., Maury, R.C., and Joron, J.L., 1993. Isotope and trace element evidence for threecomponent mixing in the genesis of the North Luzon arc lavas (Philippines). *Contrib. Mineral Petrol*, **114**, 9-23.
- Meek, W.B., 1941. The geology of the Paracale-Jose Panganiban mining district of Camarines Norte, Luzon, Philippine Islands. *Phil. Bureau of Mines*, unpublished.
- Meijer, A., 1980. Primitave arc volcanism and Boninite series: Examples from Western Pacific island arcs. *In: D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands*, A.G.U. Monograph 23, 269-282.
- Melendres, M. M., 1953. Reconnaissance geology and oil possibilities of southeastern Mindoro, *Philippine Bureau of Mines*, unpublished.
- Melendres, M, Jr. and Barnes, H., 1957. Geology and Coal Resources of the Calatrava-Toboso Region, Occidental Negros, Bureau of Mines Special Publication Series. 12 – Coal, 50p.
- Melendres, M.M. and Comsti, F.A., 1951. Reconnaissance geology of southeastern Davao. *Philippine Geologist*, **5** (2), 38 46.
- Melendres, M.M. and Versoza, R.S., 1960. Reconnaissance geology and oil possibilities of the southeastern Luzon Central Valley. *San Jose Oil Co., Inc.*, unpublished.
- Milanes, F. S.J., 1981. Report on the Geologic Mapping and Geochemical Sampling of Northern Part of Davao del Sur Province, *Bureau of Mines and Geosciences, Surigao City*, unpublished.
- Milanes, F.S.J., 1981. Report on the Geological Survey of the Malita and Kabayawa Quadrangles, Davao del Sur, *Bureau of Mines and Geosciences, Surigao City*, unpublished.
- Mines and Geosciences Development Service (DENR-Region XI), 1992. Technical Information Series No.2, p 3-7
- Mines and Geosciences Development Service (DENR-Region XI), 1992. *Technical Information Series No. 5*, p.2-4
- Meijer, A., 1980. Primitave arc volcanism and Boninite series: Examples from Western Pacific island arcs. *In: D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands*, A.G.U. Monograph 23, 269-282.
- Miranda, F. E., 1980. Application of low density sampling technique for geochemical reconnaissance exploration of Mindoro, Philippines, *Philippine Bureau of Mines and Geosciences*, unpublished.

- Miranda, F. E., 1976. Geological-geochemical survey of Caramoan Peninsula, Camarines Sur. *Phil. Bureau of Mines Report of Investigation No. 86.*
- Miranda, F. E. & Caleon, P.E., 1979. Geology and mineral resources of Camarines Norte and parts of Quezon Province. *Phil. Bureau of Mines Report of Investigation No. 94.*
- Miranda, F. E. & Vargas, B.S., 1967. Geology and mineral resources of Catanduanes Province, *Phil. Bureau of Mines Report of Investigation No. 62.*
- Mitchell, A.H.G., Hernandez, F. and de la Cruz, A.P., 1986. Cenozoic evolution of the Philippine archipelago. *J. Southeast Asian Earth Sci.* **1**, 1-20.
- Mitchell, A.H.G. and Leach, T.M., 1991. *Epithermal Gold in the Philippines: Island Arc Metallogenesis, Geothermal Systems and Geology,* Academic Press Geology Series, London, 457 p.
- MMAJ-JICA (Metal Mining Agency of Japan -Japan International Cooperation Agency), 1973. Report on the geological survey of eastern Mindanao, Phase II.
- MMAJ-JICA, 1974. Report on the geological survey of eastern Mindanao, Phase III.
- MMAJ-JICA, 1977. Report on the geological survey of northeastern Luzon, Phase III., 261 p.
- MMAJ-JICA, 1980. Report on geological survey of northwestern Luzon, Phase II..
- MMAJ-JICA, 1983. Report on Acupan-Itogon geothermal development, Phase I
- MMAJ -JICA, 1984. Report on the Geological Survey of Eastern Mindanao (Consolidated Report).
- MMAJ-JICA, 1984. Report on the Geological Survey of Mindoro Island. (Consolidated Report). 57 p.
- MMAJ-JICA, 1986. Mineral Deposits and Tectonics of Two Contrasting Geologic Environments in the Republic of the Philippines, Phase II

 Masbate area, Northern Leyte area, Southern Leyte, Dinagat, Siargao and Palawan I-IV area, 740 p.
- MMAJ-JICA,1987. Report on the Mineral Exploration, Mineral Deposits and Tectonics of Two Contrasting Geologic Environments in the Philippines, Cebu, Panay and Romblon Area, Phase 3
- MMAJ-JICA,1987. Report on the Mineral Exploration, Mineral Deposits and Tectonics of Two Contrasting Geologic Environments in the Philippines, Phase 3 (part 1), Northern Sierra Madre Area.
- MMAJ-JICA, 1988. Report on the Mineral Exploration: Mineral deposits and Tectonics of Two Contrasting Geologic Environments in the Republic of the Phili[ppines – Palawan V-VI, area, West Negros area and Samar I-IIII area, 347p.
- MMAJ-JICA, 1989. Consolidated report on the Northern Sierra Madre Area: the mineral exploration, deposits and tectonics of two contrasting geologic environments in the Republic of the Philippines
- MMAJ–JICA, 1990. Consolidated Report on Leyte-Dinagat-Siargao Area. The Mineral Deposits and Tectonics of Two Contrasting Geologic Environments in the Republic of the Philippines. - Terminal Report, Japan, 121 p., including 2 geologic and 5 mineral deposit maps.

- MMAJ-JICA, 1990. Consolidated report on Cebu-Bohol-Southwest Leyte Area. The Mineral Exploration - Mineral Deposits and Tectonics of Two Contrasting Environments in the Republic of the Philippines.
- MMAJ-JICA, 1992. Report on the Cooperative Mineral Exploration Geological & Geochemical Survey in Panay Island, Phase II
- MMAJ-JICA, 1993. Report on the Cooperative Mineral Exploration Geological & Geochemical Survey in Panay Island, Consolidated Report, 91 p.
- MMAJ-JICA, 1993. Report on the cooperative mineral exploration geological assessment of chromite, base metals, platinum and related precious metal occurrences in south central Palawan, the Republic of the Philippines, Consolidated report.
- MMAJ-JICA, 1994. Report on the Cooperative Mineral Exploration in Catanduanes area, The Republic of the Philippines, Phase I, 176 p.
- MMAJ-JICA, 1995. Report on the Cooperative Mineral Exploration in Catanduanes area, The Republic of the Philippines, Phase II, 140 p.
- MMAJ-JICA, 1996. Report on the Cooperative Mineral Exploration in Catanduanes area, The Republic of the Philippines, Phase III, 120 p.
- MMAJ-JICA, 1998. Report on the Cooperative Mineral Exploration in the Bicol Area, The Republic of the Philippines, Phase I.
- MMAJ-JICA, 1999. Report on the Cooperative Mineral Exploration in the Bicol Area, The Republic of the Philippines, Final report.
- MMAJ-JICA, 2001. Report on the Cooperative Mineral Exploration in the Bicol North Area, The Republic of the Philippines, Phase II, 77p.
- Momongan, A.L., 1979. Preliminary report on the geology of southwestern Panay, Burerau of Mines and Geosciences – Region VI, unpublished.
- Moon, K.J., Kim, Y.D., Kim, T.W., Cho, M.J. and Hwang, S.K., 1991. Report on Philippine-Korea Project, Gelological and geochemical exploration mapping on Eastern Samar and Homonhon Island of Philippines.
- Moore, G.F., Kadarisman, D., Evans, C.A. and Hawkins, J.W., 1981. Geology of the Talaud Islands, Molluca sea collision zone, NE Indonesia, *J. Structural Geology*, **3**, pp. 467-475.
- Moore, G.F. and Silver, E.A., 1983. Collision processes in the Northern Molucca Sea. - In: D.E. Hayes, Ed., *The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands: Part 2*. Geophysical Monograph 27, Washington, D.C., p. 360-372.
- Motegi, Mutsumi, 1975. Mineralization of the Philippines, a geological review: *J. Geol. Soc. Phil.*, 29 (4), 21-44.
- Mrozowski, C.L. and Hayes, D.E., 1979. The evolution of the Parece-Vela Basin. *Earth Planet. Sci. Lett.*, 46, 49-67.
- Mrozowski, C.L., Lewis, S.D. and Hayes, D.E., 1982. Complexities in the tectonic evolution of the West Philippine Sea Basin. *Tectonophysics*, 82, 1-24.
- Mula, E. Y. and Maac, Y. O., 1995. Biostratigraphic studies in Bohol Island. Report of Research and Development Cooperation. ITIT Project No. 8313 (Research fpr enhancement of reference sections of sedimentary basins in the Philippines). *Geological Survey of Japan.*
- Müller, C., Jurgan, H. and Porth, H., 1989a. Paleogeographic outlines of the Visayan Basin. *Geol. Jb.*, 70 (B), 303-316.

- Muller, C., and von Daniels (in collaboration with Paul Cepek), 1981, Stratigraphical and paleoenvironmental studies (Oligocene-Quaternary) in the Visayan Basin, Philippines, *Newsletter Stratigraphy.* **10** (1), 52-64.
- Muller, C., von Daniels, C., Cepek, P., Gramann, F., Bausa, G., and de Leon M, 1989. Biostratigraphy and Paleoenvironmental Studies in the Tertiary of the Visayan Basin, Philippines: *Geologisches Jahrbuch Reihe B, Heft* **70**, 89-146.
- Murauchi, S., Ludwig, W.J., Den, N., Hotta, H., Asanuma, T., Yoshi, T., Kubotera, A. and Hagiwara, K., 1973. Structure of the Sulu Sea and the Celebes Sea. *J. Geophys. Res.*, 78 (17), 3437-3447.
- Nakata, T., Sangawa, A. and Hirano, S.C., 1977. A report on tectonic landforms along the Philippine Fault Zone in Northern Luzon, Philippines. *Science Reports, Tohoku Univ.*, 7th Series (Geography), Sendai, Japan, 27 (2), 69-93.
- Nelson, A.R., Personius, S.F., Rimando, R.E., Punongbayan, R.S., Tungol, N., Mirabueno, H., and Rasdas, A., 2000. Multiple large earthquakes in the past 1500 years on a fault in Metro Manila, the Philippines. *Bull. Seis. Soc. Am.*, 90 (1), 73-85.
- Newhall, C.G., Daag, A.S., Delfin, F.G., Jr., Hoblitt, R.P., McGeehin, J., Pallister, J.S., Regalado Ma. T.M., Rubin, M., Tubianosa, B.S., Tamayo, R.A., Jr., Umbal, J.V., 1996. Eruptive history of Mt. Pinatubo in Newhall, C.G. and Punongbayan, R.S., eds., *Fire and Mud: eruptions and lahars of Mt. Pinatubo, Philippines*, p. 165-196.
- Nichols, G., Hall, R., Milsom, J., Masson, D., Parson, L., Sikumbang, N., Dwiyanto, B. and Kallagher, H., 1990. The southern termination of the Philippine Trench. *Tectonophysics*, 183 (1-4), 289-304.
- Nicolas, A. and Violette, J-F., 1982. Mantle flow at oceanic spreading centers: Model derived from ophiolites. *Tectonophysics* **120**, 191-209.
- Nilayan-Tan, M., 1985, Larger foraminifera from St. Paul's Limestone, northern Palawan. *Bureau of Mines*, unpublished.
- Oca, G. R., 1952. Preliminary report on the economic mineral deposits of Marinduque Province: *Philippine Bureau of Mines Report of Investigation no. 7.*
- Ocampo, V. P., 1971. Preliminary report on the stratigraphy of measured sections in the Mansalay-Caguray River area, southern Mindoro, Philippines: *Philippine Bureau of Mines*, unpublished.
- Ocean Drilling Program, Leg 124, 1991. Celebes and Sulu Seas, Philippines. Proceedings: Scientific Results, 582 p.
- Ohkura, T., Nakano, T., Besana, G.M., Sicat, M.J., Hoso, Y., Mangao, E., Geraldo, I., Daligdig, J.A., Ando, M. and Punongbayan, R.S., 2001. GPS measurements in the Macolod Corridor, Philippines. *J. Geol. Soc. Phil.*, 56 (3/4), 97-104.
- Oles, D., Foerster, R.H., Torres, R.C. and Punongbayan, R.S., 1991. Geologic Map of the Macolod Corridor (Taal-Banahaw area), southwestern Luzon, Philippines. 1:100,000 scale. *Rheinisch-West felische Technische Honschule.* Aachen, Germany.
- Oles, D., Torres, R., Förster, H., Punongbayan, R., Wolfe, J., Knittel, U., Bellon, H., Maury, R. and Defant, M., 1991. *Geology of the Macolod Corridor intersecting the Bataan-Mindoro island arc, Philippines.* German Research Society and German Agency for Technical Cooperation, 161 p.

- Ozima, M., Kanaeoka, I. and Ujiie, A., 1977. 40K-39Ar age of rocks and the development mode of the Philippine Sea. *Nature*, 267, 816-818.
- Packham, G.H. and Falvey, D.A., 1971. An hypothesis for the formation of marginal seas in the western Pacific. *Tectonophysics*, 11, 79-109.
- Pacis, M.G., 1966. Report on the geology of parts of the provinces of Misamis Oriental, Bukidnon and Lanao del Norte. *Phil. Bureau of Mines*, 51 p., unpublished.
- Paderes, A.E., and Miranda, F. E., 1965. Geology of the Vitali and Anungan quadrangles, Zamboanga Peninsula: *Philippine Bureau* of *Mines*, unpublished.
- Pagado, E.S., Camit, G.R.A., Rosell, J.B., and Apuda, N.A., 1995. The geology and geothermal systems of Biliran Island. *J. Geol. Soc. Phil.*, **50**, 1-20.
- Panem, C.C. and Alincastre, R.S., 1985. Surface geology of the Bacon-Manito Geothermal Reservation, *PNOC-EDC*, unpublished.
- Panem, C.C. and Cabel, A.C., 1998. Geology of Isarog-Iriga geothermal prospect. *PNOC-EDC*, unpublished.
- Panem, C.C. and Delfin, F.G., Jr., 1988. Geology of Bulusan Geothermal Prospect. *PNOC-EDC*, unpublished.
- Pautot, G., Rangin, C., Briais, A., Tapponier, P., Beuzart, P., Lericolais, G., Mathieus, X., Wu, J., Han, S., Li, H., Lu, Y. and Zhao, J., 1986. Spreading direction in the Central South China Sea. *Nature*, 321, 6066, 150-154.
- Pelayo, A. M., 1981. Stratigraphy of a portion of the Sierra Madre in the Norzagaray quadrangle, Bulacan. *Phil. Bureau of Mines & Geosciences*, unpublished.
- Pelletier, B., 1985. De la fosse de Manille à la chaîne de Taiwan, étude géologique aux confins d'une subduction et d'une collision actives. Modèle géodynamique. *Thèse de doctorat*, Université de Bretagne Occidentale, France, 268 p.
- Peña, R.E., 1970. Brief geology of a portion of the Baguio District. *J. Geol. Soc. Phil.*, **24** (4), 41-43.
- Peña, R. E., 1992. Review of the stratigraphy of Baguio district. *J. Geol. Soc. Phil.*, **47**, 151-166.
- Peña, R. and Reyes, M.C., 1970. Sedimentological study of a section of the "Upper Zigzag" formation along Bued River, Tuba, Benguet. J. Geol. Soc. Phil., 24 (1), 1-19.
- Peña, R.E., Tamesis, E.V., Peleo-Alampay, A.M., Militante-Matias, P.J., Foronda, J.M., De Leon, M.M., Siringan, F.P., Agadier-Zepeda, M.A., Maac-Aguilar, Y., Santos-Yñigo, L., David, S.G., Jr., Lubas, L.L., Caagusan, N.L., Lasam, A.G., 2001. Philippine stratigraphic guide, J. Geol. Soc. Phil. 56, 1-30.

Penrose Conference, 1972. Ophiolitis. Geotimes, 17, 24-25.

- PHIVOLCS (Philippine Institute of Volcanology and Seismology), 2002. Volcanoes of the Philippines. 41 p.
- Phivolcs, 1998. Distribution map of active, potentially active and inactive volcanoes in the Philippines.
- PHIVOLCS, 1997. Catalogue of Philippine Volcanoes, vol. 1, Active Volcanoes, (revised from 1994 version), unpublished.
- PHIVOLCS, 1995. Volcanoes of the Philippines. 41 p.
- PHIVOLCS, 1991. Camiguin Island Profile.
- PHIVOLCS, 1988. The Bicol Volcanic Chain (poster).
- PHIVOLCS 1981. Volcanoes and Geothermal Areas in Mindanao.

- PODCO (Philippine Oil Development Company), 1978. Geology of Bondoc Peninsula, unpublished report.
- Pilac, J., 1965. Geology of northern Leyte. Bureau of Mines, unpublished report.
- Pineda, M. Y., Guazon E. B. and Panganiban, D. V., 1992. Notes on the regional tectonics of Palawan Ridge and the geology of the Ulugan Bay Area. J. Geol. Soc. Phil, 47 (3-4), 135-150.
- Pinet, N. 1990. Un exemple de grand decrochement actif en contexte de subduction oblique: la faille Philippine dans se partie Septentrionale. Doctorate Thesis, Univ. de Nice, 390 p.
- Pinet, N. and Cobbold, P., 1992. Experimental insights into the partitioning of motion within zones of oblique subduction. *Tectonophysics*, 206, 371-388.
- Pinet, N. and Stephan, J. F., 1990. The Philippine wrench fault system in the Ilocos Foothills, northwestern Luzon, Philippines: *Tectonophysics*, **183**, 207-224.
- Portacio, Jr. J.S., 1982. The geology of the Anagasi Zn-Cu-Au-Ag deposits, Samar Province, Philippines. *Proceedings of the 4th Reg. Conf. on Geol. Mineral- Energy Resource of Southeast Asia, Manila*, p. 573-587.
- Porth, H., Muller, C., and von Daniels, C., 1989. The sedimentary formations of the Visayan Basin, Philippines: *Geologisches Jahrbuch Reihe B, Heft* **70**, pp. 29-88.
- Porth, H. and Von Daniels, C.H., Eds., 1989. The sedimentary formations of the Visayan Sea Basin. *Geol. Jb.*, 70 (B), 428 p.
- Pratt, W.E. and Smith, W,D., 1913. The geology and petroleum resources of the southern part of Bondoc Peninsula, Tayabas Province, Philippine Islands, *Phil. Jour. Sci.*, Sec. A **8** (5)
- Prioul, R., Cornet, F.H., Dorbath, L., Ogena, M. and Ramos, E., 2000. An induced seismicity experiment across a creeping segment of the Philippine Fault. J. Geophys. Res. In press – copy prepared with AGU's Latex macros v4. formatted 3 May 2000.
- Pubellier, M., Quebral, R. D., Deffontaines, B., and Rangin, C., 1993. Neotectonic map of Mindanao Island, Philippines. 1 map + explanatory note, 23 p. Published and distributed by Asia Geodyne Corporation, Quezon City, Philippines.
- Pubellier M., Quebral R., Rangin, C., Deffontaines, B., Muller C., Buuterlin, J. and Manzano J., 1991. The Mindanao Collision Zone: a soft collision event within a continuous Neogene strike-slip setting, J. Southeast Asia Earth Sciences, 6 (3-4), 239-248.
- Pubellier, M., Rangin, C., Quebral, R. and Deffontaiones, B., 1990. Where is the extension of the Molluca sea collision zone in the Philippines? In: *Orogenesis in Action: tectonics and processes in the west equatorial Pacific margin*, London, April 18-20, 1990.
- Punay, O.A., Borja, A.B. and Melendres, M.M., 1972. Annual report on PEC no. 319, South Cotabato. Sabena Mining Corp, unpublished.
- Punongbayan, R.S., Rimando, R.E., Daligdig, J.A., Besana, G.M. and Daag, A.S., 1990. Ground rupture of the 16 July 1990 Earthquake. *In: The third annual geological convention*, 5-7 December 1990, UP-NIGS Quezon City, Philippines. Abstracts, p. 32.
- Purser, R.J. and Diomampo, E.O., 1995. New stratigraphic information for Metro Manila and its engineering implications. Proc. Geol. Soc. Phil. 8th Annual Geol. Convention (December 6-8, 1995, Quezon City).

- Quebral, Ramon D., 1994. *Tectonique du segment meridional de la faille philippine, Mindanao Oriental, Philippines: passage d'une zone de collision à une zone de décrochement.* These de doctorat, Université Pierre et Marie Curie, Paris, France.
- Querubin, C.L., Yumul, G.P., Jr., Cabantog, A.V., Lucero, J.N., 1999. The central Zamboanga rift margin, Mindanao, Philippines: implications on the tectonic evolution of western Mindanao, unpublished.
- Ramos, C. V., 1964, Preliminary report on the reconnaissance geology of Cuyo-Agutaya islands group, Palawan. *Bureau of Mines*, unpublished.
- Ramos, E.G., Ferrer, A.P. and Rollan, R.R., 2000. Digital geomorphic mapping of Mariveles Volcano, Bataan, (Abstract), *Proceedings Geological Convention, Dec.6-8, 2000*, Mandaluyong City, p. 25.
- Rangin, C., 1989. The Sulu Sea: A back-arc basin setting within a Neogene collision zone. *Tectonophysics*, 161, 119-141.
- Rangin, C., Dahrin, D., Quebral, R. and the MODEC Scientific Party, 1996. Collision and Strike Slip Faulting in the northern Molucca Sea (Philippines and Indonesia): Preliminary Results of a Morphotectonic Study. In : Hall, R. and Blundell, D. (eds.). *Tectonic Evolution of Southeast Asia,* Geological Society Special Publication No. 106, 29-46.
- Rangin, C., Jolivet, L., Pubellier, M. and the Tethys Pacific working group, 1990. A simple model for the tectonic evolution of Southeast Asia and Indonesian region for the past 43 m.y. *Bull. Soc. géol. France*, 6, (6), 889-905.
- Rangin, C., Le Pichon, X., Mazzotti, S., Pubellier, M., Chamot-Rooke, N., Aurelio, M., Walpersdorf, A. and Quebral, C., 1999. Plate convergences measured by GPS across the Sundaland/Philippine Sea Plate deformed boundary: the Philippines and eastern Indonesia. *Geophys. J. Int.*, 139, 296-316.
- Rangin, C, Porth, H. and Müller, C., 1989a. Neogene geodynamic evolution of the Visayan Region. *Geol. Jb.*, 70, 7-27.
- Rangin, C. and Pubellier, M., 1990. Subduction and accretion of Philippine Sea Plate fragments along the Eurasian margin. In: J. AUBOIN and J. BOURGOIS, Eds., Tectonics of Circum-Pacific continental Margins., VSP, 139-164.
- Rangin, C., Silver, E.A. et l'équipe du Leg 124, 1989b. Forages dans les bassins marginaux du SE asiatique: résultats préliminaires du leg 124, ODP. *C.R. Acad. Sci.*, 309 (II), 1333-1339.
- Rangin, C., Stephan, J.F., Blanchet, R., Baladad, D., Bouysee, P., Chen, M.P., Chotin, P., Collot, J.Y., Daniel, J., Drought, J.M., Marchadier, Y., Marsset, B., Pelletier, B., Richard, M. and Tardy, M., 1988a. Seabeam survey at the Southern end of the Manila Trench. Transition between subduction and collision processes, offshore Mindoro Island, Philippines. *Tectonophysics*, 146, 261-278.
- Rangin, C., Stephan, J.F., Butterlin, J., Bellon, H., Muller, C., Chorowicz, and Baladad, D., 1991. Collision neogene d'arc volcaniques dans le centre des Philippines: stratigraphie et structure de la chaine d'antique (Ile de Panay). *Bull. Soc. Geol. France*, **162** (3), 465-477.
- Rangin, C., Stephan, J.F. and Muller, C., 1985. Middle Oligocene oceanic crust of South China Sea jammed into Mindoro collision zone (Philippines). *Geology*, **13**, 425-428.
- Rangin, C., Stephan, J.F., Muller, C., Bellon, H., Butterlin, J., and Boirat, J.M., 1988. Stratigraphy, chronology and structure of the eastern

Philippine arc basement in Bicol (Philippines): an exotic terrane accreted to the Eurasian margin? (Abstract): *Proc. Int'l Symposium Geodynamic Evolution of the Eastern Eurasian Margin* Paris, p. 28

- Ranken, B., Caldwell, R.K. and Karig, D.E., 1984. Kinematics of the Philippine Sea Plate. *Tectonics*, 3(5), 555-575.
- Ranneft, T.S.M., Hopkins, R.M., Froehlich, A.J. and Gwinn, J.W., 1960. Reconnaissance geology and oil possibilities of Mindanao, *AAPG Bull.*, **44** (5), 529-569.
- Rashka, H., Nacario, E., RammImair, D., Samonte, C. and Steiner, L., 1985, Geology of the ophiolite of central Palawan Island, Philippines. *Ofioliti*, **10**, p. 375-390.
- Repetti, W.C., 1935. Tectonic lines of the Philippine Islands. *Phil. Weather Bu. Seismol. Bull.*, 57-71.
- Revilla, G.P. & Malaca, E.R., 1987. Geology of southern Sierra Madre. *Phil Bureau of Mines & Geosciences,* unpublished.
- Reyes, F. T., 1964. Geology of Central Pujada Peninsula, Davao Province, Mindanao. *Bureau of Mines*, unpublished.
- Reyes, C.A., 1971. Geological investigation of Palawan Island. Oriental Petroleum & Mineral Corp., unpublished.
- Reyes, M.V. and Ordoñez, E.P., 1970. Philippine Cretaceous smaller foraminifera. J. Geol. Soc. Phil., 24 (2), 1-13.
- Richard, M., Maury, R., Bellon, H., Stephan, J., Boirat, J., and Calderon, A., 1986. Geology of Mt. Iraya volcano and Batan island, northern Philippines: *Phil. J. Volcanology*, **3**, p.1-27.
- Rimando, R. E., 1994. Philippine Fault zone and hazards due to faulting. *In: Proc. National Conf. on Natural Disaster Mitigation*, 19-24 October 1994, Quezon City, pp. 61-70.
- Rimando, R.E., Punongbayan, R.S., Macaspac, R. and Tansinsin, L., 1996. Creeping fault segment of the West Marikina Valley Fault in Muntinlupa-San Pedro-Biñan area. *PHIVOLCS Unpbl. Rep.*, Quezon City, 44 p.
- Ringenbach, J.C, 1992: La Faille Philippine et les châines en décrochement associés (centre et nord de Luzon): Evolution cénozoique et cinématique des déformations quaternaires. Doctoral Thesis; Univ. de Nice, 316 p.
- Ringenbach, J.C., Maleterre, P., Stephan, J.F. and Bellon, H., 1988. Structure and geological history of the Lepanto-Cervantes releasing bend on the Abra River Fault, Luzon Central Cordillera, Philippines. *In: Int. Symp. Geodynamic Evolution of Eastern Eurasian Margins.* Abstracts. Paris, France, p. 94.
- Ringenbach, J.C., Pinet, N., Deltail, J. et Stephan, J.F., 1992. Analyse des structures engendrées en régime décrochant par le séisme de Nueva Ecija du 16 juillet 1990, Luzon, Philippines. *Bull. Soc. géol. France*, 163 (2), 109-123.
- Ringenbach, J.C., Pinet, N., Muyco, J. et Billedo, E., 1991. Analyse de la rupture associée au séisme du 16 juillet 1990 le long de la faille philippine (Luzon, Philippines). *C.R. Acad. Sci.*, 312 (II), 317-324.
- Ringenbach, J. C., Stephan, J. F., Maleterre, P. and Bellon, H., 1990. Structure and geological history of the Lepanto-Cervantes releasing bend in the Abra River Fault, Luzon Central Cordillera, Philippines. *Tectonophysics*, **183**, 225-241.
- Ringis, J., Jones, D. G., Roberts, P. D. and Caringal, R. R., 1993. Offshore geophysical investigations, including use of a sea bed gamma spectrometer, for heavy mineral exploration in Imuruan Bay,

northwest Palawan, southwest Philippines. *British Geological Survey Technical Report WC/92/65* Overseas Geology Series, 54 pp.

- Roeder, D., 1977. Philippine arc system Collision or flipped subduction zones? *Geology*, 5, 203-206.
- Roque, V. P., Reyes, B. P. & Gonzales, B. A., 1972. Report on the comparative stratigraphy of the east and west of the mid-Luzon Central Valley, Philippines. *Mineral Engineering Magazine*, 24: 11-62.
- Rowlett, H. and Kelleher, J.A., 1976. Evolving seismic and tectonic patterns along the Western margin of the Philippine Sea Plate. *J. Geophys. Res.*, 81, 3518-3524.
- Rutherford, M.J., 1993. Experimental petrology applied to volcanic processes. *EOS* **74**, 49-52.
- Rutherford, M.J. and Devine, J.D., 1991. Pre-eruption conditions and volatiless in the 1991 Pinatubo magma. (Abstract) *EOS Trans. AGU* **72**, Fall Meeting, p. 62.
- Rutland, R.W.R., 1968. A tectonic study of the Philippine fault zone. *Quarterly J. Geol. Soc. London*, **123**, 295-325.
- Rutland, R.W.R., 1967. Preliminary report on the geology of the Laur-Dingalan Fault Zone, Luson, Philippines. *Bu. Mines Report of Investigation No.* 63.
- Sajona, F, G. 1995. Slab melting in subduction/collison zones: geochemistry, geochronology petrology of Pliocene-Quaternary magmatism of Mindanao (Philippines). These de doctorat, Université de Bretagne Occidentale, Brest, France.
- Sajona, F. G., H. Bellon, R. C. Maury, M. Pubellier, R. D. Quebral, J. Cotton, F. E. Bayon, E. Pagado, and P. Pamatian. 1997. Tertiary and Quaternary magmatism in Mindanao and Leyte (Philippines): geochronology, geochemistry and tectonic setting. *J. Asian Earth Sciences.* **15** (2-3), 121-153.
- Sajona, F.G., Maury, R.C., Bellon, H., Cotten, J., Defant, M. and Pubellier, M., 1993. Initiation of subduction and generation of slab melts in western and eastern Mindanao, Philippines. *Geology*, 21, 1007-1010.
- Sajona, F.G., Maury, R.C., Prouteau, G., Cotton, J., Schiano, P., Bellon, H. and Fontaine, L., 2000. *The Island Arc.* **9** (4) 472-486.
- Sajona, F. G., Villones, R. I. and Diegor, W. G., 1986. The geology of Bohol Island, central PHilippines, *RP-Japan Mineral Exploration Project, Phase I.* Mines Geosciences Bureau, unpublished, 76 p.
- Saldivar-Sali, A., 1978. Reef exploration in the Philippines. Paper presented at the Second Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii, 30 July 4 August 1978.
- Saldivar-Sali. A., Oesterle, H. G. and Brownlee, D. N., 1981. The geology of offshore northwest Palawan, Philippines-1. *Oil and Gas Journal*, p. 119-128.
- Sales, A.O., Jacobsen, E.C., Morado, A.A., Jr., Benavidez, J.J., Navarro, F.A., Lim, A.E., 1997. The petroleum potential of deep-water northwest Palawan Block GSEC 66. *J. Asian Earth Sciences*, 15, 217-240.
- Samaniego, R. M. and Nilayan-Tan, M., 1988, Triassic in the Philippines. Bureau Mines and Geosciences, unpublished.
- Santiago, A. B., 1983. Preliminary report on the semi-detailed geologic mapping of Malaybalay, Valencia and parts of Cabanglasan and

Lumbayao Quadrangles, Province of Bukidnon In: Geological Survey Division-Bureau of Mines and Geosciences, *Papers Presented in the 1983 Geology Seminar, vol.* **2**, 35 p.

- Santiago, P. D., 1978. Some late Paleogene Foraminifera found in Talahib creek-Middle Tumalo River section, Mansalay, Oriental Mindoro: *Philippine Bureau of Mines*, unpublished.
- Santos, P.J., 1968. Geology and Section Measurements in Iloilo Basin, Panay Island, Philippines, *Phil. Geologist*, vol. **22**, no. 1, 62 p.
- Santos, R. A., 1992. The geology of Palawan Ophiolite and a characterization of the associated chromite mineralization (abs.) *J. Soc. Res. Geol.*, p. 210.
- Santos, R. A., 1989. The geology of Palawan and its tectonic implication. Bureau of Mines and Geosciences, unpublished.
- Santos, R.A., 1988. Tectonic implications of the geology and mineral resources of Central Palawan. *RP-Japan Mineral Exploration Project, Technical Reports*, Manila.
- Santos, R. A. and Santos, E. A., 1987, Geology of south central Palawan and its tectonic implications. In: *Annual National Geological Seminar (Abstract)*, Philippine Bureau of Mines, p. 4.
- Santos, R.R., and Baptista, A. 1963. Preliminary Report on the Geology and Mineral Resource of Southern Cotabato. *Mines and Geosciences Bureau*, unpublished.
- Santos, R. R., Obial, R. C., Zerda, R. R., and Austria, V. Jr., 1962. Report on the Geologic Reconnaissance of Surigao Peninsula and Vicinity. *Bureau of Mines*, unpublished.
- Santos-Yñigo, L.M., 1999. The Cretaceous basement of central Cebu: does it really exist?, unpublished (submitted to J. Geol. Soc. Phil., 1999).
- Santos-Yñigo, L.M., 1965, Distribution of iron, alumina, and silica in the Pujada Laterite of Mati, Davao Province, Mindanao Island, Philippines: *Phil. Geologist*, **19**, 97-110.
- Santos-Yñigo, L.M., 1956. Geology and copper-pyrite deposits of the Lanuza district, Surigao. *Phil. Geologist*, **11** (1), 1-23
- Santos-Yñigo, L.M., 1956. Copper deposits of Atlas Consolidated Mining and Development Corporation, Cebu, in Kinkel, A.R., Jr., Santos-Yñigo, L.M., Samaniego, S. and Crispin, O. (eds): *Copper Deposits* of the Philippines. BM Spec. Proj. Series No. 16, 143-169.
- Santos-Yñigo L.M., 1953. Geology of Southern Zamboanga Province. *Phil. Geologist*, **7** (2), 45-64.
- Santos-Yñigo L.M., 1951. Geology of Central Cebu. Bureau of Mines, unpublished, 178p.
- Santos-Yñigo L.M., 1949. Geology of pyrite deposits of southern Antique, Panay. *Phil. Geologist*, **4** (1), 1-13.
- Santos-Yñigo, L.M., 1944. *Geology of the Surigao Gold District*, unpublished.
- Santos-Yñigo, L.M., Lucas, M.R. and De Guzman, R.I, 1961, Geology, structure and origin of the magnesite deposits of Piso Point, Municipality of Lupon, Davao Province: *Phil. Geologist*, **15** (3), 108-133.
- Santos-Yñigo, L.M. and Oca, G.R., 1946. Preliminary Report on the Geology of Ilog Quadrangle, Negros Occidental. *Bureau of Mines*, 13 p., unpublished.
- Santos-Yñigo, L.M., Vergara, J.P., Crispin, O., 1951. Geology and ore reserves of the Camcuevas property of Samar Mining Company. Bureau of Mines, unpublished.

- Sarewitz, D.R., and Karig, D.E., 1986. Stratigraphic framework of western Mindoro Island, Philippines. *J. Geol. Soc. Phil.*, **40**, 3-51.
- Sarewitz, D.R. and Lewis, S.D., 1991. The Marinduque intra-arc basin, Philippines: Basin genesis and in situ ophiolite development in a strike-slip setting. *Geol. Soc. Am. Bull.*, 103, 597-614.
- Schafer, P.A., 1956. Some phases of the geology of the Baguio District: In *Proceedings 8th Pacific Sci. Congress*, V. IIa, 347-355. National Research Council of the Philippines, Quezon City.
- Schoell, W.U. and Casareo, F., 1989. Geology of the Teresa quadrangle, Rizal province.., *UP-National Inst. of Geol. Sciences.*, unpublished.
- Schoell, W.U. and Duyanen, J.P., 1988. Stratigraphy and Sedimentology of the Maybangain Formation (Paleogene) in a portion of the SW Sierra Madre, *UP-National Inst. Geol. Sciences*, unpublished.
- Schoell, W.U., Foronda, J.M., Jagolino, O.C. and Siringan, F.P., 1985. Geology and facies of part of Laguna Formation, Rizal Province. *U.P. Nat'l. App. Sci. Bull.*, **37** (1) 37-52.
- Schoell, W.V. and Fuentes, J.M.B., 1989. Geology of the Antipolo Quadrangle. UP-Nat'l. Inst. Geol. Sci., unpublished.
- Schweller, W.J., Karig, D.E. and Bachman, S.D., 1983. Original setting and emplacement history of the Zambales Ophiolite, Luzon, Philippines, from stratigraphic evidence. *In: D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands:Part 2.* A.G.U. Monograph 27, 124-138.
- Schweller, W.J., Roth, P.H., Karig, D.E. and Bachman, 1984. Sedimentation history and biostratigraphy of ophiolite-related Tertiary sediments, Luzon, Philippines. *Geol. Soc. Am. Bull.*, 95, 1333-1342.
- Scott, R. and Kroenke, L., 1980. Back-arc spreading and arc volcanism in the Philippine Sea. In: D.E. HAYES, Ed., TheTectonic and Geologic Evolution of Southeast Asian Seas and Islands, A.G.U. Monograph 23, 283-291.
- Seno, T., 1977. The instantaneous rotation vector of the Philippine Sea Plate in relation to the Eurasian Plate. *Tectonophysics*, 42, 209-226.
- Seno, T., 2000. Why the Philippine Sea Plate move as it does. *J. Geol. Soc. Phil.*, 55 (1&2), 105-117.
- Seno, T. and Eguchi, T., 1983. Seismotectonics of the western Pacific region. In: T.W.C. HILDE and S. UYEDA, Eds. Geodynamics of the western Pacific - Indonesian region, Geodyn. Ser. 11, A.G.U., 5-40.
- Seno, T. and Maruyama, S., 1984. Paleogeographic reconstruction and origin of the Philippine Sea. - *Tectonophysics*, Amsterdam, 102, 53-84.
- Shepard, F.P., 1981. Abra delta and Northward continuation of Philippine Great Fault. *Mar. Geol.*, 41, 103-111.
- Sillitoe, R. H. and Angeles, C. A., Jr., 1985. Geological characteristics and evolution of a gold-rich porphyry copper deposit at Guinaoang, Luzon, Philippines. *Asian Mining*, 15-26.
- Silver, E.A. and Moore, J.C. 1978a. Philippine arc system collision or flipped subduction zones? Comment. *Geology*, 6, (4) p. 199.
- Silver, E.A. and Moore, J.C. 1978b., The Molucca Sea collision zone, Indonesia. *J. Geophys. Res.*, Washington, D.C., 83, B4, pp. 1681-1691.

- Silver, E.A., Gill, J.B., Schwartz, D., Prasetyo, H. and Duncan, R.A., 1985. Evidence for a submerged and displaced continental borderland, North Banda Sea, Indonesia. *Geology*, 13, 687-691.
- Silver, E.A., McCaffrey, R. and Smith, R.B., 1983. Collision, rotation, and initiation of subduction in the evolution of Sulawesi. *J. Geophys. Res.*, 88 (11), 9407-9418.
- Silver, E.A. and Rangin, C., 1991. Development of the Celebes Basin in the context of Western Pacific marginal basin history. *In: Proc. ODP, Scientific Results*, Leg 124, 39-50.
- Smith, W.D., 1906. Orbitoids from the Binangonan limestone, etc. *Phil. Jour. Sci.* **1** (2).
- Smith, W. D., 1907. The geology of the Compostela-Danao Coal Fields. *Phil. Jour. Sci.*, **1** (2).
- Smith, W. D., 1907. The asbestos and manganese deposits of Ilocos Norte with notes on the geology of the region. *Phil. Jour. Sci.*, 2, 155-179.
- Smith, W. D., 1913, Contributions to the stratigraphy and fossil invertebrate fauna of the Philippine islands. *Phil. Jour. Sci.*, Sec. A, **8** (4).
- Smith, W.D., 1924. *Geology and Mineral Resources of the Philippines*. Phil. Bureau of Printing, Publ. No. 19, 559 p.
- Smith W.D. and Eddingfield, F.T., 1911. Additional notes on the economic geology of Baguio Mineral District. *Phil. Jour. Sci.* **6**, 429-445.
- Sorem, R. H., 1951. Preliminary report on the geology and manganese deposits of Siquijor Island, Negros Oriental, Philippines, 75p., *Bureau of Mines*, unpublished.
- Sorem, R., Capistrano, P. and Fernandez, N., 1984. Geologic and mineral occurrences of Siquijor Island. *Bureau of Mines and Geosciences, Region VII*, unpublished report.
- Sosa, L.A., 1981. Report on the Semi-detailed Geological Activities in Malita, Davao del Sur, *Bureau of Mines and Geosciences, Davao City*, unpublished.
- Sosa, L.A., 1981. Geology of Talaguton Quadrangle, *Bureau of Mines and Geosciences*, *Surigao City*, unpublished.
- Stainforth, R.M., Lamb, J.L., Luterbacker, H., Beard, J.H., Jeffors, E.M., 1975. Cenozoic planktonic foraminiefral zonation and characteristics of index forms. *Univ. of Kansas Paleontological Contributions,* Article 62.
- Stephan, J.F., Blanchet, R., Rangin, C., Pelletier, B., Letouzey, J. and Müller, C., 1986. Geodynamic evolution of the Taiwan-Luzon-Mindoro Belt since the Late Eocene. *Tectonophysics*, 125, 245-268.
- Sto. Domingo, Z. P., Toliao, J. L. and Sta. Ana, M. C. V., 1990. Stratigraphic mapping of Mogpog, Sta. Cruz and vicinities, Marinduque, Department of Environment and Natural Resources, Mines and Geo-Sciences Development Service, Region IV, unpublished.
- Sudo, M., Listanco, E.L., Ishikawa, N., Tagami, T., Kamata, H. and Tatsumi, Y., 2000. K-Ar dating of the volcanic rocks from Macolod Corrifdor in southwestern Luzon, Philippines: toward understanding of the Quaternary volcanism and tectonics. *J. Geol. Soc. Phil.*, 55, 89-104.
- Sunga, V. and Palaganas, U., 1986. Geology and Mineral Resources of Dinagat Island, *Bureau of Mines and Geosciences*, unpublished.

- Suzuki, S., David S. D., Takemura, S., Yutani, M. and Militante-Matias, 2001. Large scale overturned structure and associated cleavages of the sedimentary successions along northern Honda Bay, central, Palawan. *J. Geol. Soc. Phil.*, **56** (1-2), 43-49.
- Tamayo, R.A., Jr., Yumul, G.P., Jr., Santos, R.A., Jumawan, F. and Rodolfo, K.S., 1998. Petrology and mineral chemistry of a backarc upper mantle suite: example from the Camarines Norte Ophiolite Complex, south Luzon. J. Geol. Soc. Phil. 53 (1-2), p. 1-23
- Tamesis, E.V., 1976. The Cagayan Valley basin: a second exploration cycle is warranted. *SEAPEX Program*, offshore Southeast Asia Conference, paper 14.
- Tamesis, E.V., Lorentz, R.A., Pascual, R.V. & Dizon, E.M., 1981. Stratigraphy and geologic structure of the Central Valley Basin, Luzon, Philippines, Geology and Tectonics of the Luzon-Marianas Region, *Phil. SEATAR Committee Spec. Publ.*: 83-119.
- Tan, M. N., 1994. Kennon and Mirador: early Middle Miocene carbonates in the Baguio District, Northern Luzon, *u*npublished.
- Tapponier, P., Peltzer, G., Le Dain, A.Y., Armijo, R. and Cobbold, P., 1982. Propagating extrusion tectonics in Asia: New insights from simple experiments with plasticine. *Geology*, 10, 611-616.
- Tapponier, P., Peltzer, G. and Armijo, R., 1986. On the mechanics of the collision between India and Asia. *In: M.P. COWARD and A.C. RIES, Eds., Collision Tectonics*, Geol. Soc. Special Publication No. 19, 115-157.
- Taylor, B. and Hayes, D.E., 1983. Origin and history of the South China Sea Basin, In: D.E. Hayes (ed.), *The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands - Part 2*, AGU Monograph No. 27, pp. 23-56.
- Taylor, B. and Hayes, D.E., 1980. The tectonic evolution of the South China Sea Basin. *In: D.E. HAYES, Ed., The Tectonic and Geologic Evolution of Southeast Asian Sea and Islands*, A.G.U. Monograph 23, 89-104.
- Taylor, B. and Karner, G.D., 1983. On the evolution of marginal basins. *Rev. Geophys. Space Phys.*, 21, 1727-1741.
- Tebar, H.J., 1988. *Petrology and Geochemistry of Volcanic Rocks from the Pocdol Mountains, Bicol Arc (Philippines).* MS Thesis, University of Canterbury, 139 p.
- Tebar, H. and Pagado, E.S., 1989. Geology of the Surigao Geothermal Prospect. *PNOC-EDC internal report*, unpublished.
- Teledyne Isotopes, Ltd., 1988. Report to Philex Mining Corp. on samples submitted for K-Ar dating, unpublished.
- Tera, F., Brown, L., Morris, J., Sacks, I.S., Klein, J. and Middleton, R., 1986. Sediment incorporation in island arc magmas: inferences from ¹⁰Be. *Geochimica et Cosmochimica Acta* **50**, 535-550.
- Teves, J. S., 1954. The pre-Tertiary geology of southern Oriental Mindoro: *Philippine Geologist*, **8** (1), 2-36.
- Teves, J. S., 1956. Synthesis of Philippine Cenozoic stratigraphic units. *Mines and Geosciences Bureau*, unpublished.
- Teves, J. S., Vergara, A. A., and Badilo, N., 1951. Report on the Geologic Reconnaissance of Agusan. *Philippine Geologist*, **5**, 24-50.
- Teves, J.S. and Gonzales, M.L., 1950. The Geology of the University site, Balara area, Quezon City; *Phil. Geologist*, **4** (3), 1-10.

- Torres, M. A., 1973. Progress report of Team B on the geological and geochemical survey on part of southeastern Mindanao. *Bureau of Mines*, unpublished.
- Tumanda, F., 1984. Biostratigraphic study of the Rosario Formation. *Phil. Geologist*, **38** (2), 25-34.
- Tumanda, F. P., 1991. Radiolarian biostratigraphy in central Busuanga Island, Palawan, Philippines. J. Geol. Soc. Phil., **46** (1-2), 49-103.
- Tumanda, F.P., 1994. Permian radiolarian from Busuanga Island, Palawan, Philippines. *J. Geol. Soc. Phil.*, **49**, 119-193.
- Tumanda, F.P. and Agadier-Zepeda, M.A., 1995. Stratigraphy and paleontology of southwestern Mindoro, Philippines. Research for Enhancement of Reference Sections of Sedimentary Basins in the Philippines (ITIT Project No. 8319), 90-119.
- Tumanda, F. P., Maac, Y. O., Agadier, M. A. and Nilayan, M. S., 1984. Notes on the paleontology of northern Marinduque, *Bureau of Mines and Geosciences Technical Information Series No. 68-86*, 9p.
- Tumanda, F. P., Santos, R., Tan, M. N., David, S. D., Jr., Billedo, E. B. and Peña, R., 1995. *Guidebook for fieldtrips*, 23 p., Third Symposium of IGCP 350, Cretaceous Environmental Change in East and South Asia,
- Tumanda-Mateer, F., Sashida, K. and Igo, H., 1996. Some Jurassic radiolarians from Busuanga Island, Calamian Island Group, Palawan, Philippines. In Noda and Sashida, K. (eds.), Prof. Hisayoshi Igo Commemorative Volume, Geology of Japan and Southeast Asia, p. 165-192.
- Tumanda, F. P., Sato, T. and Sashida, K., 1990, Preliminary Late Permian radiolarian biostratigraphy of Busuanga Island, Palawan, *Philippines. Annual Report, Institutue of Geoscience, The University of Tsukuba,* no. 16, p. 3-45.
- Tupas. M.H. 1952. Preliminary report on the geology and mineral deposits of Lanao, western Misamis Oriental. *Phil. Geologist.* **7** (1).
- Ueda, A. and Sakai, H., 1984. Sulfur isotope study of Quaternary volcanic rocks from the Japanese island arc. *Geochimica et Cosmochimica Acta* **48**, 1837-1848.
- UNDP (United Nations Development Programme), 1984. Geology of Northern Agusan, Mindanao, *Technical Report No.* 2, 36 p.
- UNDP, 1984. Geology of the Banadero-Umabay area, Masbate Island, *Technical Report No. 1,* 30 p.
- UNDP, 1985. Geology of central Palawan., Technical Report No. 6, 45 p.
- UNDP, 1986. Geology of southwestern Panay, *Technical Report No. 8*, 55 p.
- UNDP, 1987, Geology and mineralization in northwest Bohol. *Technical Report no. 3,* 28p.
- UNDP, 1987. Geology and gold mineralization of Surigao del Norte, *Technical Report No. 4*, 58 p.
- UNDP, 1987. Geology and mineralization in the Baguio area, Northern Luzon. *Technical Report No. 5.*
- UNRFNRE (United Nations Revolving Fund for Natural Resources Exploration), 1986, Chromite Exploration in the Philippines, Final Report, Vol. III: Exploration Area II, Dinagat Island.
- Uyeda, S., 1986. Facts, ideas and open problems on trench arc back arc systems. *In: F.C. WEZEL, Ed., The origin of arc*, Elsevier Science Publishers, 435-460.

- Uyeda, S. and Ben Avraham, Z., 1972. Origin and Development of the-Philippine Sea. *Nature*, 240, 176-178.
- Vallesteros, E.Y. and Argano, W.P., 1965. The geology and mineral resources of the Romblon Island Group, *Bureau of Mines*, unpublished.
- Vergara, J. F. and Spencer, F.D., 1957. Geology and Coal Resources of Bislig-Lingig Region, Surigao. *Bureau of Mines Special Projects Series Publication* 14.
- Victoriano, A. and Gutierrez, B., 1980. Geology of the Surigao del Sur Contract Area. Total Exploration (Phil.), unpublished.
- Villamor, R., Ausa, C. A., and Marcos, D. M., 1984. Report on the geology of Sigaboy, Tugabili and Cape San Agustin quadrangles, southern Pujada Peninsula, Davao Oriental, *Philippine Bureau of Mines and Geosciences, Regional Office No. X, Surigao City*, 39 p. with maps, unpublished.
- Villanueva, C. G., Tan, M. N. and Zepeda, M. A., 1995. Paleontological and paleoenvironmental studies of the sedimentary record in eastern Bulacan. Research for enhancement of reference sections of sedimentary basins in the Philippines (ITIT Project No. 8813). Geol. Survey of Japan and Mines and Geosciences Bureau, 180 p.
- Villavicencio, M. L. and Andal, P. P., 1964, *Distichoplax biserialis* (Dietrich) in the Philippines. *Philippine Geologist*,**18** (4), 103-113.
- Villones, R.D., Jr., 1980. The Aksitero Formation and its implications on the emplacement of the Zambales Ophiolite. Phil. Bureau of Mines and Geosciences Tech. Info. Series No. 16-80, 22 p.
- Walther, H.W., Forster, H., Harre, W., Kreuzer, H., Lenz, H., Muller, P. And Raschka, H., 1981. Early Cretaceous porphyry copper mineralization on Cebu Island, Philippines, dated with K-Ar and Rb-Sr methods. *Geol. Jb.*, **48**, 21-35.
- Weiss, W. and Gramann, F., 1985. Micropaläontologischer Bericht, Cebu, Philippinen, Federal Inst. For Geosciences and Natural Resources, Hannover, unpublished.
- Weissel, J.K., 1981. Magnetic lineations in marginal basins of the West Pacific. *Phil. Trans. R. Soc. London*, Ser. A., 300, 223-247.
- Weissel, J.K. and Hayes, D.E., 1977. Evolution of the Tasman Sea reappraised. *Earth Planet. Sci. Lett.*, 36, 77-84.
- Weissel, J.K. and Watts, A.B., 1979. Tectonic evolution of the Coral Sea Basin. J. Geophys. Res., 84, 4572-4582.
- Weller, J. M. and Vergara, J. F., 1955. Geology and coal resources of the Bulalacao region, Mindoro Oriental: Philippine Bureau of Mines Special Project Series Publ. No. 1, 37 p..
- White, W.M., and Hofmann, A.W., 1982. Sr and Nd isotope geochemistry of oceanic basalts and mantle evolution. *Nature* **296**, 821-825.
- Willis, B., 1944. Philippine earthquakes and structure. *Seismol. Soc. Am. Bull.*, 34, 69-81.
- Willis, B., 1937. Geologic observations in the Philippine Archipelago. *Nat. Resources Council Bull.*, Manila, Philippines, no. 13.
- Wolcke, F. and Scholz, J., 1988. Uber die paläobiogeographische Bedeutung eines Vorkommens caprinider Rudisten aus der Unterkreide von Cebu (Philippinen). *Mitt. Geol. Paleont. Inst. Univ. Hamburg.* Heft 67, 121-133.

- Wolfart, R., Cepek, P., Graman, F., Kemper, E. and Porth, H., 1984, Stratigraphy of Palawan Island, Philippines. *Federal Institute for Geosciences and Natural Resources, Hannover.*
- Wolfart, R., Cepek, P., Graman, F., Kemper, E. and Porth, H., 1986, Stratigraphy of Palawan Island, Philippines. *Newsletters on Stratigraphy*, **16**, 19-48.
- Wolfe, J.A., 1981. Philippine geochronology. *Jour. Geol. Soc. Phil.*, **35** (1), 1-30.
- Wolfe, J.A., Manuzon, M.S., and Divis, A.F., 1980. The Taysan porphyry copper deposit, southern Luzon Islands, Philippines: *J. Geol. Soc. Phil.*, **34**,(1).
- Wolfe, J.A., and Self, S., 1983. Structural Lineament and Neogene Volcanism in Southwestern Luzon. In: Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Part 2, Geophys. Monograph Ser., 27, 157-172.
- Wright, W.S. Quicho, R.B., Santos-Yñigo, L.M., Salazar, A., Manigque, M.D., 1958. Iron-nickel-cobalt resources of Nonoc and southern Dinagat Island in Parcel II of the Surigao Mineral Reservation, Surigao, Mindanao. Spec. Proj. Series No. 17, Bureau of Mines, 276 p.
- Yang, T., Lee, T., Chen, C., Cheng, S., Knittel, U., Punongbayan, R., and Rasdas, A., 1996. A double island arc between Taiwan and Luzon: consequence of ridge subduction: *Tectonophysics* 258, 85-101.
- Yabe, H. and Hanzawa, S., 1929. Tertiary foraminiferous rocks of the Philippines. Sci. Rep. Tohoku Imp. Univ., 2nd ser. 11(3), 137-190.
- Yap, A.L., 1972. Geologic report on PEC 65 A, Negros Occidental Rep. *Maremco Mineral Corp*, unpublished.
- Yeh, K., 1992. Triassic radiolarian from Uson Island, Philippines. *Bull. Natn. Mus. Nat. Sci. (Taiwan),* No. 3, 51-91.
- Yumul, G.P., 1990. Varying mantle sources, multi-stage melting and ophiolite generation: Inferences from the Zambales Ophiolite Complex (Philippines). *EOS* **71**, 956.
- Yumul, G.P. Jr., 1989. Petrological characterization of the residualcumulate sequences of the Zambales Ophiolite Complex, Luzon, Philippines. Ofioliti 14, 253-291.
- Yumul, G.P. Jr., 1987. Petrology and geochemistry of a supra-subduction zone ophiolite - Zambales Ophiolite Complex, Luzon, Philippines. PhD thesis, University of Tokyo, 247 p.
- Yumul, G.P., Jr. and Datuin, R.T., 1991. Bulk chemistry of a Cretaceous marginal basin ophiolitic complex Angat Ophiolitic Complex, Luzon, Philippines. *J. Geol. Soc. Philippines*, 46, 1-14.
- Yumul, G.P. Jr. and Datuin, R.T., 1990. Zambales Ophiolite Complex a rifted Paleocene-Eocene South China Sea fragment? *J. Geol. Soc. Phil.* **45**, 51-68.
- Yumul, G.P., Jr., De Jesus, J.V. and Jimenez, F.A., Jr., 2001. Zamboanga Peninsula: geological characterization of a new mining district. (Terminal report), *PCIERDD*
- Yumul, G.P., Jr., Samson, M.T., Claveria, R.J.T., de Silva, L.P., Jr., Diomampo, E.O. and Rafols, J.P., 1992. Preliminary geochemical evidences for a marinal basin basement complex for the Baguio Mining District, Luzon, Philippines, J. Geol. Soc. Phil., 47, 5-17.
- Yumul, G. P., Tamayo, R. A., Jumawan, F. and David, C. P., 1995. Southeast Bohol Ophiolite Complex, Visayas, Philippines: a

forearc to backarc supra-subduction zone ophiolite complex?, *Abstract volume GEOSEA* '95, p. 60.

- Zaide-Delfin, M.C., Gerona, P.P., Layugan, D.B., Maturgo, O.O., Padua, D.O., Panem, C.C., Rosell, J.B. and Salonga, N.D., 1995. Mount Labo Geothermal Project Resource Assessment Update. *PNOC-EDC*, unpublished.
- Zamoras, L. R. and Matsuoka, A., 2000, Early Late Jurassic radiolarians from the clastic unit in busunaga Island, North Palawan, Philippines. *Science Report, Niigata, University, Series E* (*Geology*), no. 15, p. 91-109.
- Zanoria, A.S., Domingo, E.G., Bacuta, G.C. and Almeda, R.L., 1984. Geology and tectonic setting of copper and chromite deposits of the Philippines. *Geol. Survey Japan* Report No. 263, 209-233.
- Zepeda-Agadier, M.A., Tumanda, F.P. and Revilla, A., 1992. The Paleogene-Neogene sequence of southwest Mindoro island, Philippines – stratigraphy and events. Bureau of Mines, unpublished.
GEOLOGY OF THE PHILIPPINES

INDEX of STRATIGRAPHIC NAMES

Stratigraphic Name	Page/s
Abra de Ilog Formation	231
Abuan Formation	109, 110, 111, 121,
Acoje Block	127, 129, 130
Adgaoan Formation	418, 419
Agbahag Conglomerate	221
Aglalana Limestone Member	284
Aglipay Formation	114, 115, 125
Agno Batholith	96, 99
Agtuuganon Limestone	431, 441, 442
Agudo Basalt	283
Aksitero Formation	78, 79, 80, 127, 129, 130
Alagao Volcanics	87, 88, 89, 151, 152
Alat Conglomerate	91, 153, 154
Alat Conglomerate member	91
Albuera Diorite	344, 353
Alegria Andesite Porphyry	433
Alfonso XIII Formation	237, 261, 262, 263
Alicia Schist	327, 329, 330
Alipao Andesite	430, 431
Allah Formation	450
Aloneros Conglomerate	172
Alpaco Member	316
Altar Formation	467
Amacan Volcanic Complex	442, 443
Amlan Conglomerate	303, 304
Amlang Formation	82, 83, 84, 100, 102
Amnay Ophiolitic Complex	233
Amontay Sandstone	341, 343, 344
Anagasi Formation	362, 364, 365
Anahao Formation	293
Anahawan Formation	437
Ananawin Formation	224
Anawan Formation	140, 141
Anda Limestone member	336
Angat Formation	86, 87, 88, 149, 150, 151, 152
Angat Ophiolite	85, 144
Ania Conglomerate	301
Animasola Conglomerate	215, 218

Anoling Andesite	435
Ansuwang Amphibolite	460, 462, 466
Antamok Diorite	96, 99
Antipolo Basalt	154, 155
Antipolo Diorite	148, 149
Antique Ophiolite	270
Anungan Formation	379, 381, 382, 383, 384
Apaoan Volcaniclastics	95
Aparri Gorge Member	81
Apdo Formation	275
Apo Volcanic Complex	414
Apud Limestone	196, 197
Argao Group	323
Aringay Member	82, 83
Aroroy Quartz Diorite	209
Aroroy Schist	207, 215
Asiga Diorite	429
Asiga Member	113
Assisig Member	282, 283
Aurora Formation	391
Awang Ultramafic Complex	399, 400
Awang-Table Limestone	454
Awiden Mesa Formation	116
Babacolan Formation	140, 141, 142
Babatngon Schist	358
Babuyan de Claro Island	108
Babuyan River Turbidites	244, 245, 246
Bacnotan Limestone	84
Bacuag Formation	374, 375, 428, 429, 430
Bacuit Chert	237
Bacuit Formation	237, 238, 240, 243
Bacungan River Group	255
Bad-as Dacite	433, 434
Bagacay Andesite	201
Bagahupi Formation	361
Bagalangit Coal Measures	218, 219
Baggao Limestone	407, 417, 436, 437
Bagon Intrusive	99, 100
Baguio Formation	102, 103, 104
Bailan Limestone	247
Bairan Agglomerate	302

Balabac Formation	259, 260, 262, 263
Balacbac Andesite	104
Balakibok Volcanic Complex	135
Balanga Formation	227
Balatoc Dacite Plug	105
Balbalan Sandstone Member	113
Baleno Schist	207
Balic Mudstone Member	279
Balili Formation	95, 97, 98, 101
Balinsasayao Formation	304, 305, 306
Balo Formation	362, 363, 364, 365, 366
Balog-Balog Diorite	130
Balongkot Limestone	400, 402
Baloy Formation	272
Balut Volcano	460
Bamban Formation	81 82, 84
Banahaw Volcanic Complex	164
Bangui Formation	71, 73, 74, 76, 77
Banoy Volcanics	157, 158
Banton Volcanic Complex	293
Bantoon Serpentinite	311
Barangay Andesite	178
Barasan Sandstone	277
Barcelona Formation	439
Barenas-Baito Formation	85, 86, 145, 146
Barili Formation	319, 320, 321, 336, 337
Barot Diorite	312
Barton Group	243, 246, 249
Barton Metamorphics	237, 243, 244, 245, 246, 249
Baruyen Formation	71,72,73
Basac Formation	325, 326, 327
Basak Formation	295, 296
Basiaw Limestone	465
Bata Formation	348, 349
Bataan Volcanic Arc Complex	133, 161
Batac Formation	76
Batalay Diorite	190
Batan Island	107, 192, 193, 194, 195
Batang Formation	345
Batangan Formation	222, 223
Batangas Volcanics	157

Bato Dacite Porphyry	104, 105
Bayabas Formation	85, 86, 147
Baybay Limestone	219
Baye Limestone	312
Bayuso Volcanics	280, 282, 283
Beaufort Ultramafic Complex	253, 254, 255
Bicobian Basalt	117, 118
Bicol Formation	198
Bigbiga Limestone member	78, 131
Bilbao Formation	195
Biliran Volcanic Complex	356
Binabac Limestone	316
Binangonan Formation	146, 149, 150
Binoog Formation	292, 293
Bislian Quartz Diorite	141
Bislig Formation	417, 436, 437, 438
Bitaogan Amphibolite	462
Black Mountain Quartz Diorite	103
Boac Formation	169
Boayan Formation	243, 245, 246, 247, 255, 256
Boayan-Caruray Clastics	246
Bohol Ophiolite	329
Bojeador Formation	73, 74, 75, 76, 77, 78
Bokod Formation	97, 98
Bolinao Limestone	133
Bolok-bolok Member	321
Bongao Formation	378, 379
Bongbongan Series	270, 271
Boracay Formation	208
Bordeos Formation	138, 139, 142, 143
Bosigon Formation	178, 180, 201
Bote Limestone	190
Buayan Formation	457, 458, 459
Buenacop Limestone member	87, 151, 152
Bugnam Formation	149
Buenavista Limestone	225
Bugtong Formation	223, 224
Bugui Pt. Limestone	214
Buhang Ophiolite	139
Bukidnon Formation	404
	404

Buluan Member	114
Bulusan Volcanic Complex	205
Bunawan Limestone	424, 426
Bungiao Mélange	381, 382
Burburungan Amphibolite	229, 230, 233
Burgos Member	78, 130, 131
Buruanga Metamorphic Complex	267, 268, 269, 289
Buso and Altar Formation	467
Busuanga Chert	240
Butac Limestone	98
Butong Limestone	323, 324, 325, 344
Buyag Formation	211, 212, 213, 214
Cabadbaran Diorite	429
Cabagan Formation	115, 116
Cabalian Volcanic Complex	356
Cabaluan Formation	131, 132
Cabanglasan Gravel	405, 411
Cabariohan Limestone	271
Cabatuan Formation	279
Cablacan Formation	444, 447, 448, 449
Cadig Ophiolitic Complex	170, 175, 182, 196
Cagayan Gravel	404, 411
Cagbaong Basalt	341
Cagraray Peridotite	192, 196
Caguray Formation	221, 222, 223, 226
Caibaan Basalt	357, 359, 360
Calagasan Formation	323, 324
Calaogao Pyroclastics	305
Calape Limestone	331
Calatagan Formation	157, 158, 159, 160
Calatrava Quartz Diorite	290
Calayan Island	108
Calicoan Formation	369
Caliling Formation	304
Callao Formation	114, 115
Caloi Formation	395
Calubian Limestone	347, 349, 350, 351, 352
Calumpang Formation	208
Camanga Formation	389, 390
Camarines Norte Ophiolite Complex	176
Camarong Gneiss	229

Camcuevas Volcanic Complex	363, 364, 365, 366, 367
Camiguin Island	108, 398, 412, 415, 416
Camiguin Volcanic Complex	415, 416
Can-agong Limestone	325, 326
Cancajanag Volcanic Complex	357
Canguinsa Formation	172, 713
Canlaon Volcanic Complex	305, 306
Cansi Basalt	308, 309
Cansirong Limestone	345
Cantabaco Mudstone	316
Canturay Formation	302, 303
Caraballo Formation	110, 119, 120, 121, 122, 123, 124, 125
Caraballo Group	109, 120
Carabao Limestone	288
Carabao Sandstone	288, 289
Caracaran Siltstone	194, 195
Caramay Schist	243, 244, 245, 246
Caramoan Formation	184, 185
Carcar Limestone	307, 308, 320, 321, 322, 327 339, 352
Carmen Clastics and Pyroclastics	/11
earnen eraenee and i greenaenee	411
Carmen Formation	333, 334, 335, 336, 337, 338
Carmen Formation Cataguintingan Formation	333, 334, 335, 336, 337, 338 82, 83, 84
Carmen Formation Cataguintingan Formation Catagupan Member	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Limestone	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Limestone Cebu Orbitoid Limestone	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344 314, 315
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344 314, 315 92, 96, 100
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Limestone Cebu Urbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 315, 317, 344 314, 315 92, 96, 100 353, 354
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation	 333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344 314, 315 92, 96, 100 353, 354 263, 264
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Coal Measures Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation Clastic Member	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 315, 317, 344 314, 315 92, 96, 100 353, 354 263, 264 420, 423, 440, 442, 450, 454
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Catbel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation Clastic Member Coal Harbor Limestone	333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344 314, 315 92, 96, 100 353, 354 263, 264 420, 423, 440, 442, 450, 454 193
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Coal Measures Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation Clastic Member Coal Harbor Limestone Coal Measures	 333, 334, 335, 336, 337, 338 82, 83, 84 260, 262 187, 188 368, 369 440 314 314 315, 317, 344 314, 315 92, 96, 100 353, 354 263, 264 420, 423, 440, 442, 450, 454 193 193, 194, 195, 196, 200, 201 218, 219, 224, 225
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Catbalogan Formation Cateel Quartz Diorite Cebu Coal Measures Cebu Formation Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation Clastic Member Coal Harbor Limestone Coal Measures	333, 334, 335, 336, 337, 33882, 83, 84260, 262187, 188368, 369440314314315, 317, 344314, 31592, 96, 100353, 354263, 264420, 423, 440, 442, 450, 454193193, 194, 195, 196, 200, 201 218, 219, 224, 225194
Carmen Formation Cataguintingan Formation Catagupan Member Catanduanes Formation Catbalogan Formation Catbel Quartz Diorite Cebu Coal Measures Cebu Coal Measures Cebu Formation Cebu Limestone Cebu Orbitoid Limestone Central Cordillera Diorite Complex Central Highland Volcanics Clarendon Formation Clastic Member Coal Harbor Limestone Coal Measures	333, 334, 335, 336, 337, 33882, 83, 84260, 262187, 188368, 369440314314315, 317, 344314, 31592, 96, 100353, 354263, 264420, 423, 440, 442, 450, 454193193, 194, 195, 196, 200, 201 218, 219, 224, 225194188, 190, 191

Coloy Formation	386, 395, 396
Columbus Formation	95, 96, 98
Concepcion Greenschist	427, 430
Concepcion Phyllite	244, 245, 246
Copias Limestone	101, 102
Cordillera Batholith	96
Cordon Syenite Complex	123
Coron Formation	237, 241, 242, 243
Coronel Formation	120, 121
Corregidor Formation	159
Cortes Limestone	337, 338, 339
Coto Block	127, 130
Cuernos de Negros	305, 306
Culianan Limestone	382, 383, 384
Curuan Formation	384, 385
Cutad Pyroclastics and sedimentary rocks	159
Dacao Formation	345, 346, 347, 348
Dacongbanwa Formation	411
Dacongcogon Formation	300
Dagatan Wacke	158, 159
Dagot Limestone	74, 75
Daguma Diorite	445, 449
Dalrympole Amphibolite	252, 253, 256, 257
Dalugan Schist	119
Dalupirip Schist	92
Damortis Formation	84
Danao Limestone	346, 347, 348
Dansalan Metamorphic Complex	386, 387, 389
Dao Member	352
Daram Formation	367, 368
Dawan Sediments	465
Del Pilar Formation	186
Dibuakag Volcanic Complex	117, 118, 119
Dibuluan Formation	111, 112, 125
Dibut Bay Metaophiolite	117, 139
Dikinamaran Chert	117, 118
Diliman Tuff	153, 154, 155
Diliman Tuff member	91, 154
Dimuluk Conglomerate	454
Dinagat Ophiolite Complex	370, 371, 372, 373, 374, 375

Dinalungan Diorite Complex	120, 122
Dingalan Formation	85, 122, 123
Dinganen Formation	453
Dingle Formation	283
Disubini Formation	123, 124
Diwata Diorite	436
Diwata Limestone	435
Dolores Formation	351, 353, 355
Dumagok Member	394
Dumaguet Sandstone	383, 394, 395
Dumali Volcanic Complex	234
Dumatata Formation	109, 110, 111, 122, 123
Dupax Diorite Complex	121, 122, 123, 125
Eastern Volcanic Belt	136
Emerald Creek Complex	104
Eplog Lava Flows	235
Escalante Formation	297
Espina Formation	253, 254, 255, 256, 257, 258, 260,
	262
Famnoan Formation	226, 227
Felsic Volcanic Rocks	366
Formations I, II, III	120
Fragante Formation	269
Fuentes Green Tuff	299
Gaba Coal Measures	196
Galicia Sandstone	195
Gamut Limestone	420
Garchitorena Formation	183, 184, 186
Gasan Formation	167, 169
Gilonon Formation	343
Giporlos Ultramatic Complex	362
Glan Formation	456, 457, 458
Gotas Member	394
Guadalupe Formation	91, 153, 154
Guijalo Limestone	177, 178, 184
Guimaras Diorite	280, 281
Guimbal Mudstone Member	278
Guinaoang Quartz Diorite	104
Guindaruhan Conglomerate	315
Guinibasan Conglomerate	315
Guinlo Formation	237, 238, 242, 243

Gulang-Gulang Slates	240
Gumaca Schist	170
Gumasa Formation	458, 459
Gunyan Mélange	388
Gutusan Member	352
Hagbay Formation	368
Halcon Metamorphic Complex	228, 231, 232, 233
Head Allah Limestone	447
Hibulungan Volcanics	354
Hilawan Limestone	178, 189, 190
Hill 169/259 Hornblende Andesite	433
Hill Limestone	190, 194
Himalyan Formation	399, 400, 401, 402, 403, 404
Hinabangan Formation	368
Hinatigan Limestone	435
Hinatuan Limestone	438
Hindang Diorite	344, 353
Hondagua Formation	172, 173, 181
Hubasan Conglomerate	349
Hubay Formation	321, 349, 350, 355
Humandum Serpentinite	427, 430
Iba Formation	464, 465, 466
Ibulao Limestone	111, 112, 113, 114, 115
Iday Formation	278, 279, 284
Igbayo Pelagic Complex	271
Igsawa Pyroclastics	273
Igtalongon Shale	277
Ilag Limestone	314, 315, 316, 324
Ilagan Formation	115, 116, 126
Ilihan Plug	331, 333, 334
Ilihan Shale	333, 335, 336, 337, 338
Ilocos Peridotite	71, 73
Ilog Formation	295, 296
Imbaguila Dacite	105
Imorigue Limestone	241, 242
Inagauan Metamorphics	256, 257
Indahag Limestone	403
Inopacan Formation	351
Insulman Formation	227
Ipil Andesite	432, 433, 434
Iponan Formation	404

GEOLOGY OF THE PHILIPPINES

Irahuan Metavolcanics	252, 255
Iriga Volcano	206
Irisan Formation	102, 103
Isabela Ophiolite	116, 117, 118, 119, 124, 139
Isabela Ultramafic Complex	117
Isarog Volcanic Complex	202
Isio Limestone	297
Isugod Formation	261, 262
Itogon Quartz Diorite	76, 96, 99, 100
Iwahig Formation	263
Jagna Andesite	333, 334
Jagupit Formation	432
Jetafe Andesite	330, 331, 332, 334, 335
Jolo Volcanic Complex	379
Kaal Formation	209, 210, 211
Kabagtican Formation	420, 421, 422
Kabangan Metamorphics	256, 257
Kabulao Conglomerate	338, 347
Kadlum Conglomerate	348
Kalagutay Formation	406, 408, 409, 410
Kalumbuyan Formation	302, 303, 305
Kalunasan Basalt	460, 461, 462, 464, 465, 466
Kamanga Limestone	450, 451
Kanaipang Formation	119, 124, 126
Kanan Formation	147, 148
Kanglasog Volcanic Complex	325, 326
Kantaring Limestone	344, 346
Kanturao Volcanics	354, 355
Kapalong Formation	410
Kapatagan Group	404
Kapoas Granite	249, 250
Karlagan Formation	143, 144
Katablingan Metamorphics	139
Katanglad Volcanic Complex	414
Kauswagan Road Volcaniclastics	331
Kayakian Shale	222
Kelly Diorite	96, 99
Kennon Limestone	75, 97, 98, 99, 100
Kiamba Formation	443, 444, 445, 446, 447, 448, 449
Kiblawan Limestone	459
Kilada Formation	454

Kilapagan Formation	407, 408
Kinabuan Formation	145, 146, 147
King Ranch Formation	241, 242
Kitcharao Limestone	431
Klondyke Formation	76, 82, 98, 99, 100, 101, 102, 103
Koronadal Formation	411
Labangan Formation	397
Labayug Limestone	77, 82, 101
Labo Volcanic Complex	203
Labog Limestone	258
Laboon Conglomerate	346, 347
Lagdo Formation	274
Lagonoy Ophiolite	181, 182, 183, 192, 202, 203
Laguna de Bai	163
Laguna Formation	153, 154
Lahuy Formation	187
Lalat Member	393, 394
Lambak Formation	89
Lamon Andesite	210
Lanang Conglomerate	211
Lanang Formation	211, 213
Lanao Volcanic Complex	412
Langoyen Limestone	143, 144
Laoag Formation	77
Lapangan Tuff	106
Larap Volcanic Complex	178, 179, 180
Lasala Formation	231, 232
Latian Limestone	455
Lawaan Formation	364, 366, 367
Lawagan Gabbro	341, 343
Lazi Member	325, 326
Lepanto Formation	94, 99
Lepitan Limestone	222
Leyte Volcanic Arc Complex	356
Libertad Formation	269, 275
Libog Formation	192, 193
Licuan Group	94
Ligao Formation	199, 200, 204
Liguan Formation	194, 195
Liminangcong Formation	237, 239, 240, 241, 242
Linapacan Metamorphic Series	240

Linut-od Formation	323, 324
Liuanan Sandstone	420
Lobo Agglomerate	160
Lobo Quartz Diorite	168
Locawan Diorite	409
Looc Limestone	295
Looc Volcanic Complex	157
Loquilocon Limestone	367, 366
Loreto Formation	372, 376
Lourdes Limestone	211
Lower Buyag Formation	211
Lower Coal Measures	314, 315, 323, 324
Lower Limestone Member	305, 320, 321, 337
Lower Zigzag Formation	111
Lubang Granite	232, 233
Lubang Turbidites	331
Lubi Formation	140, 141
Lubingan Formation	119, 139
Lubuagan Formation	112, 113, 114, 115, 125
Luka Formation	317
Lumao Diabase	460, 464
Lumbayao Formation	410
Lumbog Formation	383, 392, 393, 394, 395
Lumbog Volcaniclastic Member	336
Lumbuyan Formation	272
Lumintao Basalt	233, 234
Lungag Dike Complex	464
Lupa Granodiorite	141, 142
Lutak Limestone	313
Lutopan Diorite	311, 312
Mabaca River Group	113
Mabuhay Andesite	433
Mabuhay Clastics	432
Mabuhay Formation	375, 428, 431, 437
Macamote Silt	219
Macasilao Formation	301, 302
Macde Limestone	125, 126
Maco Limestone	467
Macogon Formation	108, 201
Macolod Volcanic Complex	161, 162
Madanlog Formation	374

Madlum Formation	87, 89, 90, 152, 153
Magabbobo Limestone	73
Maganoy Formation	446, 447, 451
Magapua Limestone	165, 166
Magbanco Conglomerate	301
Magpapangi Greenschist	460, 462, 466
Magsinulo Andesite	303, 304
Mahaba Sandstone	305
Maibu Mudstone and Sandstone	454
Maingit Formation	319
Mainit Formation	434
Makalawang Limestone	217
Makapilapil Formation	90
Makato Formation	274
Makiling-Malepunyo Complex	163
Malabago Formation	299
Malaguit Schist	175, 176, 177
Malajog Limestone	368
Malajon Limestone	241, 242
Malama Siltstone	199, 200
Malambo Andesite	410, 411
Malampaya Sound Group	237, 238, 243, 244, 245
Malaya Formation	103, 104, 105, 106
Malayanan Formation	408
Maliao Wackes	273
Malindang Volcanic Complex	414
Malindig Volcanic Complex	169, 170
Malinta Formation	79, 80, 81, 82
Malita Formation	455, 456
Malitbog Ophiolite	340, 357
Malitep Formation	92, 94, 95, 96
Malo Pungatan Limestone	79, 80
Malubog Formation	316
Mambuaya Andesite	412
Mamburao Group	231
Mamparang Formation	111, 120, 122, 123, 125
Manamrag Volcanics and	189
Mananga Group	308, 312, 313
Manapao Basalt	207. 208. 209
Manay Formation	441, 442

Madanlog Formation	427, 428
Mandaon Formation	209, 210, 211
Mandog Sandstone	420, 422, 423, 424
Mangabel Formation	392
Mangagoy Formation	437
Manguao Basalt	250, 251
Mangyan Igneous Rocks	289
Maniayao Andesite	433, 434, 435
Maniki Quartz Diorite	402
Manila Formation	155
Mankayan Dacitic Complex	104, 106
Manlawaan Gabbro	297
Mansalay Formation	220, 222
Maonon Diorite	197
Mapanas Limestone	367
Mapulo Limestone	158, 160
Maraat Diorite	429
Maraget Sandstone	279, 280, 285
Maranat pillow lavas	255
Marbel Formation	454
Marcelino Point Limestone	141, 147, 148
Maribojoc Formation	335, 336, 337, 339
Marinduque Formation	164, 165
Mariveles Volcanic Complex	135
Masaba Conglomerate	349
Masbate Formation	210, 213
Masbate Limestone	213, 214
Masipi Green Tuff	110, 111
Masonting Formation	344, 348, 349, 350
Masuhi Formation	421, 422, 423, 424
Masungi Limestone	146, 147, 148
Mataas na Gulod Volcanic Complex	161
Matabao Formation	217
Matalao Gabbro	460, 463, 464
Matalom Limestone	352
Matan-ao Clastics	459
Matinloc Formation	237, 248, 262
Matulas Gravel	451
Matuno Formation	126, 127
Matutum Volcanic Complex	415
Maubid Amphibolite	328

522

Mawab Formation	423, 424
Mawo Volcanics	367
Maybangain Formation	85, 86, 145, 146, 147, 148, 149
Mayha Clastic Member	294
Mayon Volcano	206
Mayos Formation	273
Maysawa Formation	149, 150
Maytiguid Limestone	242, 246, 247, 248, 258
Mekoupe Formation	437, 438
Merida Member	351
Midsalip Diorite	384, 395
Mindanao Ultramafic Complex	387
Mindoro Metamorphics	228
Mingan Formation	120, 121
Minilog Limestone	237, 238, 239
Mirador Limestone	77, 100, 101, 102, 103
Mobo Diorite	212
Montalban Formation	149, 150
Montalban Ophiolite	144
Moriones Formation	78, 79, 80, 81, 130
Motherlode Turbidite Formation	430
Mountain Maid Limestone	210, 211
Mt. Amorong	137
Mt. Arayat	134, 136
Mt. Balungao	137
Mt. Cagua Volcano	109
Mt. Corte Conglomerate	338
Mt. Cresta Formation	109, 110
Mt. Cuyapo	137
Mt. Mabaho Monzonite	430
Mt. Mandalagon	305, 306
Mt. Pandan Volcanics	280
Mt. Silay	305, 306
Musuan Volcano	416
Nabangig Formation	210, 212, 213
Nabanog Formation	428
Nabongsuran Andesite	213
Nabua Formation	200
Naga Andesite	433
Naga Group	314
Nagas Peridotite	460, 463

Nagtal-o Formation	429
Nakal Formation	446, 447, 451, 453, 456
Nalikban Conglomerate	302
Nap Conglomerate	215, 218
Napisian Formation	224, 225
Nasipit Formation	422, 432
Natbang Formation	125
Nicaan Formation	453
Nido Limestone	237, 248, 261
Nilabsan Formation	406, 407, 408
North Bay Member	260
Northern Sierra Madre Batholith	122
Nueva Estrella Schist	371
Odeong Formation	299
Odiongan Andesite	285
Olutanga Limestone	396, 398
Omanay Marl	455
Opol Formation	400, 401, 402, 403
Oreng Formation	228
Pabellion Limestone	246, 247, 258
Paco Andesite	434
Paco Volcanics	434
Pacul Limestone	288
Pag-asa Formation	237, 248
Pagbahan Granodiorite	232, 233
Paghumayan Shale	301
Paglaum Diabase Complex	359
Pagsangahan Formation	176, 177, 183, 184, 185
Paitan Member	298
Pakol Diorite	269, 273
Palali Batholith	123
Palali Formation	124, 125
Palanan Formation	119, 126
Palanog Formation	360
Palapag Limestone	369
Palawan Metamorphics	244, 245
Palawan Ophiolite	248, 252, 254, 256
Paly Serpentinite	243, 253
Pamaypayan Formation	417, 437,438
Panablan Limestone	282
Panaon Limestone	171

524

Panas Formation	246, 254, 256, 257, 258, 259, 264
Pandan Formation	306, 307, 308, 311, 312, 313, 322,
	325
Pandian Formation	258, 259, 261, 262, 263
Panganiran Diorite	197
Panganiran Peridotite	196, 197
Panganuran Formation	385
Pangasugan Formation	351, 353, 354, 355, 361
Pangatban Diorite	295
Pangulanganan Basalt	427
Pangyan Formation	456, 457
Paniciuan Mélange	274
Panoyan Limestone	263, 264
Panpanan Formation	275, 276
Pansol Clastic Member	336
Pantabangan Formation	126, 127
Pantao Limestone	177, 178, 196, 197
Pantaron Ultramafic Complex	406
Paracale Granodiorite	175, 176, 179
Paraschists and Altered Arkose	256
Parker Volcanic Complex	413, 450, 451
Pasaleng Quartz Diorite	75, 76
Pasig Silt	219
Pasonanca Formation	382, 383
Passi Formation	282, 283, 284
Pasuquin Limestone	76, 77, 78
Patnanongan Formation	143
Paton-an Formation	302, 303
Patria Quartz Diorite	268, 274
Patut Formation	446, 447, 452, 453
Pau Sandstone Member	81
Paulba Sandstone	199
Payo Formation	177, 178, 188, 189, 191
Peli Formation	294
Peliw Formation	294
Piatt Mudstone	222
Pico Pyroclastics	101, 102, 103
Pictoran Formation	390
Piedras Andesite	250
Pilar Formation	281
Pilar Monzonite	281

Pinamucan Formation	160
Pinatubo Volcanic Complex	135
Pingkian Ophiolite	93, 117
Pitogo Conglomerate	172
Placer Conglomerate	432, 435
Pleistocene-Recent Volcanic Centers	106
Pocanil Formation	224, 225
Pocdol Volcanic Complex	204
Polanco Ophiolite	387, 388
Polangui Volcanic Complex	202
Polillo Diorite	139, 141, 142
Port Barrera Formation	212, 213, 214
Porvado Conglomerate	168
Pugo Formation	92, 96, 97, 103
Pujada Ophiolite	439, 460, 463, 464, 465, 466, 467
Pulute Formation	258, 259
Punso Conglomerate	226
Pusok Conglomerate	263, 264
Quaternary Volcanic Complex	398
Quezon Formation	86, 87, 150, 262
Quezon Marl and Limestone	262
Quidadanom Schist	119, 139, 140
Quilla Formation	215, 218
Radiolarite	239, 240, 241
Ragang Volcanic Complex	412
Ragas Point Olistostrome	184, 185
Ragay Andesite	198, 198
Ransang Limestone	248,261
Rapu-Rapu Schist	192
Recent Deposits	377, 420
Reed Bank Limestone	248
Rizal Basaltic Wacke	331, 332
Rizal Serpentinite	243
Romblon Metamorphic Complex	286
Rosario Formation	82, 83, 103
Rosario Limestone	438
Sablayan Group	232
Sabtang Island	108
Sagada Formation	94, 95, 96
Sagasa Mélange	259
Sagasa Point Tectonic Complex	247, 259

Sagay Volcanics	305, 306
Salbuyon Schist	443 ,444, 445, 446, 448, 450, 451
Salngan Member	282, 283
Salog Andesite Formation	332
Salomon Member	346
Salug Volcanics	344
Salvacion Limestone	281, 282
Samal Limestone	425
Samar Ophiolite	362
Sambulawan Formation	209, 210, 211, 212
San Agapito Dacite	155, 157
San Antonio Formation	166, 167
San Isidro Limestone	352, 353
San Jacinto Formation	216, 217
San Jose Formation	360, 361, 364, 365, 366, 367
San Jose Limestone	365, 366
San Juan Formation	153, 154, 155, 156, 157, 158, 159,
	160
San Lorenzo Sediments	204
San Mateo Mudstone	454
San Nicolas Claystone	367
San Pascual Formation	217, 218, 219
San Rafael Formation	216
San Ricardo Formation	361, 362
San Teodoro Volcanic Complex	234
San Vicente Basalt	331
San Vicente Conglomerates	191
San Vicente Gabbro	252, 254
Sanghay Formation	466, 467
Sansotero Limestone	79, 80
Santiago Schist	340
Sara Diorite	281
Saugan Formation	437, 438
Saul Creek Facies	453
Sayab Formation	262, 263
Sayon Formation	419
Semirara Formation	225
Sevilla Marl	337, 338, 339
Sewaragan Member	276
Siana Beds	429
Siargao Limestone	376, 435

Sibala Formation	280
Sibuguey Diorite	395
Sibuguey Formation	392, 393
Sibul Formation	87, 88, 152
Sibutu Diorite	377
Sibuyan Ultramafic Complex	289
Sicalao Limestone	112, 114, 115
Sierra Bullones Limestone	336
Sigaboy Formation	460, 465, 466, 467
Siguil Formation	443, 449, 450
Sigumay Member	260, 262
Siloay Formation	413, 445
Siloay Limestone	449
Sindangan Basalt	388
Singit Formation	275, 276, 277
Siquijor Limestone	327
Sirawai Formation	330, 331, 332
Siruma Schist	181, 182
Smooth Hills Ultramafics	253
Socorro Group	228
Sohoton Greenschist	427
Soleplep Volcanic Complex	383, 384, 385
Sorsogon Marl	200
Southeast Bohol Ophiolite Complex	329
St. Paul Limestone	237, 246, 248, 258, 261
Sta. Barbara Member	280
Sta. Cruz Formation	131, 132, 133
Sta. Cruz Sediments	269
Sta. Elena Formation	178, 179, 180, 181, 201
Sta. Fe Formation	122, 123, 124, 126
Sta. Ines Diorite	148, 150
Sta. Maria Volcanic Complex	386, 397
Sta. Teresa Marl	284
Stavely Gabbro	254
Sto. Domingo Limestone	191
Sto. Thomas Limestone Member	284
Stripe Peak Granite	249
Sula Formation	177, 178, 192, 193
Sulop Formation	457, 458
Sultan Peak Gabbro	254
Sulu Sea Mine Formation	255, 256

Sulu Serpentinite	377
Sumbiling Limestone	247, 254, 256, 257, 258
Summit Clastic Member	284
Surop Peridotite	460, 461, 462, 463, 464, 466
Susong Dalaga Volcanic Complex	201
Suyo Schist	71, 74
Suyoc Conglomerate	100, 101
Taal Volcanic Complex	162
Tabgon Flysch	185, 186
Tabionan Formation	169
Tablas Volcanic Complex	290
Tabon Formation	262, 263
Tabu Formation	298
Tabuk Formation	116
Taclaon Clay	369
Tacloban Ophiolite	357, 359, 361
Tacloban Volcanics	357, 359
Tagabaca Member	346, 347
Tagabakid Formation	436, 440
Taganaan Marl	430
Tagawili Ultramafic Complex	358
Tagbacan Formation	409
Tagbobo Conglomerate	425
Tagburos Siltstone	255
Tagkalasa Member	260
Tagnocot Formation	346, 348
Tago Schist	398, 399, 400, 405
Tagburos Siltstone	255
Tagburos Opalite	265
Tagugpo Schist	462
Talahib Andesite	157, 158, 160
Talahib Formation	222
Talamban Diorite	313
Talave Formation	302, 303
Talave Limestone	302
Talavera Group	318
Talibon Diorite	330, 332, 333, 334
Talisay Formation	198, 199, 200
Talisay Schist	214
Taluntunan-Tumicob Formation	166, 167
Tamala Formation	140, 141, 146

Tamayoc Andesite	273
Tamayoc Volcanics	273
Tambang Diorite	186, 202, 203
Tamisan Diorite	180
Tampanan Limestone	449, 450
Tampilisan Mélange	388, 389, 400
Tangon Formation	224
Tanian Limestone Member	276
Taog Formation	340, 346, 348, 354
Taragona Conglomerate	441, 442
Tarao Formation	277, 278, 248
Tarlac Formation	81, 84, 133, 135
Tartaro Formation	90, 91, 126
Teresa Siltstone	149
Tibiao Metasediments	272
Ticao Limestone	216
Tigatto Terrace Gravel	424, 425
Tigbao Clastics	302
Tigbao Formation	299
Tigbao Gabbro	358
Tigbauan Formation	342, 429
Tigbauan Limestone	447
Tigbinan Formation	175, 176, 177
Tigpalay Conglomerate	386
Timamana Limestone	375, 376, 377, 428, 431, 432, 435, 438
Timonan Formation	391
Tinalmud Formation	198, 199, 200
Tineg Formation	95
Tiniguiban Granodiorite	249
Tinitian Creek Conglomerate	246, 247
Tinobdan Limestone	350, 351
Tinupa Agglomerate	433
Toledo Formation	317, 318, 320, 335
Tolos Diorite	155
Torrijos Formation	167, 168
Trankalan Limestone	298
Tres Reyes Microdiorite	384, 395
Tual Quartz Diorite	448, 449
Tubigon Conglomerate	333, 335, 337, 338
Tubungan Siltstone Member	277

Tuburan Limestone	307, 308, 309, 310, 311
Tuguis Limestone	292
Tugunan Formation	431, 432, 434, 435
Tuktuk Formation	351
Tulang Wacke	331
Tumalo Member	222
Tumarbong Formation	262
Tumbaga Formation	177, 178, 180
Tungauan Schist	379, 380, 381, 382
Tunlob Schist	306, 307, 308, 309, 311, 314, 328, 329
Tuod Formation	401, 402, 403
Tupilac Formation	382, 383
Twin Peaks Formation	99
Ubay Formation	327, 328, 330, 331, 332, 334, 336
Ulian Formation	279, 285
Uling Limestone	317, 318
Ulugan Bay Ultramafics	253
Umayam Limestone	407, 436
Unisan Formation	170, 171
Universal Formation	177, 179
Upian Limestone	421, 422
Uplifted Coral Reefs	77
Upper Buyag Formation	213
Upper limestone member	86, 131, 132, 146, 149, 151, 195, 196
Upper Zigzag Formation	113, 114
Uson Limestone	211
Viga Conglomerates	191
Vigo Formation	171, 172
Villa Wave Formation	149
Viñas Formation	181
Virac Granodiorite	96, 99
Visares Limestone	356
Vista Alegre Dacite Porphyry	300
Vitali Diorite	378, 383, 384
Wahig Formation	326, 330, 331,332, 334, 335, 336, 344
Wawa Formation	378, 418, 419, 420
Western Volcanic Belt	134, 135
Yating Monzonite	281
Yop Formation	176, 177, 187, 188, 189, 190

Zambales Limestone and Conglomerate	131
Zambales Ophiolite Complex	127, 129, 130
Zamboanga Volcanic Complex	386, 396, 397
Zigzag Formation	75, 92, 96, 97, 98, 99, 102, 103, 104, 111, 113, 114