AN ILLUSTRATED GUIDE TO THE BRITISH MIDDLE EOCENE VERTEBRATES Second Edition

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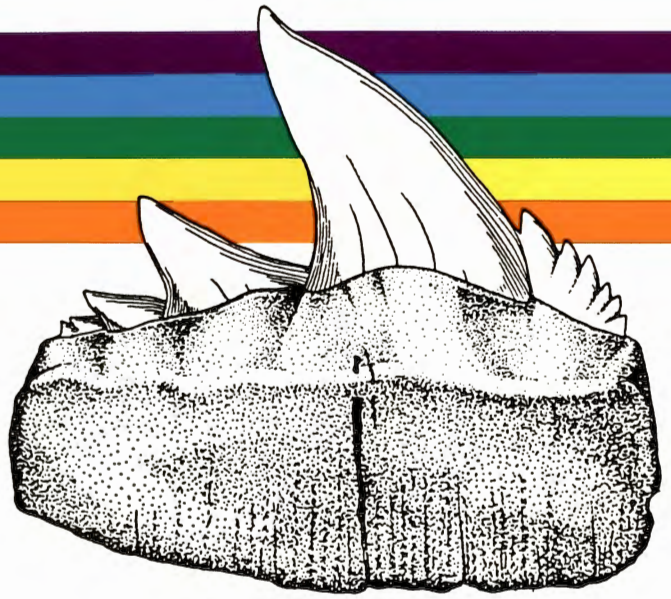

David Ward

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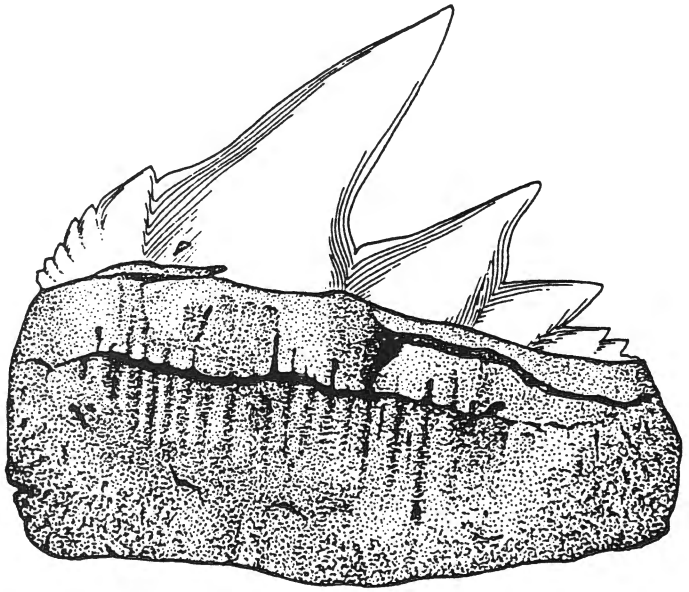

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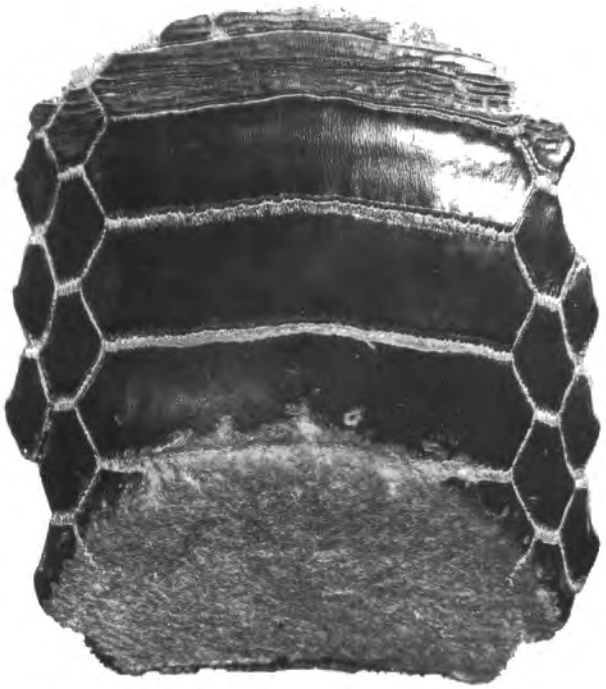
Front cover and page i: Tooth of the cow shark *Notorynchus kempi*, front cover, lingual surface; page i, labial surface; Selsey Formation, Lee-on-the-Solent, Hampshire, UK.

Back cover: Lower palate of the eagle ray *Aetobatis irregularis*, lingual surface; Selsey Formation, Lee-on-the-Solent, Hampshire, UK.

Below: Lower palate of the eagle ray *Myliobatis dixoni*, lingual surface; Earnley Formation, Bracklesham Bay, West Sussex, UK.



Contents

NOTES on the SECOND EDITION

During the twenty five years since this booklet was first published there have been a number of changes in shark and ray taxonomy. These have been included in the Tables and Plate explanations - in red.

There have been no changes made to the bony fish, reptile and mammal identifications, nor have the references been updated.

This publication is only available as an open-access pdf edition.

Publisher's Note - 1st Edition

The style and content of this book is modelled on that of the "***British Fossils***" trilogy published by the Natural History Museum, London. I feel that it is regrettable that this, very successful, formula, which figures most of the common British fossils, has not been expanded upon. ***British Palaeozoic Fossils***, ***British Mesozoic Fossils*** and ***British Caenozoic Fossils***, may be purchased at: The Natural History Museum Bookshop, The Natural History Museum, Cromwell Road, London SW7 5BD.

Fig. 1. Temporary excavations in the Wittering & Earnley Formations, M27 motorway, Dummer's Copse, West End, near Southampton, Hampshire, 1983.

INTRODUCTION - by David J. Kemp

Living near the richly fossiliferous Middle Eocene outcrops at Lee-on-the-Solent in Southern England, like most young collectors in the early 1960's, I was eager to find a means of idenfying the vertebrate fossils I found. No such book existed at that time so I resolved that eventually would I do something about it; hence this book.

The scope of the book has been limited to the Middle Eocene Bracklesham Group and Elmore Member of the Barton Clay Formation of the Gosport area. To include the Barton Beds of Christchurch Bay, a logical extension, would have delayed the project considerably, with little additional benefit.

The task has taken several years and involved compiling information from specialist journals and monographs as well as researching the collections of the Natural History Museum, London and a number of provincial museums.

The material illustrated is principally from the Gosport/Lee-on-the-Solent and Bracklesham areas, both from foreshore outcrops and temporary exposures created during construction projects. It has been mainly collected by myself and is now housed in the National Collection, Gosport Museum Collection or various private collections.

The illustrations are the result of many hours of work by my wife, Liz, with whom I am proud to share authorship.

Chris King helped me with the stratigraphy, whilst Alison Longbottom, Cyril Walker, Colin Harrison and Jerry Hooker, all of the Natural History Museum, London, assisted with some of the identifications.

The many early drafts of the manuscript were typed by Paquita Wood and David Ward.

David Ward's enthusiasm proved invaluable in the final stages of the book; sufficient for his inclusion as an author

DJK - June 1990

STRATIGRAPHY

WHEN WAS THE EOCENE?

The last 541 million years of geological time is divided into a number of periods of varying duration. One of the more recent of these is called "The Tertiary". This, is in turn, divided into a number of Epochs, one of which is the Eocene (Fig. 2). The Middle Eocene is a period of time that started some 50 million years ago, 18 million years after the death of the last dinosaur, and lasted about 10 million years.

SETTING THE SCENE

The cool, deep London Clay ocean that dominated southern Britain during the Early Eocene was succeeded in the Middle Eocene by a more shallow sea and a warmer climate. As it does today, Britain lay to the south-west of the North Sea basin, but with the bulk of the south east of England under water. Being on the rim of the basin, small, cyclic,changes of sea-level were reflected by differing environments and a variety of sediments (facies). These deposits, the Bracklesham Beds (or more accurately the *Bracklesham Group*) are, for the most part, shallow marine sands and silts. Some terrestrial deposits occur in places, generally clays rich in plant material, probably from coastal swamps. Estuarine horizons also occur, characterised by masses of oysters and occasional turtle and crocodile bones. The sediments of the overlying Barton Group is quite similar to those of the Bracklesham Group. One could reasonably argue that their separation owes more to history and geography than to stratigraphy. The sedimentation was again cyclic, becoming increasingly shallow up the succession, heralding the predominately non-marine Late Eocene and Oligocene.

HISTORICAL PERSPECTIVES

The name "Bracklesham" in "Bracklesham Group" is derived from the type locality at Bracklesham Bay, West Sussex. The strata within the Bracklesham Group have been sub-divided and described over the past 140 years. In 1850, in a large work on the geology and fossils of Sussex, Southern England, Frederick Dixon illustrated a number of the more common fossils. He chose many of the current experts to describe them, making this still a valuable source of information. Dixon named the beds exposed on the foreshore at Bracklesham after their

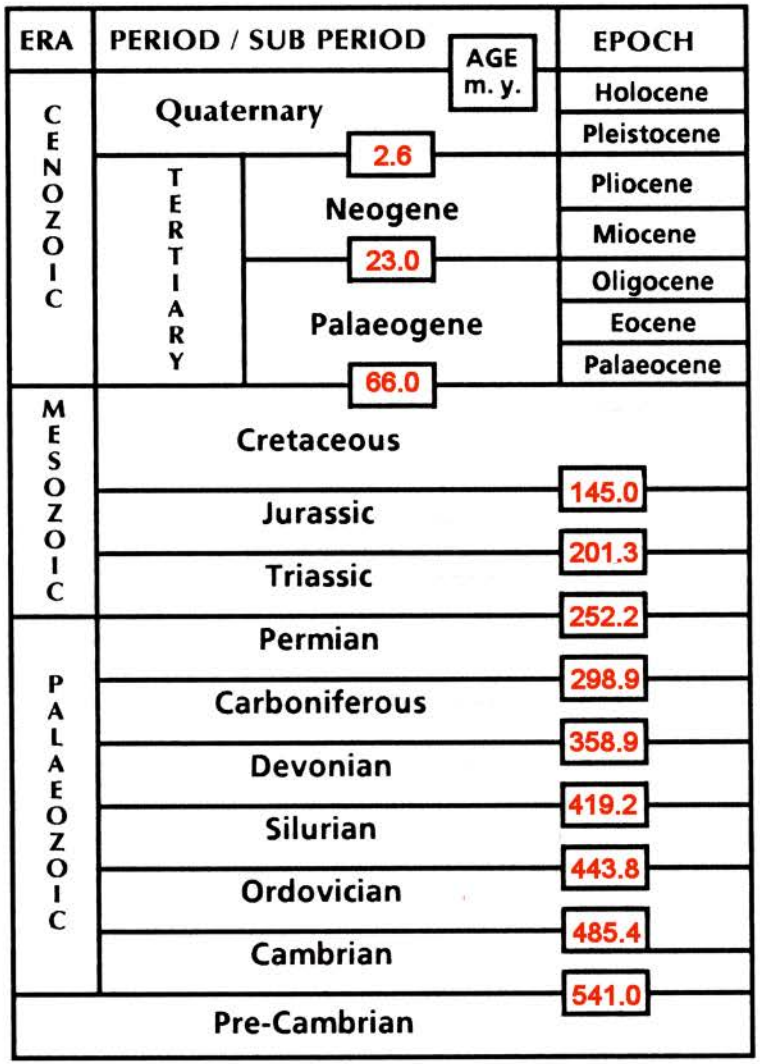


Fig. 2. The geological time scale. Age (in million years) after Gradstein *et al*, 2012.

location or a characteristic fossil, coining names like "Park-Bed","Cypraea-Bed", "Palate-Bed" and "Turritella-Bed". These names, probably based on those used by local (commercial) collectors, were incorporated into the numbered section published by the Reverend Osmond Fisher in 1862. Fisher's description of the beds at Bracklesham Bay, Lee-on-the-Solent, Whitecliff and Alum Bays, were still in use until quite recently. In 1977, Curry, King, King and Stinton published the first major overhaul of Bracklesham Bay stratigraphy since Dixon and Fisher. They described some estuarine beds below those seen by Dixon, the Wittering division (now Wittering Formation) and introduced a new numbering system. Since then there have been many papers refining the stratigraphy further, these are included in the Bibliography on pages 58 and 59. They included some silts and silty clays seen in the New Forest and on the Isle of Wight in their "Huntingbridge division", of the Bracklesham Group. These deposits along with the Elmore

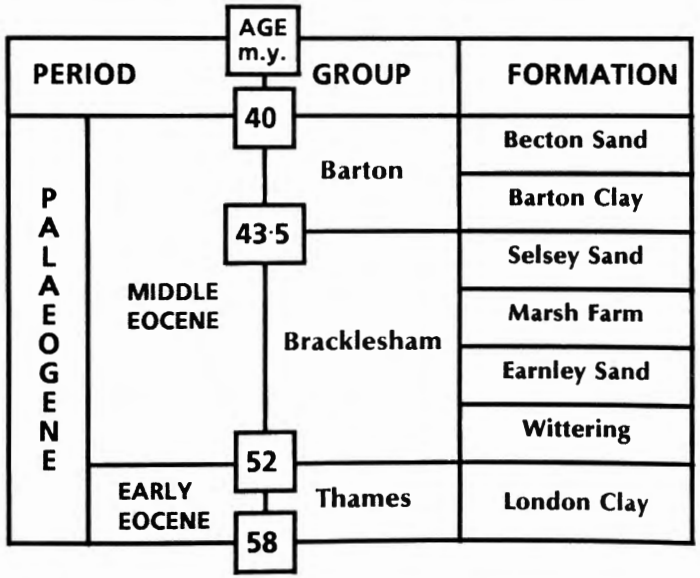


Fig. 3. The Early and Middle Eocene stratigraphy of the Hampshire Basin (after King, 1981; Edwards & Freshney, 1986 and Hooker 1986); dates (in million years) after Berggren,1985.

Formation at Lee-on-the-Solent have recently been incorporated in the overlying Barton Clay Formation.

WHERE TO SEE THE MIDDLE EOCENE

Middle Eocene deposits can be seen in the cliffs at Whitecliff Bay, Isle of Wight; in stream sections in the New Forest and on the lower foreshores of Lee-on-the-Solent, Hampshire and Bracklesham Bay, West Sussex (Fig. 4.) Recently, engineering projects have generated temporary exposures at Southampton Docks, the M27 motorway near Southampton and deep outfall excavations across the Gosport peninsula (Figs 5, & 6).

Foreshore deposits are quite likely to be covered by drifting sand and mud, so can be unreliable. The best times of year are

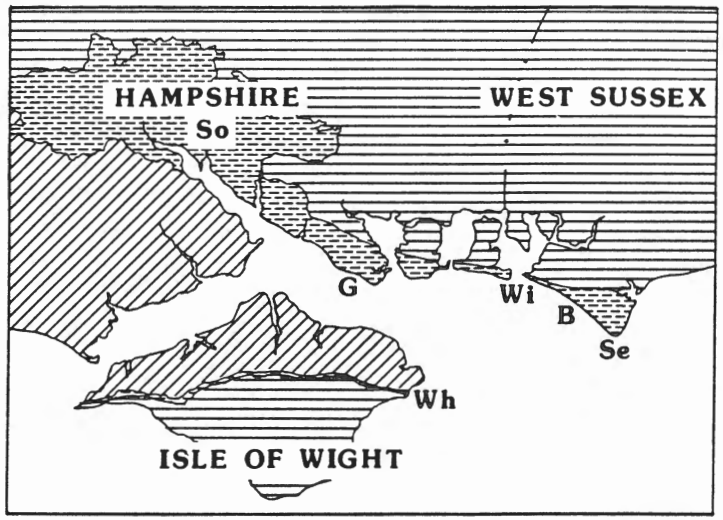


Fig. 4. The Middle Eocene outcrop in southern England.
Horizontal dash: outcrop of Bracklesham Group in Hampshire & West Sussex (Pleistocene and Recent deposits omitted). Horizontal lines: Sediments older than the Middle Eocene. Oblique lines: Sediments younger than the Middle Eocene.
So, Southampton; **G**,Gosport; **B**, Bracklesham Bay; **Wi**, Wittering **Se**, Selsey; **Wh**, Whitecliff Bay

Spring and Autumn, during Spring tides. Onshore winds may well prevent the tide from falling, seaweed and layers of slime often obscure the outcrop, both very frustrating.

HOW TO COLLECT MIDDLE EOCENE FOSSILS

For the most part the best specimens are found in place (*in situ*) on the outcrop. They should be carefully removed, wrapped and bagged. Larger and fragile specimens are often better left in a block of sediment wrapped in damp paper, to be extracted later. In the case of large articulated remains, unless immediately threatened by the incoming tide, experienced assistance should be sought.

Many fine specimens can also be found in drifts of fossil or modern shell on or close to the outcrop. These can be hand picked from the surface or separated with a fine sieve. Many teeth and bones are smaller than can easily seen in the field, so it can be rewarding to take a sample of a promising bed home and sort it under a magnifying glass. In all cases, details of the locality and horizon must be included. A fossil without this information is of little scientific value.

Fig. 5. The outcrop of the Earnley Formation, Bracklesham Group on the foreshore at Bracklesham Bay, West Sussex.

Because of the unusual nature of the outcrops, one of the best way of getting to know them is to be shown as a member of a local Geological Society or Fossil Club. The local library will have the address of the Secretary; failing this, any Museum with a Natural History section will usually assist.

FURTHER INFORMATION

The Geologists' Association Guide No.25 (Isle of Wight) Has descriptions the Alum Bay and Whitecliff Bay sections; Guide No.14 (Southampton) includes Bracklesham Bay and Barton.

Collections of British Middle Eocene fossils can be found in a number of museums including the Natural History Museum, London, Hampshire County, Gosport and Chichester Museums.

ABOUT THIS BOOK

Previous illustrated works by David Kemp have concentrated on sharks, rays and chimaeroids; these have proved to be of interest both in continental Europe and North America, where deposits of similar age and fauna occur and are listed in the bibliography. It was impossible to include every tooth position and bone, so a selection of typical material was made. We hope they help!

THE CHECK LISTS - INTRODUCTION

These give an indication of the stratigraphic distribution of the vertebrate remains illustrated in Plates 1 - 21. No list can ever be complete; we would be pleased to hear of new records so that corrections can be made in future editions of this book.

The Wittering Division records are from the foreshore at East Wittering, West Sussex and M27 Motorway excavations near West End, Hampshire. Those from the Earnley Division are from Bracklesham Bay, West Sussex, M27 Motorway excavations near West End and excavations at Shoot Lane, Gosport, Hampshire. Selsey records are from the foreshores at Bracklesham Bay and Lee-on-the-Solent, Hampshire. Barton Clay Formation records are solely from the Elmore Member (previously the Elmore Formation) at Lee-on-the-Solent.

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **SHARKS**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Abdounia beaugei	●			●	●	6:2
Abdounia lapierrei		●	●	●	●	6:3
Abdounia minutissima	●	●	●			6:1
Abdounia recticona	●	●	●	●		6:4
Alopias leeensis				●		3:4-5
Anomotodon *novus*	●	●	●			3:3
Araloselachus sp.				●	●	8:4
Brachycarcharias *lerichei*	●	●	●	●	●	3:9-10
Carcharias acutissima	●		●			8:5-7
Carcharhinid gen. nov.	●		●			6:5
Carcharhinus sp.		●	●			7:8-9
aff. *Dalatias* sp.				●		7:10
Eostegostoma angustum				●		5:2
? *Foumtizia* *pattersoni*	●	●	●	●		6:8
Galeocerdo latidens	●	●		●	●	7:12
Galeorhinus ypresiensis		●	●	●	●	7:4
Hemiscyllium bruxelliensis		●	●	●	●	5:1
Heterodontus woodwardi				●		1:2
Heterodontus vincenti	●	●	●	●	●	1:1
Heterodontus sp.	●		●	●	●	1:3-5
Hypotodus verticalis	●	●	●	●	●	8:1-3
Isistius trituratus	●	●	●	●	●	7:7

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **SHARKS**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Isurolamna **inflata**	●	●	●	●	●	3:6-8
Jaekelotodus trigonalis	●	●		●	●	4:4-10
Macrorhizodus *praecursor*		●		●	●	3:1-2
Mustelus whitei					●	7:3
Notorynchus kempi				●	●	2:1-4
Nebrius thielensis	●	●		●		5:4
Odontaspis winkleri	●	●	●	●	●	4:1-3
Otodus auriculatus		●		●		2:5
Pachygaleus *lefevrei*	●					7:6
Pachyscyllium *gilberti*	●	●	●	●	●	6:6
Palaeorhincodon wardi	●	●	●	●	●	5:3
Physogaleus secundus	●	●	●	●	●	7:1-2
Rhizoprionodon sp.	●	●	●	●	●	7:5
Scyliorhinus woodwardi					●	6:7
Scyliorhinus sp.				●	●	6:9
Squalus minor	●	●		●	●	7:11
Squatina prima	●	●	●	●	●	5:5-6
Striatolamia macrota	●	●	●	●	●	9:1-8
Triakis wardi				●	●	5:7

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **RAYS**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Aetobatus irregularis	●	●	●	●	●	12:1
Aktaua sp.				●		12:2
Archaeomanta melenhorsti	●	●	●	●	●	10:9
Burnhamia daviesi	●	●	●	●	●	12:6
Coupatezia woutersi	●	●	●	●	●	10:4
Dasyatis jaekeli	●	●	●	●	●	10:8
Dasyatis tricuspidatus	●		●			10:5
Gymnura sp.			●			10:10
Heterotorpedo fowleri	●		●			10:6-7
Hypolophodon sylvestris	●					10:11
Jacquhermania duponti	●	●	●	●	●	10:3
Lophobatis sp.		●		●	●	10:7
Myliobatis dixoni	●	●		●	●	Page ii
Myliobatis latidens		●		●		14:2
Myliobatis striatus	●	●		●	●	13:1
Myliobatis toliapicus	●	●	●	●	●	14:1
Myliobatis sp.	●	●	●	●	●	
Pristis lathami	●	●		●	●	11:3
Anoxypristis sp.	●	●		●		11:2
Propristis schweinfurthi				●		11:1
Rhinobatos bruxelliensis	●	●	●	●	●	10:2
Rhinoptera sherborni				●		12:3
Rhynchobatus vincenti	●	●	●	●	●	10:1

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **CHIMAEROIDS**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Amylodon sp.				●		14:3
Edaphodon bucklandi		●		●	●	15:1-2
Edaphodon leptognathus		●		●	●	15:4
Edaphodon minor				●		15:5
Elasmodus hunteri		●				14:4
Elasmodus kempi				●		14:5-6

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **BONY FISH (teeth and bones**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Acipenser toliapicus		●		●	●	18:3
Aglyptorhynchus sp.		●		●		18:2
Albula oweni	●	●		●		17:21
Amia sp.		●	●	●		17:18
Arius egertoni	●	●			●	18:5
Brachyrhynchus sp				●		18:6
Conger sp.					●	16:5
Cybium excelsum	●	●		●	●	16:11
Cybium proosti		●		●	●	17:17
Cybium stormsi				●		17:16
Cylindracanthus rectus	●	●		●		18:1
Egertonia cf. *isodonta*	●	●	●	●		17:22

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **BONY FISH (teeth and bones**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Enniskillenus cf. *radiatus*				●		16:8
Eodiodon bauzai	●			●	●	16:3
Eotrigonodon serratus	●	●		●	●	17:19
Eotrigonodon sp.				●		17:20
Eutrichiurides winkleri	●	●	●	●	●	17:23
Eutrichiurides sp.	●	●			●	17:26
Labrus eocaenus				●	●	17:13
Lepisosteus suessionensis	●	●	●	●		18:8
Ostracion cf. *meretrix*		●		●		17:28
Phyllodus sp.	●	●		●		16:9
Platylaemus colei	●	●	●	●	●	16:1-2
Prolates sp.		●		●	●	16:10
Pseudosphaerodon antiquus		●		●	●	17:27
Pycnodus toliapicus	●	●	●	●	●	16:6
Rhinocephalus sp.					●	18:4
Sparus sp.	●	●	●	●	●	17:14
Sphyraena striata		●		●		17:15
Sphyraenodus lerichei		●		●	●	17:12
Trichiurides sagittidens	●	●	●	●	●	17:25
Trichiurus gulincki	●	●		●	●	17:24
Triodon antiquus	●	●		●	●	16:4
Xiphiorhynchus		●		●	●	16:7

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **Bony fish otoliths**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Albula sp.		●		●	●	17:11
Ampheristus waltoni		●	●	●	●	17:8
Arius crassus	●	●		●		17:10
Ganthopsis websteri				●		17:3
Lactarius amplus	●	●		●		17:4
Neobythitinarum dimidiatus		●	●	●	●	17:1
Neobythitinorum regularis		●		●	●	17:9
Paraconger sauvagei		●		●	●	17:6
Pomadasyidarum kokeni	●	●		●		17:7
Pterothrissus umbonatus	●	●		●		17:2
Sirenbinorum spinosus	●					17:5

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **Reptiles**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Allaeochelys sp.	●			●	●	20:3
Argillocheys sp.	●			●		20:1
Diplocynodon sp.	●			●		20:7
Gavialis dixoni	●	●	●	●		20:5
Palaeophis typhaeus	●	●		●	●	21:6
Puppigerus camperi	●	●	●	●	●	19:1-6

A checklist of Bracklesham Group and Barton Clay Formation vertebrates **Birds & Mammals**	BRACK GROUP				ELMORE	PL & FIG
	WITT	EARN	MFM	SELS		
Latipons gardneri				●		21:2
Litoripes medius		●				21:4
Milvoides kempi				●		21:1
Parvirallus gracilis				●		21:5
Percolinus proudlocki				●		21:3
Diadelphidae undet.	●					21:10
Lophiodon cf. *cuvieri*					●	21:11
Propalaeotherium cf. *parvulum*		●		●	●	21:7-9

Fig. 6. Landscaped cliff, promenade, foreshore & shingle with Selsey Division exposed along outer edge, Lee-on-the-Solent,Hampshire September 1971 (Photo: J. C. Lawrence & Sons Ltd)

GLOSSARY

ANTERIOR - Towards the front
BASAL - Bottom or undersurface
BATOIDEA - Rays
CARAPACE - Upper shell of turtle
CARTILAGINOUS - Firm elastic tissue in skeletons
CHIMAEROID - Rabbitfish (related to sharks and rays)
COPROLITE - Fossil dung
CUSPS or CROWNS - Enameloid covered exposed surface of tooth
DENTICULATION - puckering at the base or sides of tooth crown
DERMAL DENTICLE - Scales in cartilaginous fish
DISTAL - Furthest from mid-line of body
DORSAL - On the top or back
HYPURAL BONE - Tail bone of fish
LABIAL - Outer surface of tooth facing the lips
LATERAL POSITION - Towards the side
LINGUAL - Inner surface of tooth facing the tongue
MANDIBLE - Lower jaw parts
MESIAL - Directed towards the midline
OCCLUSAL - Top or working surface in dentitions or teeth
OTOLITH - Ear-stones (of fish)
PALATINE/MAXILLARY - Upper jaw parts
PALAEOENVIRONMENT - Fossil environment
PALAEONTOLOGY - The study of fossils
PLASTRON - Lower shell of turtle
PROXIMAL - Nearest to midline of body
RANGE - Precise chronostratigraphic distribution
ROOT - basal attachment part of tooth, usually buried in tissue
ROSTRUM - Beak-like snout in swordfish
SCREENING - sieving (Americanism)
SCUTE - Bony plate in the skin
SELACHII - Sharks
SERRATIONS - Saw-like cutting edge
SPECIES - Distinct, reproductively isolated, population of organisms
STRIATIONS - Parallel lines or grooves on teeth
SYMPHYSEAL - centre of the jaw
TELEOST - Advanced bony fish
UNDET. - Unidentified
VENTRAL - Directed towards the belly
VERTEBRA - Individual bone of the spinal column
VOMERINE/PREMAXILLARY - Upper jaw parts, nearer the front

Plate 1

Sharks

1. ***Heterodontus vincenti*** (Leriche, 1905). Lateral tooth (x2.5). Occlusal, lingual and basal views.
   RANGE: Early and Middle Eocene
2. ***Heterodontus woodwardi*** Casier, 1946. Lateral tooth (x4). Occlusal, lingual and basal views.
   RANGE: Early and Middle Eocene
3. ***Heterodontus* sp.** Lateral tooth. (x6) Occlusal, lingual and basal views.
4. ***Heterodontus woodwardi*** Casier, 1946. Anterior tooth (x5). Labial, lateral and basal views.
5. ***Heterodontus vincenti*** (Leriche, 1905). Anterior tooth (x5). Lingual view.
6. ***Otodus obliquus*** Agassiz, 1843. Upper lateral tooth (x1.25) labial view.
   RANGE: Palaeocene to Early Eocene.
   SYN: *Lamna obliqua*.
   COMMENTS: Although teeth are present in several museum collections, there is some doubt as to whether *Otodus obliquus* survived into the Middle Eocene.
7. ***Otodus obliquus*** Agassiz, 1843. Lower anterior tooth (x1.25) Lingual and labial views.

NOTE:
The teeth illustrated in Figs 6 and 7 were from the Early Eocene of Morocco. It is now certain that *Otodus obliquus* does not range into the Middle Eocene.

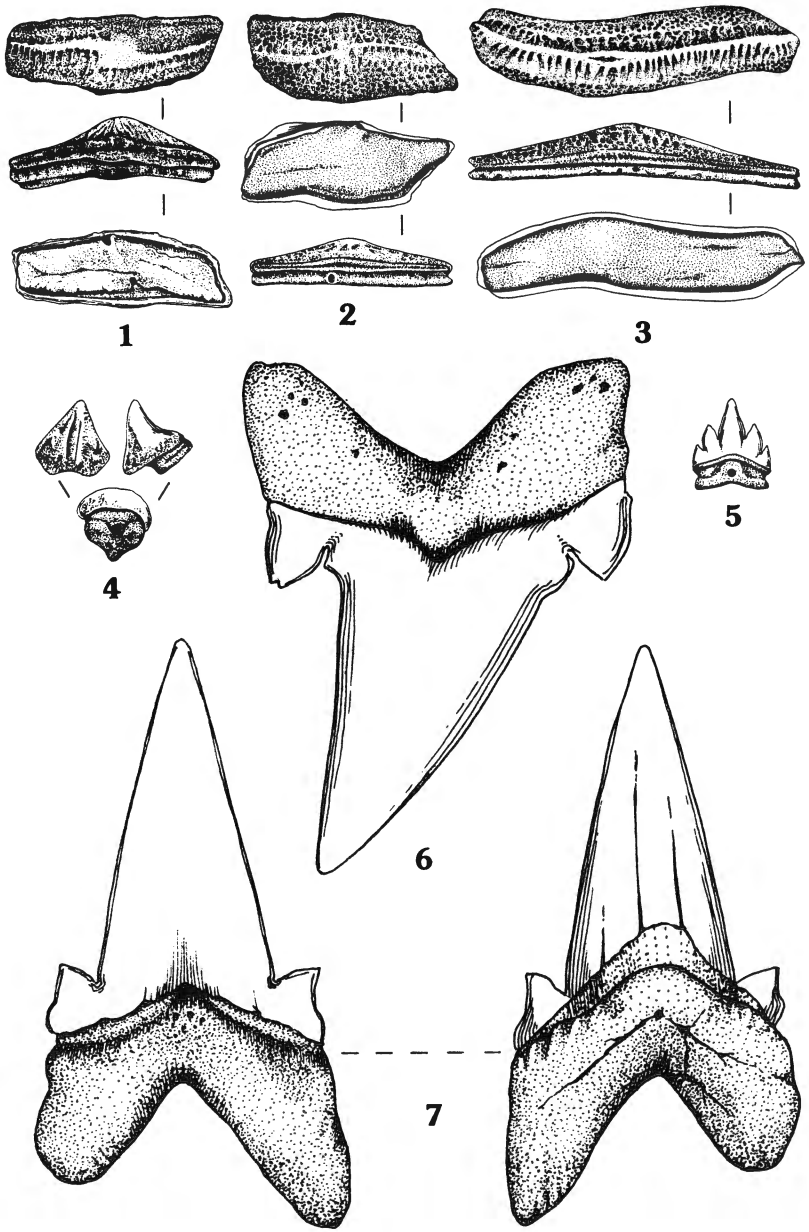


Plate 2

Sharks

1. ***Notorynchus kempi*** Ward, 1979. Lower median tooth (x2). Lingual and labial views.
   RANGE: Middle and Late Eocene
   SYN: *Notidanus primigenius, Notorhynchus primigenius.*
2. ***Notorynchus kempi*** Ward, 1979. Upper antero-lateral tooth (x2). Lingual and labial views.
3. ***Notorynchus kempi*** Ward, 1979. Lower antero-lateral tooth (x2). Labial and lingual views.
4. ***Notorynchus kempi*** Ward, 1979. Upper anterior tooth (x2). Lingual and labial views.
5. ***Otodus auriculatus*** (Blainville, 1818). Upper lateral tooth (x1.25). Labial and lingual views.
   RANGE: Middle Eocene
   SYN: *Carcharodon auriculatus, Procarcharodon auriculatus.*

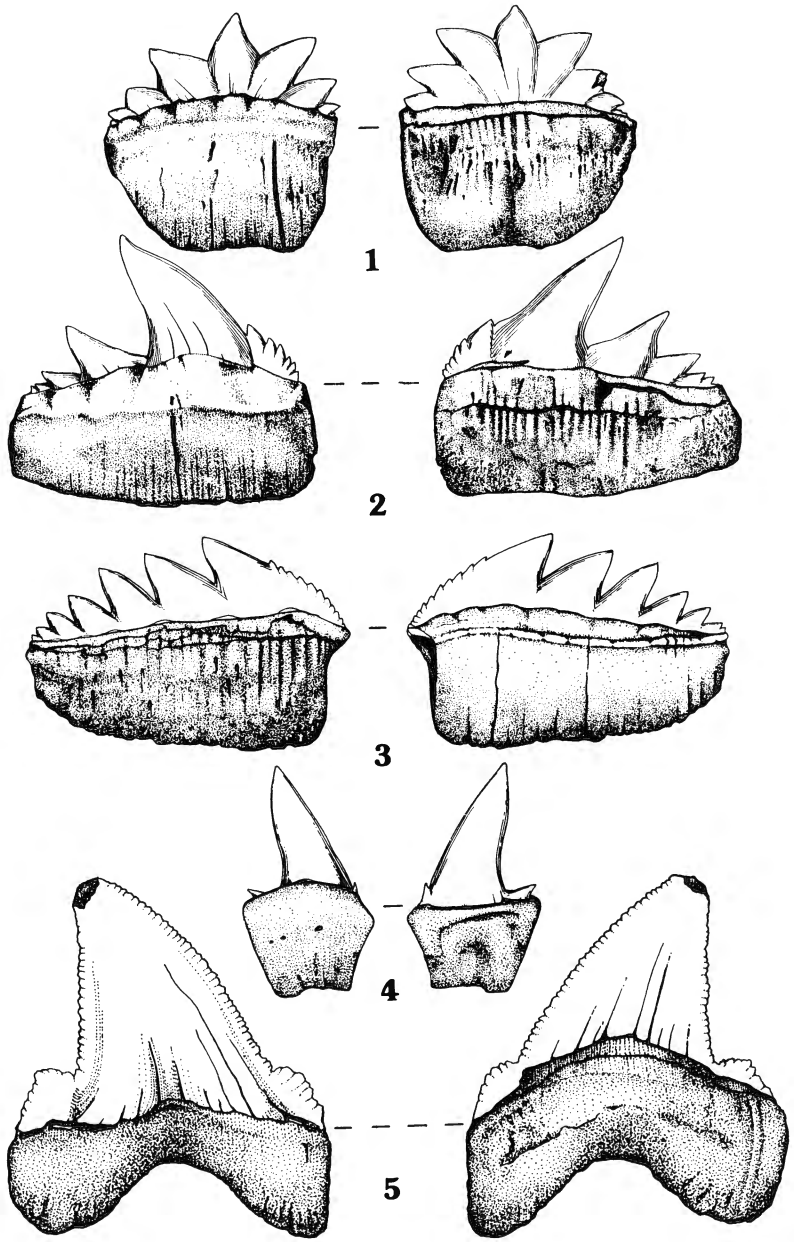


Plate 3

Sharks

1. ***Macrorhizodus praecursor* (Leriche, 1905).**
   Anterior tooth (x2). Labial and lingual views.
   RANGE: Middle to Late Eocene.

2. ***Macrorhizodus praecursor* (Leriche, 1905).**
   Lateral tooth (x2). Labial and lingual views.

3. ***Anomotodon novus*** (Winkler, 1874).
   Anterior tooth (x3). Labial and lingual views.
   RANGE: Eocene.
   SYN: ***Isurus novus***

4. ***Alopias leeensis*** Ward, 1978. Anterior tooth (x1.25). Lingual and labial views.
   RANGE: Middle Eocene.
   SYN: *Anotodus leeensis.*

5. ***Alopias leeensis*** Ward, 1978. Lateral tooth (x1.25). Labial, lateral and lingual views.

6. ***Isurolamna inflata* (Leriche, 1905).** Anterior tooth (x2). Labial and lingual views.
   RANGE: Late Palaeocene to Middle Eocene.
   SYN: *Lamna affinis, Lamna inflata, Isurolamna affinis.*

7. ***Isurolamna inflata* (Leriche, 1905).**
   Antero-lateral tooth (x2). Labial view.

8. ***Isurolamna inflata* (Leriche, 1905).**
   Anterior tooth (x2). Labial and lingual views.

9. ***Brachycarcharias lerichei* (Casier, 1946)**
   Anterior tooth (x3). Labial view.
   RANGE Middle to Late Eocene.
   SYN: *Lamna vincenti*, ***Lamna lerichei.***

10. ***Brachycarcharias lerichei* (Casier, 1946)**
    Lateral tooth (x3). Labial and lingual views.

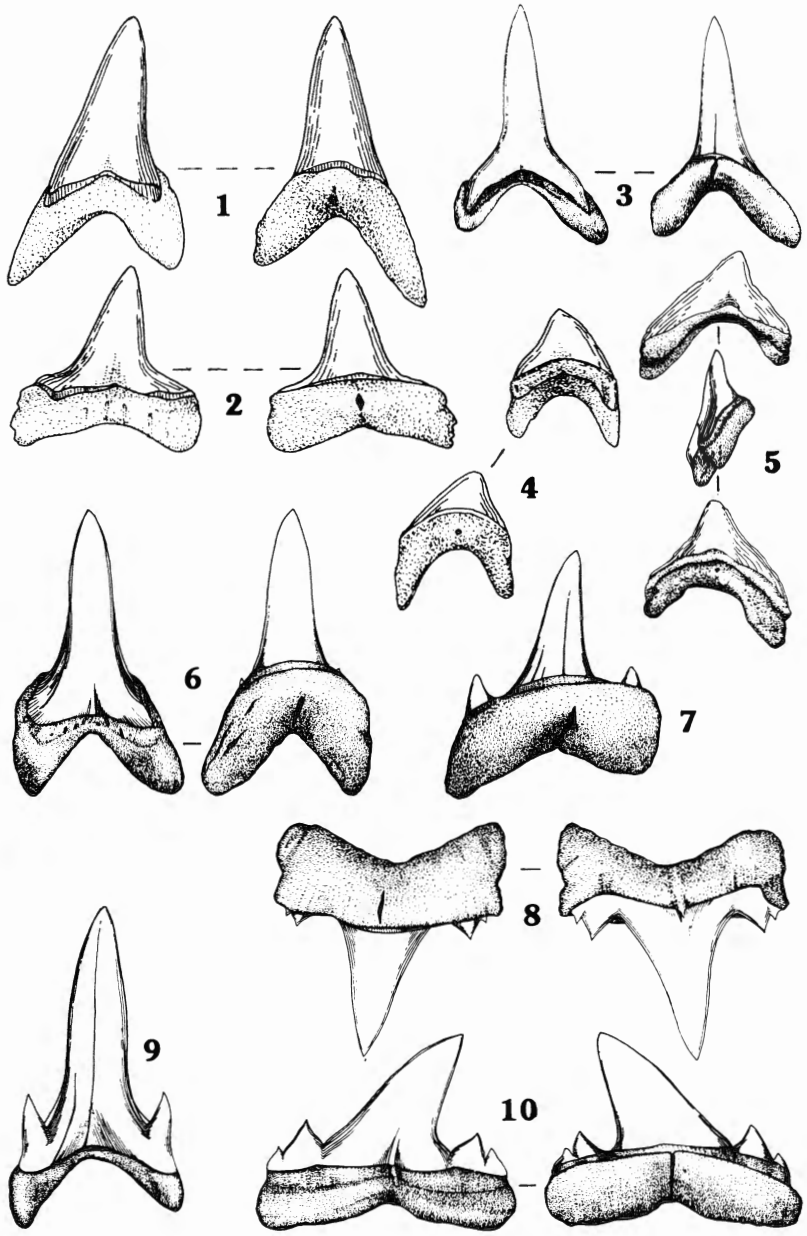


Plate 4

Sharks

1. ***Odontaspis winkleri*** (Leriche, 1905). Upper anterior tooth (x2). Labial, mesial and lingual views.
   RANGE: Palaeocene to Late Eocene.
2. ***Odontaspis winkleri*** (Leriche, 1905). Lower anterior tooth (x2). Labial, mesial and lingual views.
3. ***Odontaspis winkleri*** (Leriche, 1905). Upper lateral tooth (x2). Lingual view.
4. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Anterior tooth (x1). Labial, mesial and lingual views.
   RANGE: Middle Eocene.
   COMMENTS: There is considerable variation in the lateral cusp denticulation in large lateral teeth.
5. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Upper lateral tooth (x1). Labial view.
6. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Upper lateral tooth (x1). Lingual view.
7. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Anterior tooth (x1). Labial view.
8. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Upper intermediate (eye) tooth (x1). Lingual view.
9. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Upper lateral tooth (x1). Lingual view.
10. ***Jaekelotodus trigonalis*** (Jaekel, 1895). Upper lateral tooth .

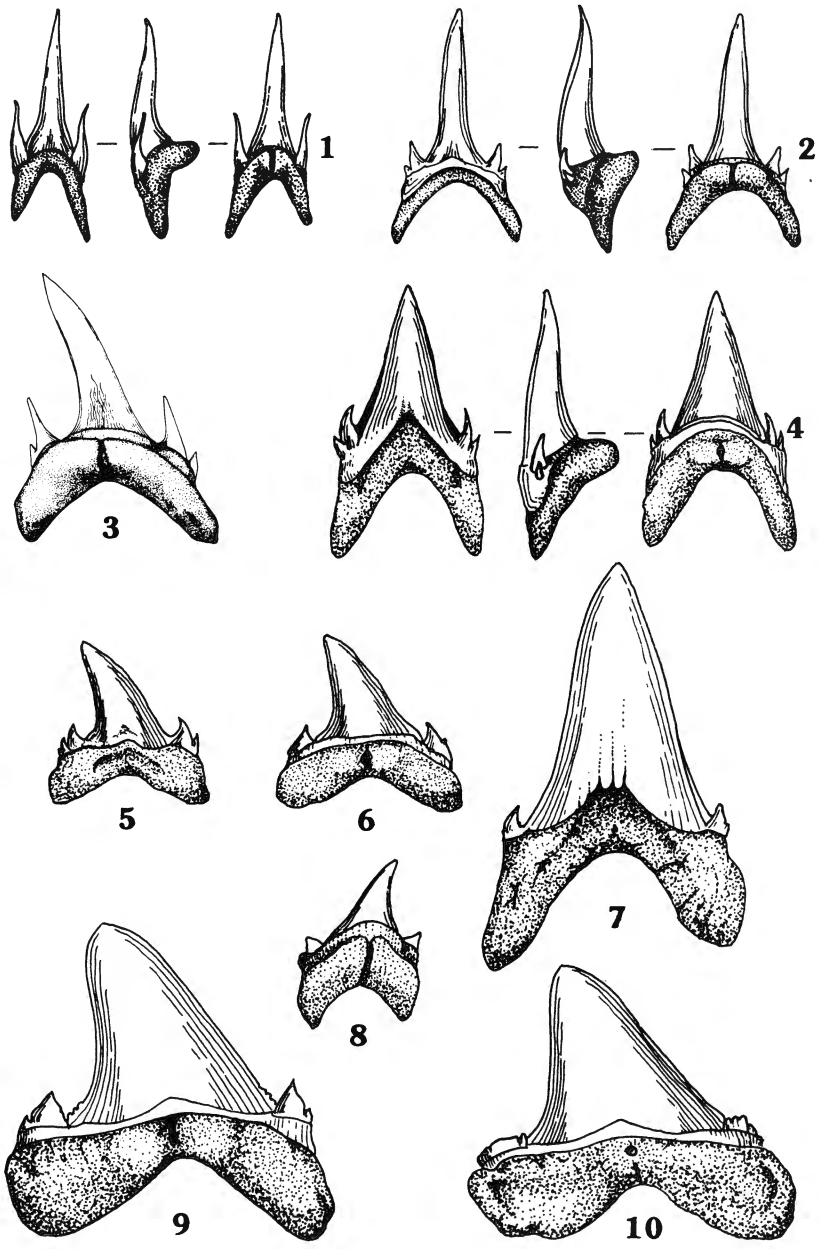


Plate 5

Sharks

1. ***Hemiscyllium bruxelliensis*** (Herman, 1977). Antero-lateral tooth (x10). Labial, basal and lateral views.
   RANGE: Middle Eocene.
2. ***Eostegostoma angustum*** (Nolf & Taverne in Herman 1977). Antero-lateral tooth (x5). Labial, basal and lateral views.
   RANGE: Middle Eocene.
3. ***Palaeorhincodon wardi*** (Herman, 1975). Antero-lateral tooth (x4). Labial, basal and lateral views.
   RANGE: Early to Middle Eocene.
4. ***Nebrius thielensis*** (Winkler, 1873). Anterior tooth (x3.5). Basal, labial, lingual and occlusal views.
   SYN: *Ginglymostoma thielense*
   RANGE: Early to Middle Eocene.
5. ***Squatina prima*** (Winkler, 1874). Lateral tooth (x2.5). Labial and lateral views.
   RANGE: Early Palaeocene to Late Eocene.
6. ***Squatina prima*** (Winkler, 1874). Anterior tooth (x2.5). Basal and labial views.
7. ***Triakis wardi*** (Cappetta, 1976). Lateral tooth (x20). Labial and lingual views.
   RANGE: Early to Middle Eocene.
   NOTE: Heavily crenulate crown base.

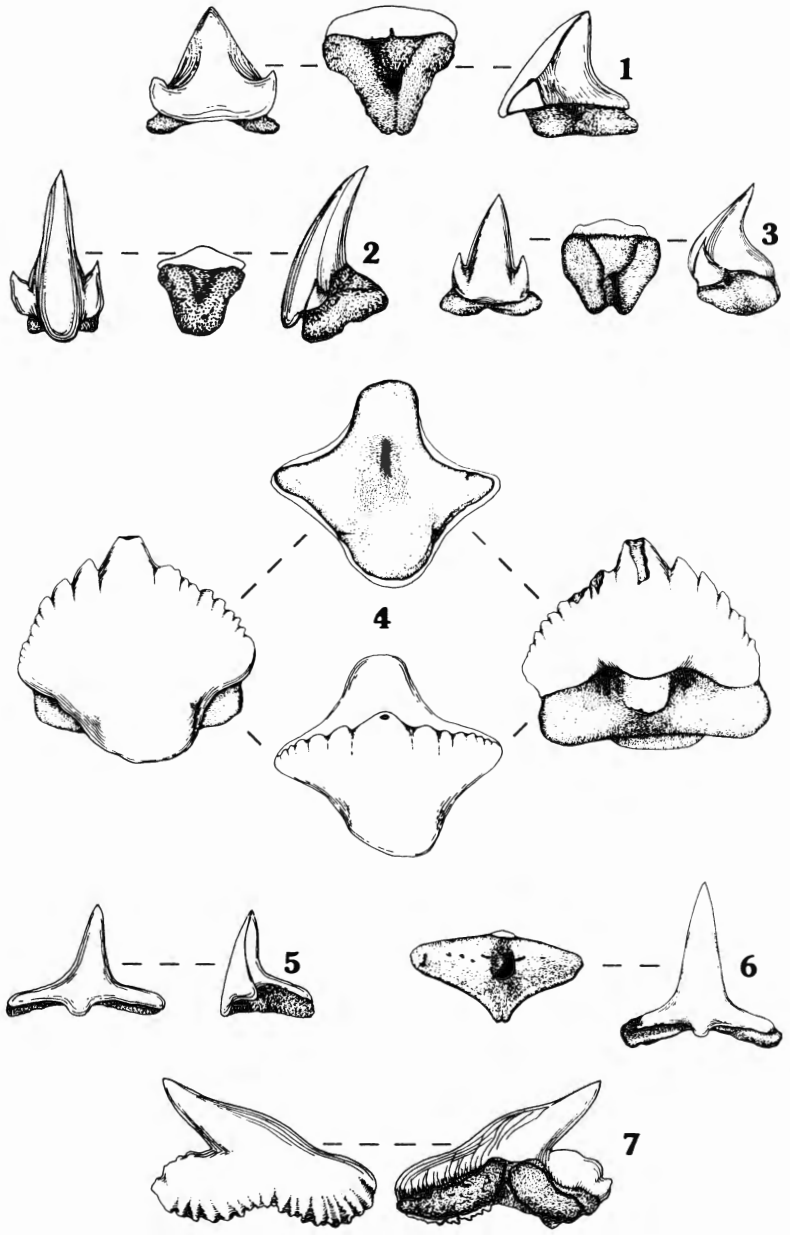


Plate 6

Sharks

1. ***Abdounia minutissima*** (Winkler, 1873). Lower antero-lateral tooth (x3). Labial and lingual views.
   RANGE: Middle Eocene.

2. ***Abdounia beaugei*** (Arambourg, 1935). Upper lateral tooth (x5). Labial and lingual views.
   RANGE: Lower and Middle Eocene.

3. ***Abdounia lapierrei*** Cappetta & Nolf, 1981. Lower anterior tooth (x5). Labial, lateral and lingual views.
   RANGE: Middle Eocene.

4. ***Abdounia recticona*** (Winkler, 1873). Antero-lateral tooth (x3). Labial and lingual views.
   RANGE: Lower and Middle Eocene.

5. **Carcharhinid gen. nov.** Lateral tooth (x12). Labial and lingual views.
   RANGE: Middle Eocene.

6. ***Pachyscyllium gilberti* (Casier, 1946).** Antero-lateral tooth (x12). Labial, lateral and lingual views.
   RANGE: Late Palaeocene - Middle Eocene.

7. ***Scyliorhinus woodwardi*** Cappetta, 1976. Anterior tooth (x25). Labial and lingual views.
   RANGE: Eocene.

8. ***? Foumtizia pattersoni* (Cappetta, 1976).** Lateral tooth (x12). Labial and lingual views.
   RANGE: Eocene.

9. ***Scyliorhinus* sp.** Lateral tooth (x12). Labial, lateral and lingual views.
   RANGE: Middle Eocene.

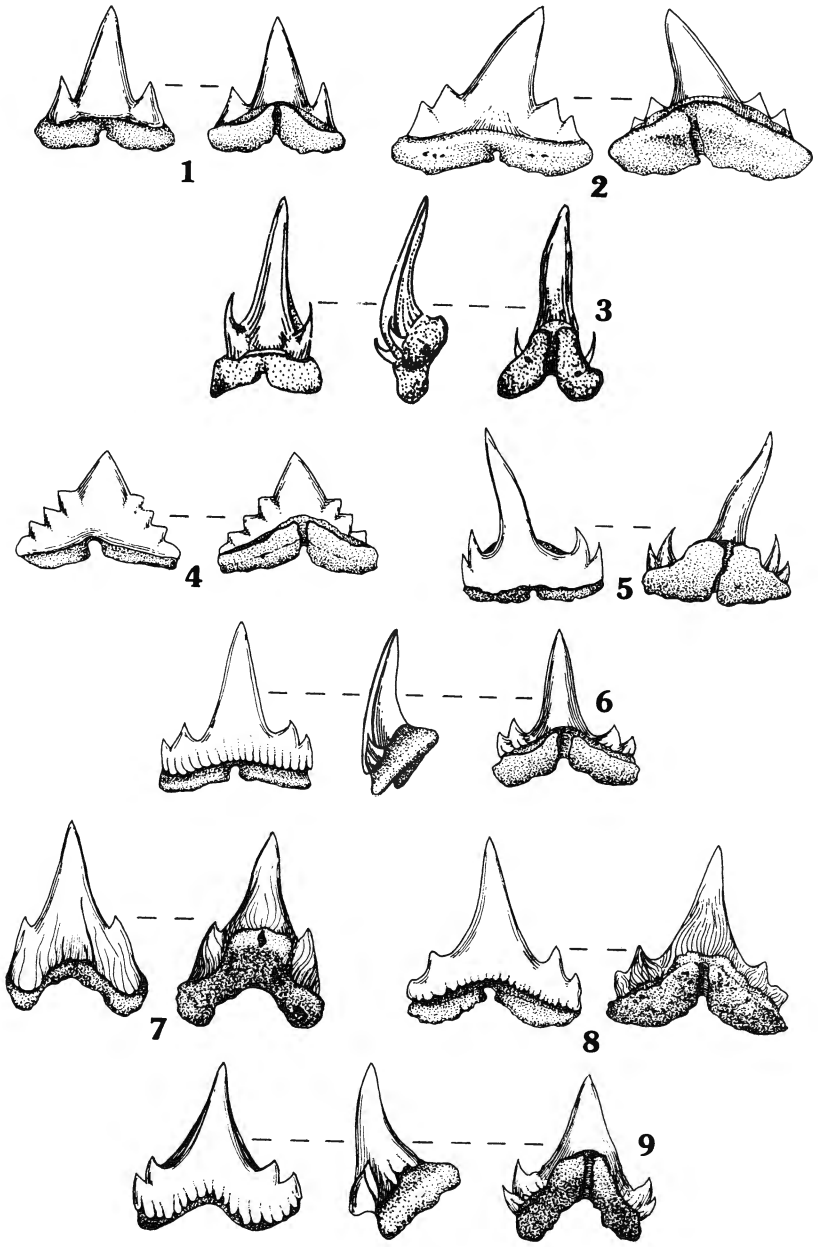


Plate 7

Sharks

1. ***Physogaleus secundus*** (Winkler, 1874). Female antero-lateral tooth (x2). Lingual and labial views.
   RANGE: Late Palaeocene to Late Eocene.
   SYN.: *Physodon secundus, P. tertius, Galeorhinus minor.*
   COMMENTS: A very common but variable species.
2. ***Physogaleus secundus*** (Winkler, 1874). Male antero-lateral tooth (x2). Lingual and labial views.
3. ***Mustelus whitei*** Cappetta,1976 Lateral tooth (x10). Labial.
   RANGE: Early and Middle Eocene.
4. ***Galeorhinus ypresiensis*** Casier, 1946. Lateral tooth (x2.5). Labial and lingual views.
   RANGE: Eocene.
5. ***Rhizoprionodon* sp.** Lateral tooth (x5). Labial and lingual views.
   RANGE: Eocene.
   SYN.: *Physodon secundus,*
6. ***Pachygaleus lefevrei*** (Daimeries, 1891). Lateral tooth (x3). Labial and lingual views.
   RANGE: Late Palaeocene to Middle Eocene.
7. ***Isistius trituratus*** (Winkler, 1874). Antero-lateral tooth (x4). Labial and lingual views.
   RANGE: Eocene.
8. ***Physogaleus* sp.** Upper tooth (x3). Labial and lingual.
   RANGE: Middle Eocene.
9. ***Carcharhinus* sp.** Lower tooth (x3). Labial and lingual views.
10. ***aff. Dalatias* sp.** Lower tooth (x4). Labial and lingual views.
    RANGE: Early to Middle Eocene.
11. ***Squalus minor*** Leriche, 1902. Antero-lateral tooth (x6). Labial and lingual views.
    RANGE: Early Palaeocene to Middle Eocene.
12. ***Galeocerdo latidens*** (Agassiz, 1843). Lateral tooth (x2.5). Labial and lingual views.
    RANGE: Middle Eocene..

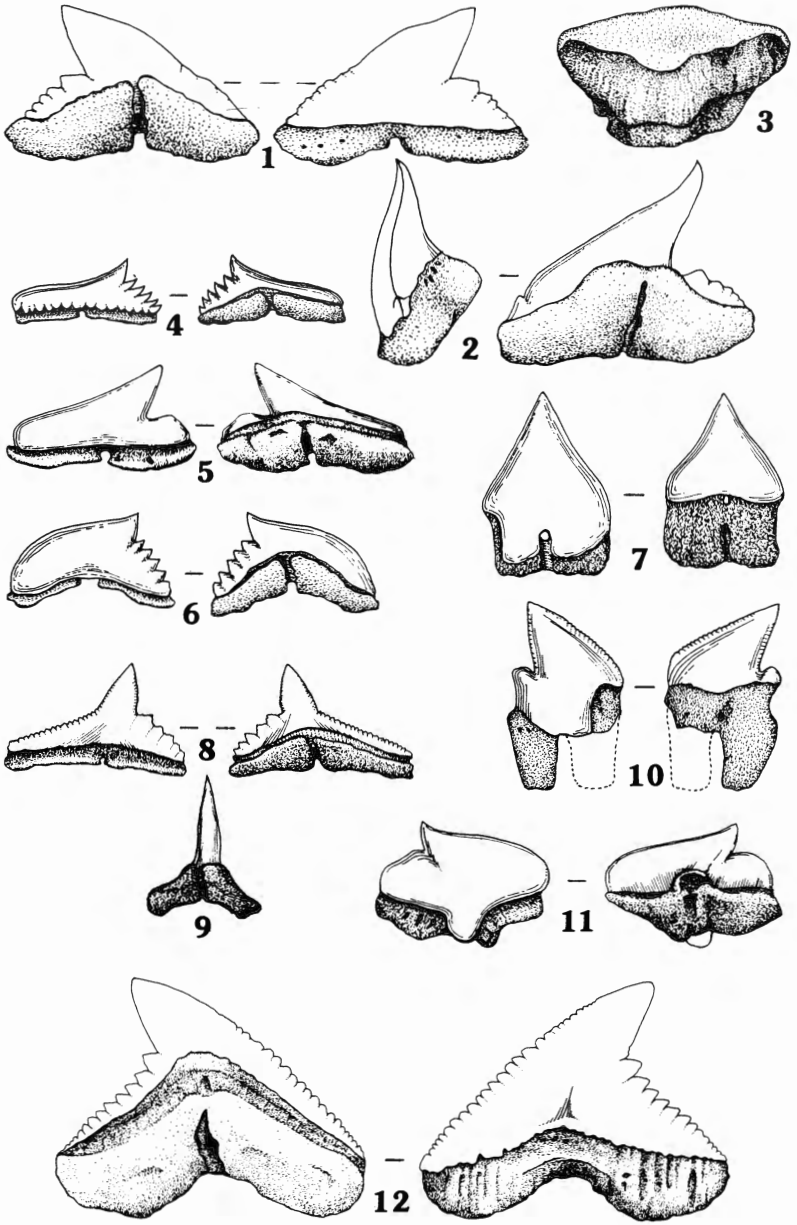


Plate 8

Sharks

1. ***Hypotodus verticalis*** (Agassiz, 1843). Lower anterior tooth (x1.25). Labial, lateral and lingual views.
   RANGE: Late Palaeocene to Late Eocene.
   SYN.: *Odontaspis hopei, Eugomphodus hopei, Carcharias hopei, Hypotodus heinzelini, Hypotodus robustus*
   COMMENTS: Has an unstriated lingual crown surface.
2. ***Hypotodus verticalis*** (Agassiz, 1843) Upper lateral tooth (x1.25). Lingual view.
3. ***Hypotodus verticalis*** (Agassiz, 1843) Lower anterior tooth (x1.25). Labial, lateral and lingual views.
4. ***Araloselachus sp.*** Upper lateral tooth (x1.25). Lateral and lingual view.
   SYN.: *Carcharias cuspidatus*
   RANGE: Middle Eocene to Miocene.
5. ***Carcharias acutissima*** (Agassiz, 1843). Lateral tooth (x1.25). Labial and lingual views.
   RANGE: Middle Eocene to Early Miocene.
   COMMENTS: Usually has a striated lingual crown.
6. ***Carcharias acutissima*** (Agassiz, 1843). Upper anterior tooth (x1.25). Labial, lateral and lingual views.
7. ***Carcharias acutissima*** (Agassiz, 1843). Lower anterior tooth (x1.25). Labial, lateral and lingual views.

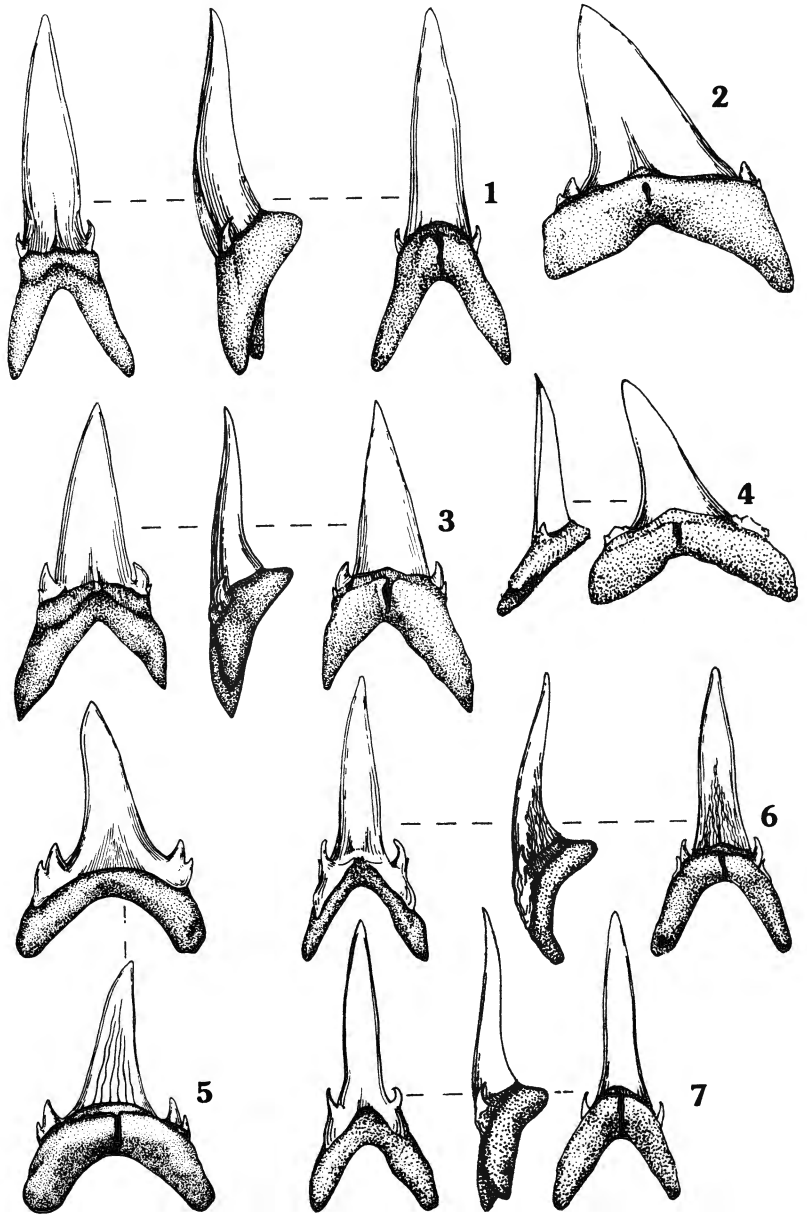


Plate 9

Sharks

Striatolamia macrota (Agassiz, 1843)

1. Lower anterior tooth (x1.25). Labial, lateral and lingual views.
2. Upper lateral tooth (x1.25). Lingual and labial views.
3. Lower anterior tooth (x1.25). Lingual view.
4. Upper anterior tooth (x1.25). Lingual and labial views.
5. Lower anterior tooth (x1.25). Labial view.
6. Lower lateral tooth (x1.25). Labial view.
7. Upper lateral tooth (x1.25). Labial view..

RANGE: Eocene.
SYN.: *Odontaspis macrota, Eugomphodus macrotus.*
COMMENTS: The most common of the Palaeogene odontaspids. The distinctive striations on the lingual crown become less marked in larger and lateral teeth.

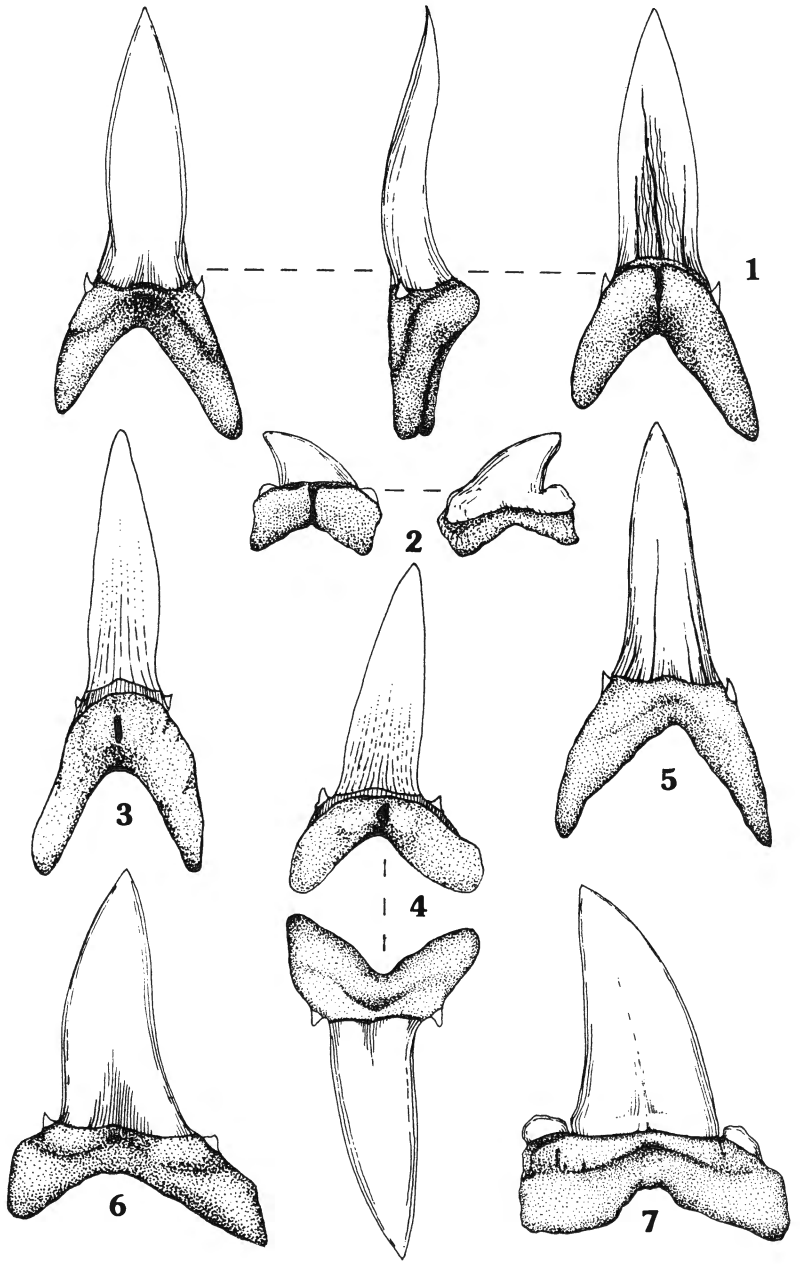


Plate 10

Rays

1. ***Rhynchobatus vincenti*** (Jaekel, 1894). Antero-lateral tooth (x6). Occlusal, lateral and basal views.
   RANGE: Eocene.
2. ***Rhinobatos bruxelliensis*** (Jaekel, 1894). Antero-lateral tooth (x9). Lingual, lateral and basal views.
   RANGE: Late Palaeocene to Eocene.
3. ***Jacquhermania duponti*** (Winkler, 1872). Antero-lateral tooth (x15). Labial, lingual and lateral views.
   RANGE: Eocene.
   SYN.: *Raja duponti, Dasyatis duponti.*
4. ***Coupatezia woutersi*** Cappetta, 1982. Female antero-lateral tooth (x6). Occlusal, lateral and basal views.
   RANGE: Eocene.
   SYN.: *Raja duponti, Dasyatis duponti.*
5. ***Dasyatis tricuspidatus*** Casier, 1946. Female antero-lateral tooth (x9). Lingual, lateral and basal views.
   RANGE: Middle Eocene.
6. ***Heterotorpedo fowleri*** Ward, 1983. Female antero-lateral tooth (x10). Labial view.
   RANGE: Middle Eocene.
7. ***Heterotorpedo fowleri*** Ward, 1983. Male antero-lateral tooth (x10). Occlusal and lateral views.
8. ***Dasyatis jaekeli*** (Leriche, 1905). Antero-lateral tooth (x10). Occlusal, lateral and basal views.
   RANGE: Eocene.
9. ***Archaeomanta melenhorsti*** Herman, 1979. Antero-lateral tooth (x6). Lateral, lingual and basal views.
   RANGE: Late Palaeocene to Middle Eocene.
10. ***Gymnura*** sp. Antero-lateral tooth (x30). Lateral, basal, labial and lingual views.
    RANGE: Early Palaeocene - Recent.
11. ***Hypolophodon sylvestris*** (White, 1931). Antero-lateral tooth (x6). Labial, lateral and basal views.
    RANGE: Late Palaeocene to Middle Eocene.
    SYN.: *Hypolophus sylvestris.*

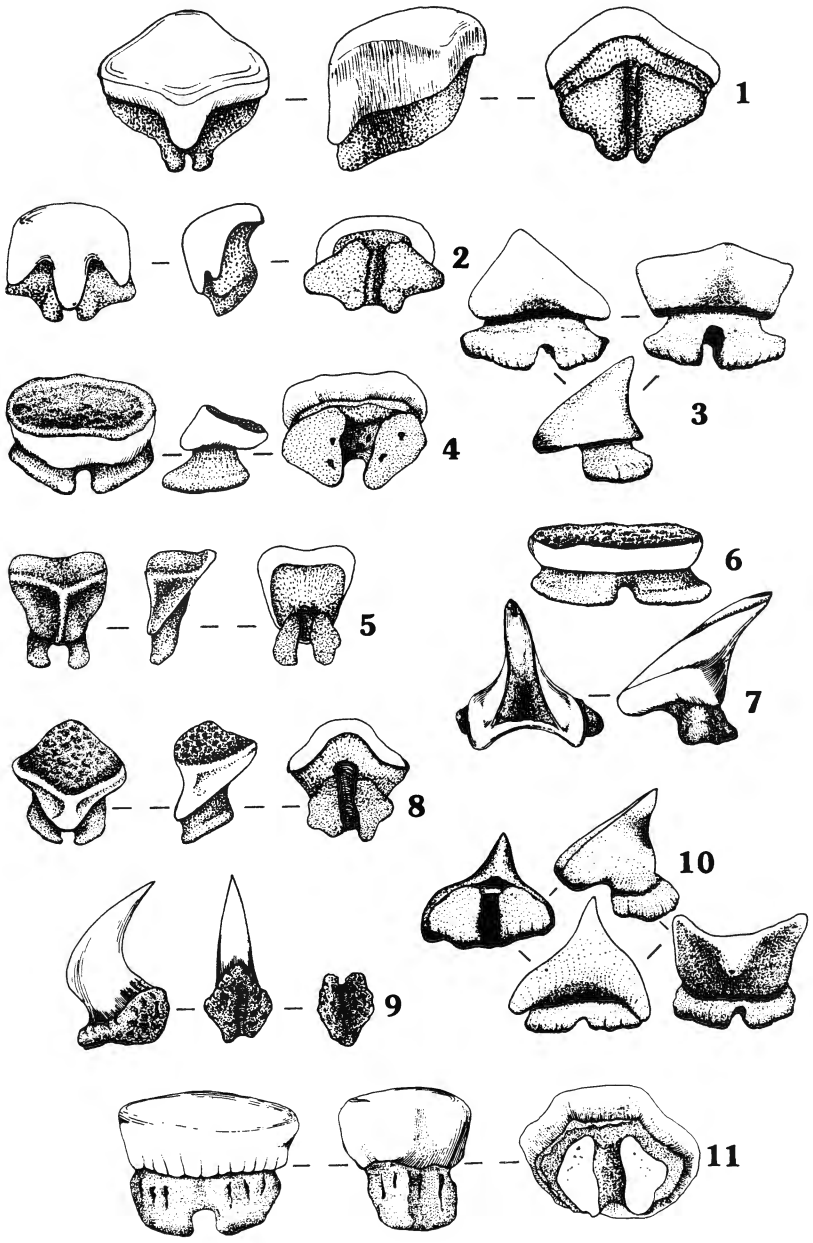


Plate 11

Rays and sharks

1. ***Propristis schweinfurthi*** Dames, 1883. Rostral tooth (x2). Lateral and basal views.
   RANGE: Eocene.
2. ***Anoxypristis* sp.** Rostral tooth (x3). Lateral and basal views.
   RANGE: Eocene - Recent.
3. ***Pristis lathami*** (Galeotti, 1837). Rostral tooth (x1.25). Lateral and basal views.
   RANGE: Eocene.
4. ***Pristis* sp.** Vertebra (x1). Lateral and basal views.
5. ***Pristis* sp.** Fragment of rostral cartilage (x0.8). dorsal view.
6. **Indet. selachian**. Spiral coprolite (x1). Lateral view.
   RANGE: Triassic to Recent.
7. **Indet. ray**. Dermal tubercle (x10). Lateral view.
   RANGE: Late Cretaceous to Recent.
8. **Indet. myliobatiform ray**. Tail spine (x8). Dorsal and basal views.
   RANGE: Late Cretaceous to Recent.
9. **Indet. ray**. Dermal tubercles (x10). Lateral view.
   RANGE: Late Cretaceous to Recent.
10. **Indet. ray**. Dorsal spine (x2). Dorsal view.
    RANGE: Late Cretaceous to Recent.
11. **Indet. lamniform shark** Vertebra (x.75). Anterior and lateral views.
    RANGE: Early Cretaceous to Recent.

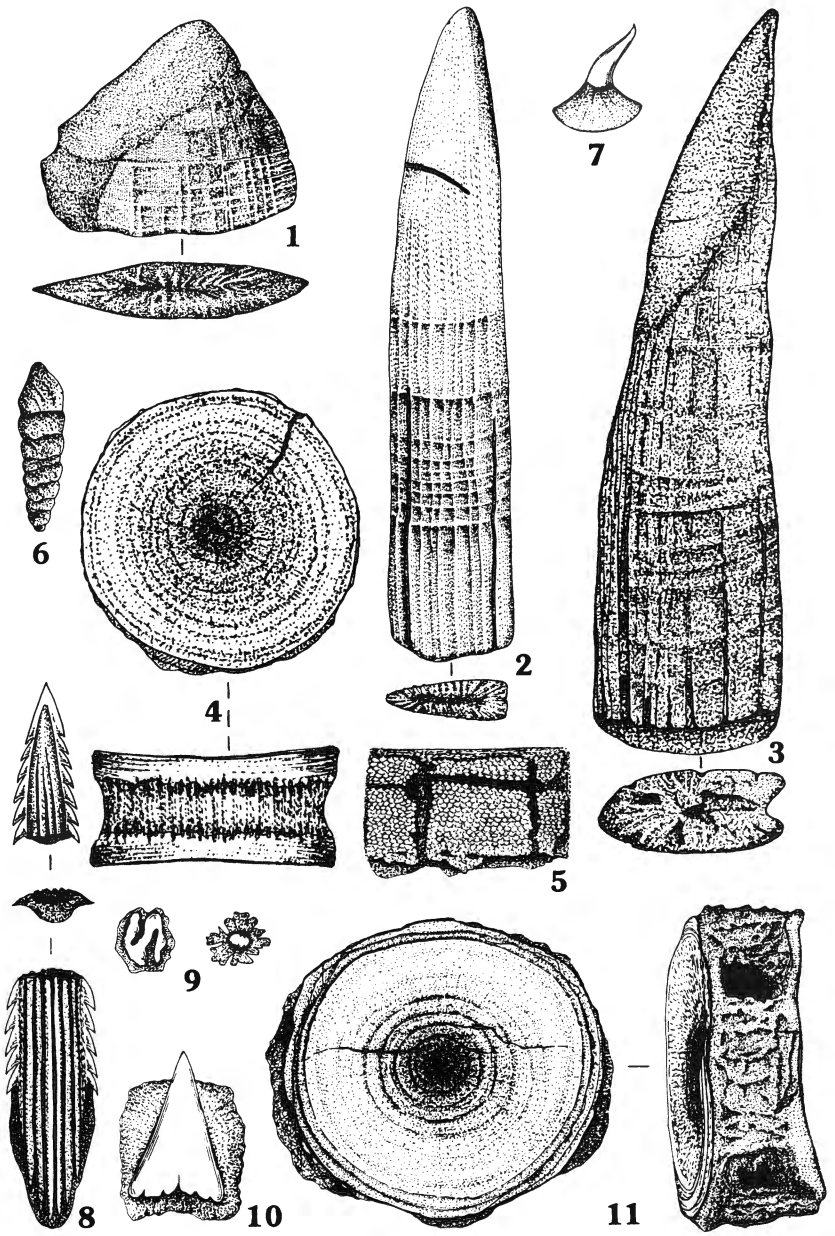


Plate 12

Rays

1. ***Aetobatus irregularis*** (Agassiz, 1843) Single tooth from lower dentition (x1.2). Basal and occlusal views.
   RANGE: Eocene.
   COMMENTS: See also back cover.
2. ***Aktaua* sp.** Worn tooth from lower dentition (x3.5). Occlusal and basal views.
3. ***Rhinoptera sherborni*** White, 1926 Articulated teeth (x1.25). Basal and lateral views.
   RANGE: Middle Eocene.
4. ***Myliobatis* sp.** Lateral tooth (x2). Basal view.
5. ***Myliobatis dixoni*** Agassiz, 1843 Median tooth (x2). Basal view.
   COMMENTS: See also title page.
6. ***Burnhamia daviesi*** (Woodward, 1889) tooth (x1.25). Occlusal, basal and lateral views.
   COMMENTS: Rim surrounding concave occlusal surface.
   RANGE: Early - Middle Eocene.
7. ***Lophobatis* sp.** Tooth (x1.75). Occlusal, basal and lateral views.
   RANGE: Middle Eocene.
   COMMENTS: Slightly convex & grooved occlusal surface.

***Aktaua* sp.**

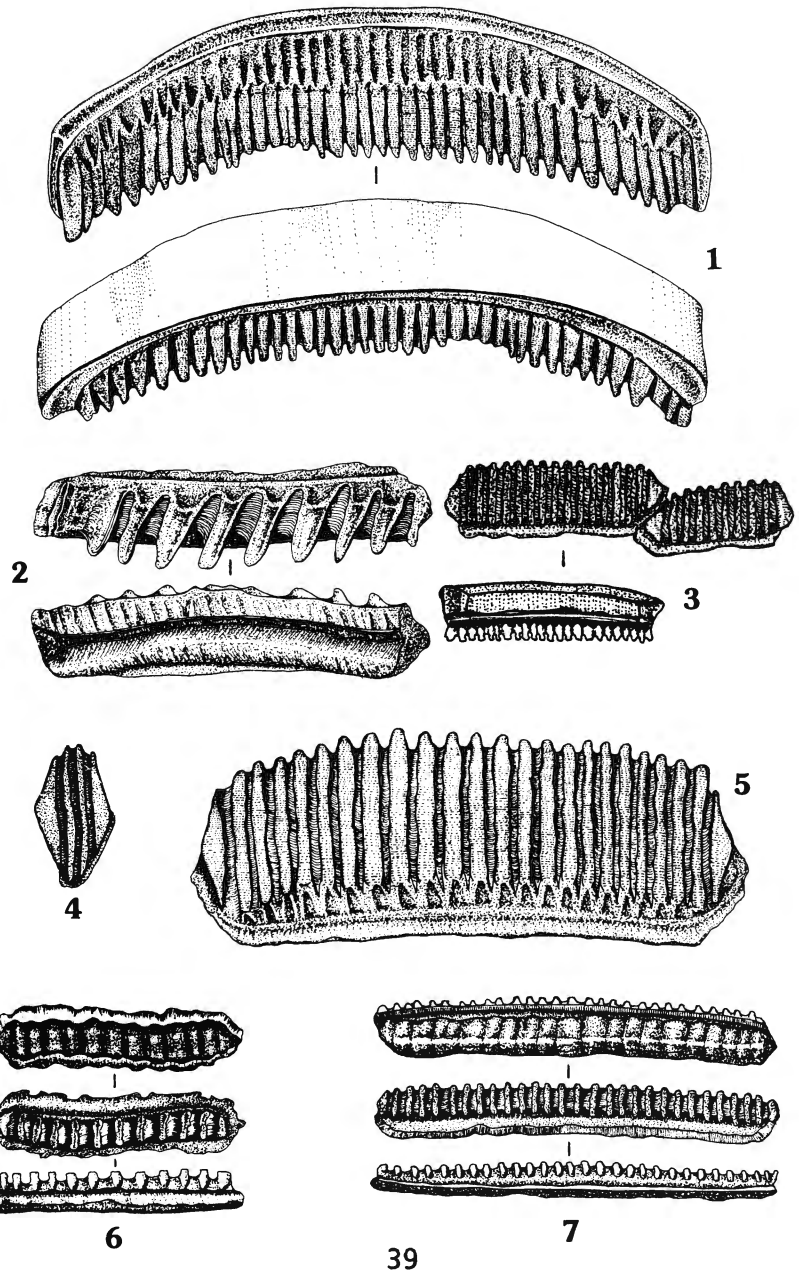


Plate 13

Ray

1. ***Myliobatis striatus*** Buckland, 1837 Lower dentition. (x1.25). Basal and occlusal views.
RANGE: Eocene.
COMMENTS: Wide median teeth and up to three rows of lateral teeth.

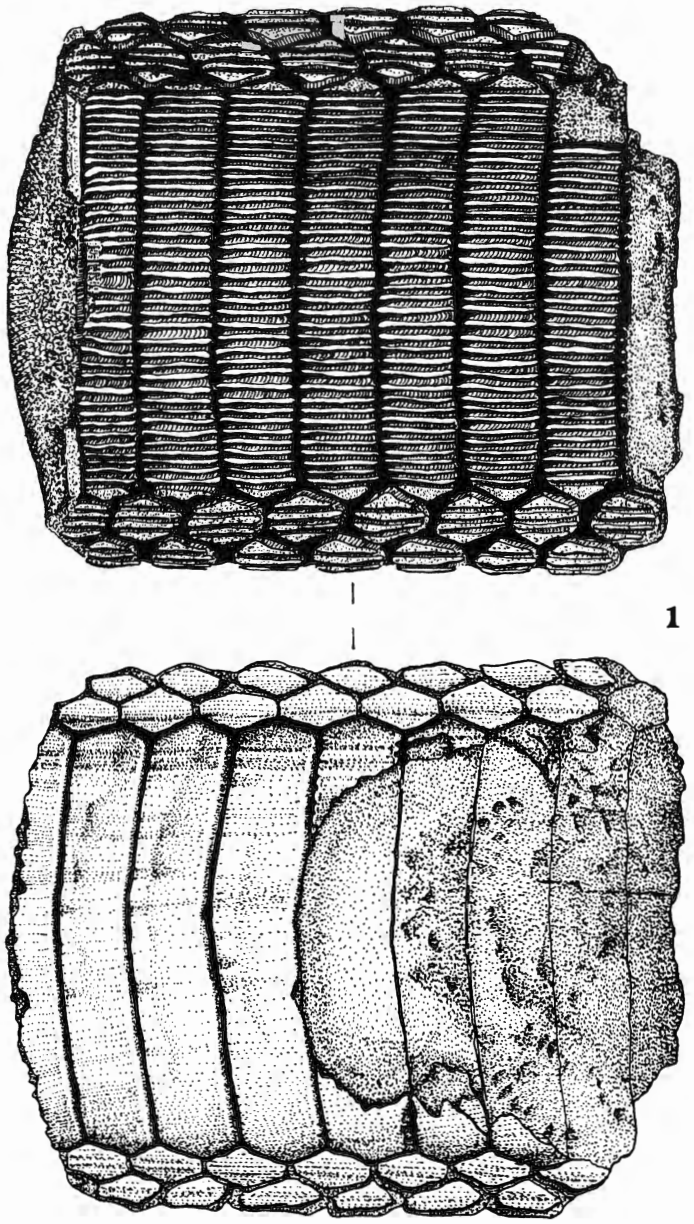


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Plate 14

Rays and chimaeroids

1. ***Myliobatis toliapicus*** Agassiz, 1843. Lower dentition. (x1.1). Occlusal view.
   RANGE: Eocene.
   COMMENTS: Wide median teeth, up to three rows of hexagonal or rhomboidal lateral teeth.
2. ***Myliobatis latidens*** Woodward, 1888. Lower dentition. (x1.5). Basal view.
   RANGE: Eocene.
   COMMENTS: Long narrow median teeth, rectangular lateral teeth.
3. ***Amylodon* sp.** Left lower (mandibular) dental plate. (x2). Lingual view.
   RANGE: Eocene.
4. ***Elasmodus hunteri*** Egerton, 1843 Left lower (mandibular) dental plate. (x1.1). Lingual view.
   RANGE: Late Palaeocene to Middle Eocene.
5. ***Elasmodus kempi*** Ward, 1976 Right upper posterior (palatine) dental plate. (x1.5). Lingual view.
   RANGE: Middle Eocene.
6. ***Elasmodus kempi*** Ward, 1976 Left lower (mandibular) dental plate. (x3). Lingual view.
   RANGE: Middle Eocene.

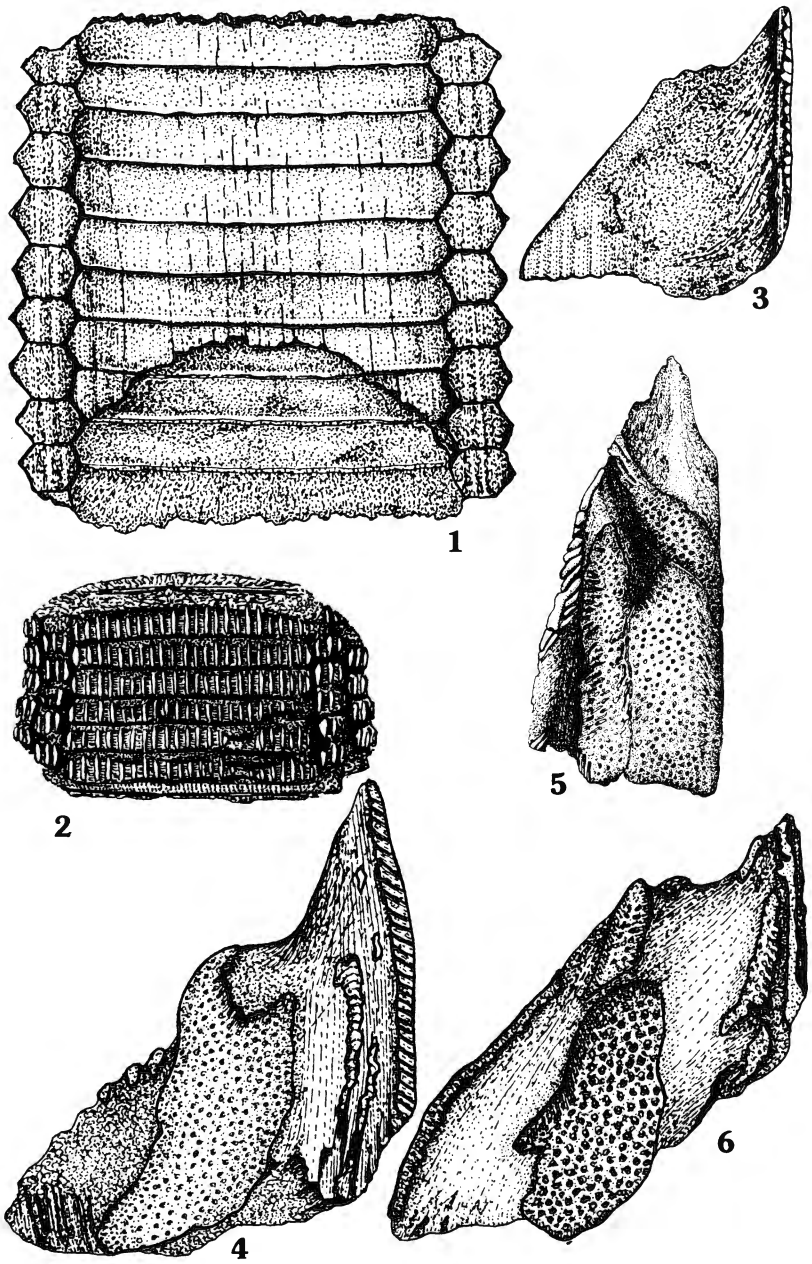


Plate 15

Chimaeroids

1. ***Edaphodon bucklandi*** Agassiz, 1843. Left lower (mandibular) dental plate. (x1.2). Lingual view.
   RANGE: Late Palaeocene to Middle Eocene.
2. ***Edaphodon bucklandi*** Agassiz, 1843. Right upper posterior (palatine) dental plate. (x1.5). Lingual view.
3. **Indet. chimaeroid** Right upper anterior (vomerine) dental plate. (x3). Lingual view.
4. ***Edaphodon leptognathus*** Agassiz, 1843. Left lower (mandibular) dental plate. (x1.5). Lingual view.
   RANGE: Middle Eocene.
5. ***Edaphodon minor*** Ward, 1973. Right upper posterior (palatine) dental plate. (x1.5). Lingual view.
   RANGE: Middle Eocene.
   COMMENTS: May be a juvenile *Edaphodon bucklandi*
6. **Indet. chimaeroid** Dorsal fin spine. (x1). Lateral view.

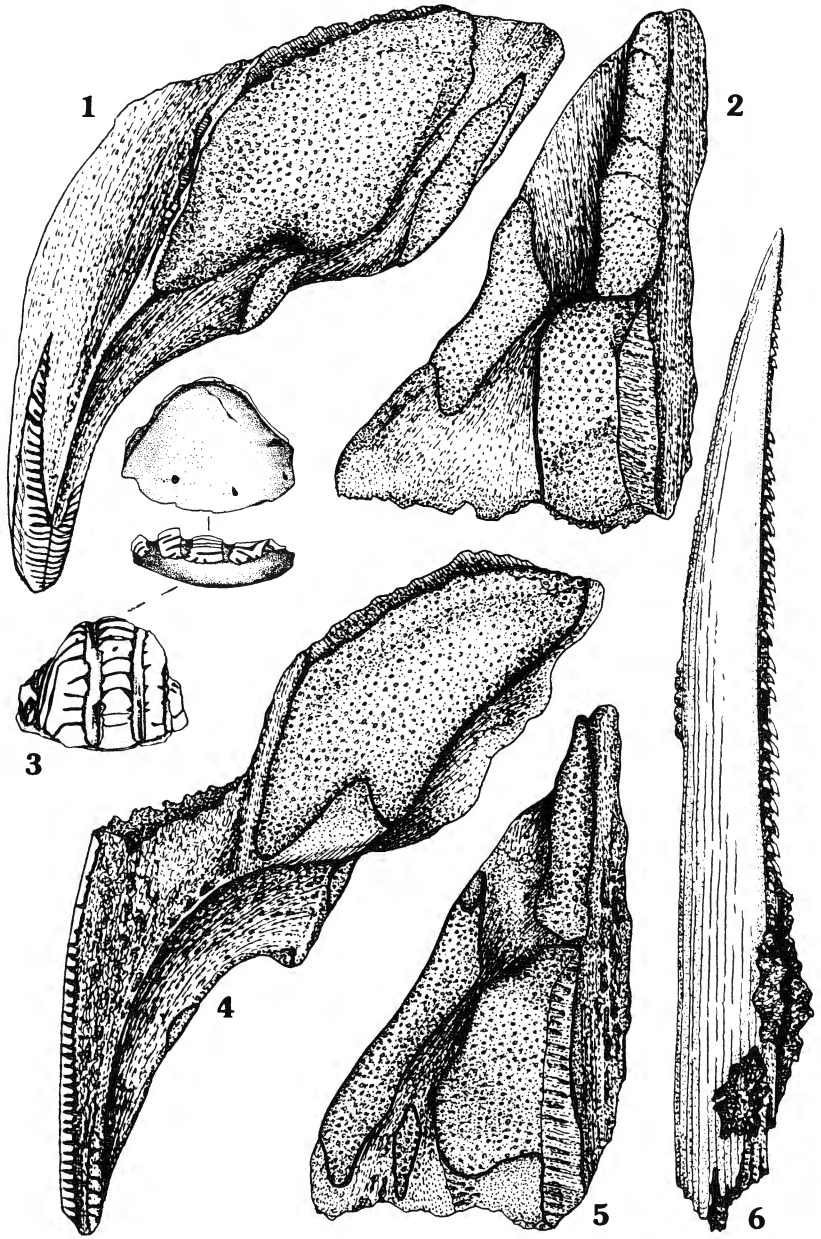


Plate 16

Bony fish

1. ***Platylaemus colei*** Dixon, 1850. Lower (mandibular) dental plate. (x1). Lingual view.
   RANGE: Eocene.
2. ***Platylaemus colei*** Dixon, 1850. Upper (maxillary) dental plate. (x1). Lingual and lateral views.
3. ***Eodiodon bauzai*** Casier, 1952. Lower (mandibular) dental plate. (x1). Lingual view.
   RANGE: Eocene.
4. ***Triodon antiquus*** Leriche, 1905. Lower (mandibular) dental plate. (x1). Lingual and lateral views.
   RANGE: Eocene.
5. ***Conger* sp.** Premaxillary bone (x2). Lingual and lateral views.
   RANGE: Eocene to Recent.
6. ***Pycnodus toliapicus*.** Agassiz, 1843. Lower dentition (x1). Lingual and lateral views.
   RANGE: Eocene.
7. ***Xiphiorhynchus*. sp.** Cranial bone (x2.5). Dorsal and lateral views.
   RANGE: Eocene.
   COMMENTS: See also Pl. 18, figs 7,10,11.
8. ***Enniskillenus* cf. *radiatus*** Casier, 1966. Cranium (x2.5). Dorsal and posterior views.
   RANGE: Eocene.
9. ***Phyllodus* sp.** Fragment of dentition (x1). Lingual and lateral views.
   RANGE: Late Palaeocene to Eocene.
10. ***Prolates* sp.** Premaxillary bone (x2.5). Lingual view.
    RANGE: Eocene.
11. ***Cybium excelsum*** Woodward, 1901. Premaxillary bone (x0.8). Labial view.
    RANGE: Eocene.
    COMMENTS: Teeth large and triangular, oval in section.

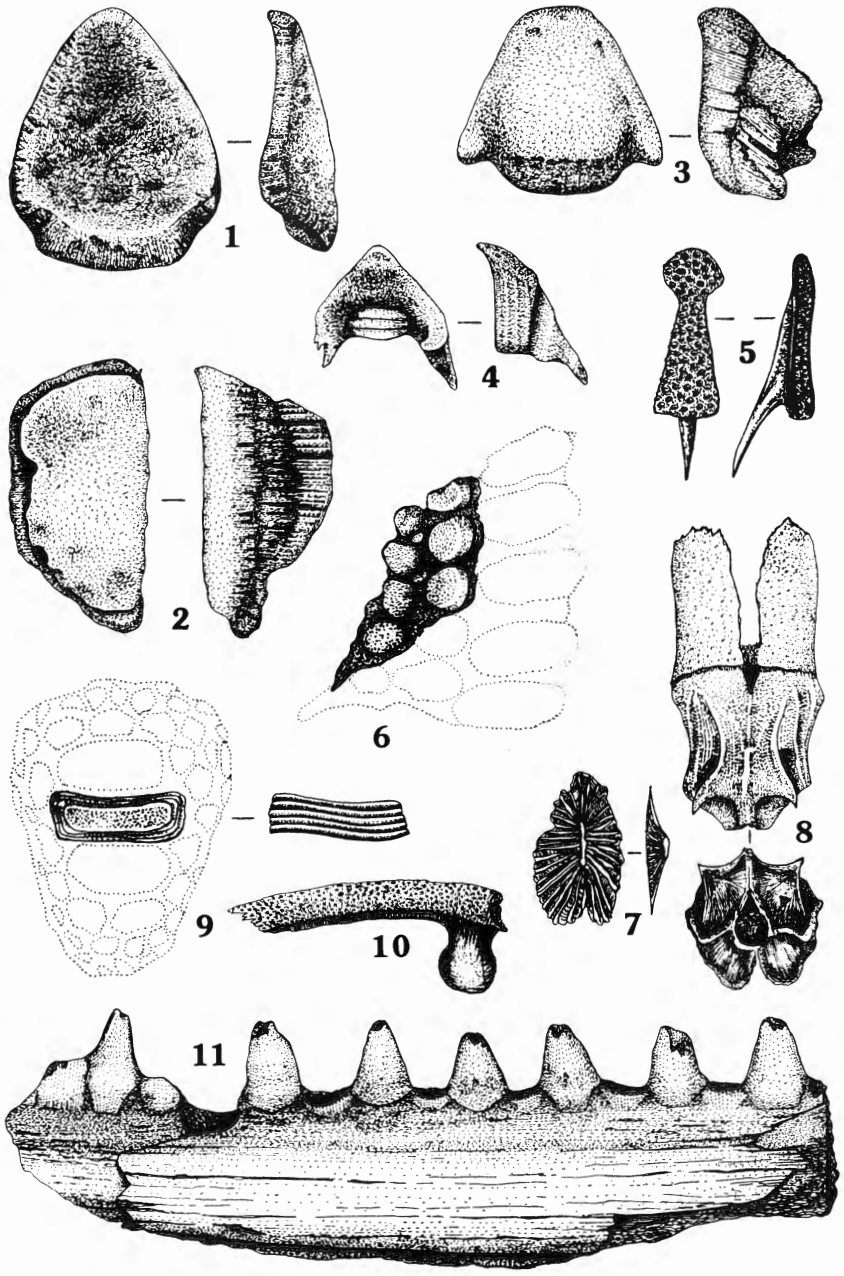


Plate 17

Bony fish

Otoliths and teeth - see page xx for distribution.

OTOLITHS

1. ***Neobythitinarum dimidiatus*** (Schubert, 1916). (x3.5)
2. ***Pterothrissus umbonatus*** (Koken, 1884). (x2.5)
3. ***Ganthopsis websteri*** (Frost, 1933). (x3.5)
4. ***Lactarius amplus*** Pomerol, 1973. (x1.5)
5. ***Sirenbinorum spinosus*** Nolf & Cappetta, 1976. (x4)
6. ***Paraconger sauvagei*** (Priem, 1906). (x2.2)
7. ***Pomadasyidarum kokeni*** (Leriche, 1905). (x3.5)
8. ***Ampheristus waltoni*** (Schubert, 1916). (x2)
9. ***Neobythitinorum regularis*** (Priem, 1911). (x3)
10. ***Arius crassus*** (Koken, 1884). (x1.5)
11. ***Albula* sp.** (x2)

FISH TEETH, Mesial & basal views, unless otherwise stated.

12. ***Sphyraenodus lerichei*** Casier, 1944. (x1.25)
13. ***Labrus eocaenus*** Casier, 1946. (x2.5)
14. ***Sparus* sp.** (x3)
15. ***Sphyraena striata*** Casier,1946. (x2.5)
16. ***Cybium stormsi*** Leriche, 1905. (x2)
17. ***Cybium proosti*** (Storms, 1867). (x1.5)
18. ***Amia* sp.** (x2)
19. ***Eotrigonodon serratus*** (Gervais, 1852). (x2)
20. ***Eotrigonodon* sp.** (x1.5)
21. ***Albula oweni*** (Owen, 1845). (x1.5) Occlusal & lateral views.
22. ***Egertonia* cf. *isodonta*** Cocchi, 1866. (x1.5) Lateral and occlusal views.
23. ***Eutrichiurides winkleri*** Casier, 1946. (x1.5)
24. ***Trichiurus gulincki*** Casier, 1967. (x1.5)
25. ***Trichiurides sagittidens*** (Winkler, 1874). (x1.5)
26. ***Eutrichiurides* sp.** (x1.5)
27. ***Pseudosphaerodon antiquus*** Casier, 1966. (x1) Lateral and occlusal views.

DERMAL PLATE

28. ***Ostracion* cf. *meretrix*** Daimeries, 1891. (x3)
RANGE: Late Palaeocene to Middle Eocene.

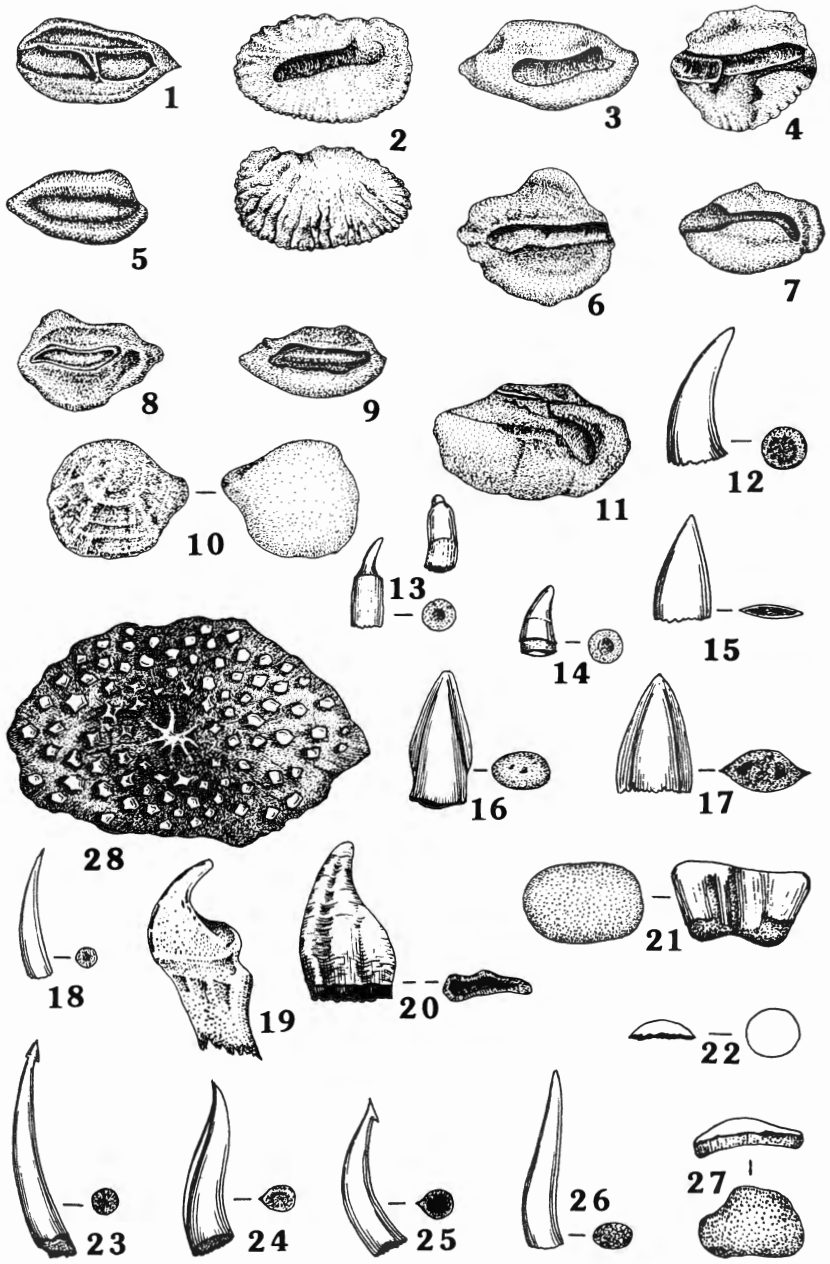


Plate 18

Bony fish

1. ***Cylindracanthus rectus*** Dixon, 1844. Rostrum. (x0.8). Dorsal and basal views.
   RANGE: Eocene.
2. ***Aglyptorhnchus* sp.** Rostrum. (x1.25). Ventral and basal views.
   RANGE: Eocene.
3. ***Acipenser toliapicus*** Fragment of fin ray. (x1).
   RANGE: Late Palaeocene to Eocene.
4. ***Rhinocephalus* sp** tooth.(x2) Lateral and basal views.
   RANGE: Middle Eocene.
5. ***Arius egertoni*** Dixon, 1850. Pectoral fin spine (x2) Ventral view.
   RANGE: Middle Eocene.
6. ***Brachyrhynchus* sp.** Rostrum (x1) Dorsal and basal views.
   RANGE: Early and Middle Eocene.
7. ***Xiphiorhynchus* sp.** Rostrum (x1.2) Dorsal and basal views.
   RANGE: Early and Middle Eocene.
8. ***Lepisosteus suessionensis*** (Gervais, 1852). Flank scale (x1.25) Outer surface.
   RANGE: Late Palaeocene to Eocene.
9. ***Lepisosteus suessionensis*** (Gervais, 1852) Vertebra (x1) Outer surface.
   NOTE: Concavo-convex articulation surfaces.
10. ***Xiphiorhynchus* sp.** Vertebra (x0.75) Basal and lateral views.
11. ***Xiphiorhynchus* sp.** Hypural vertebra (x1.25) Anterior and lateral views.
12. **Indet teleost.** Atlas vertebra (x0.6) Anterior and lateral views.
    RANGE: Late Cretaceous to Recent.

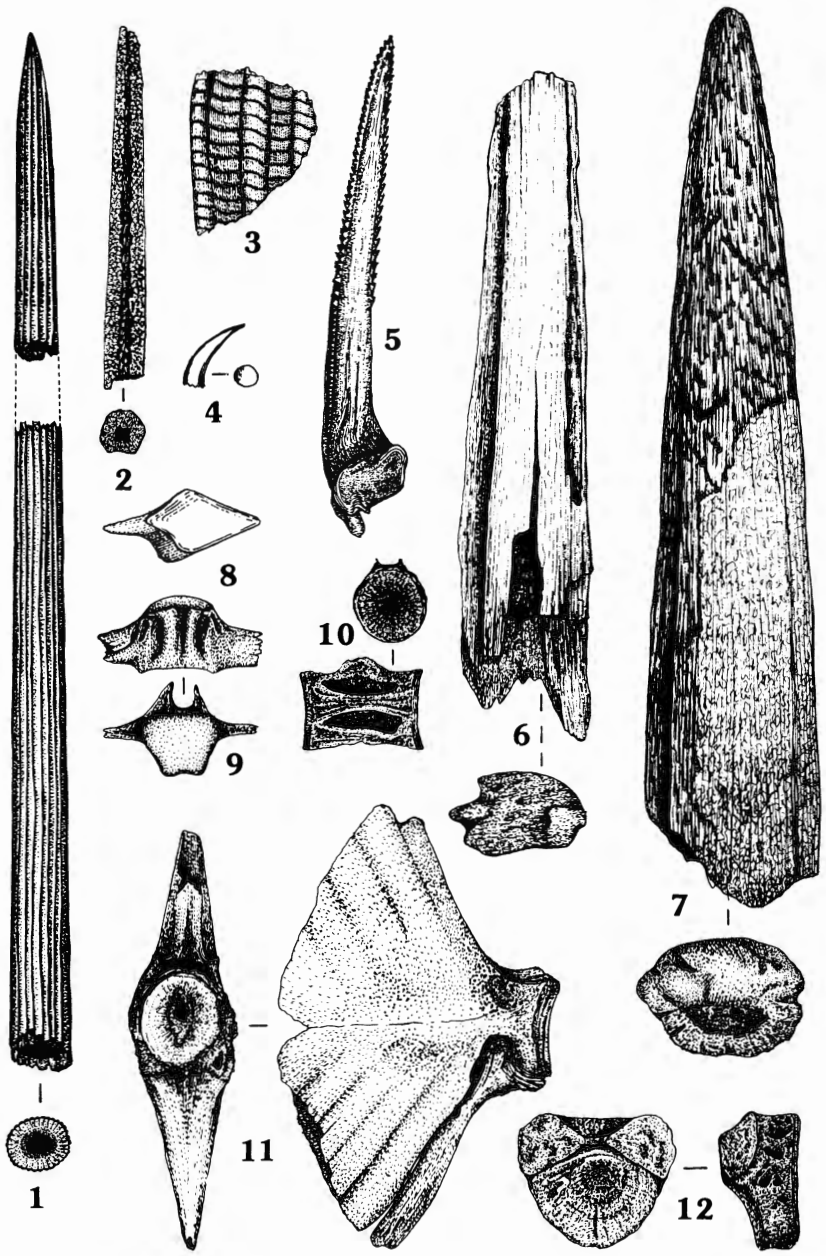


Plate 19

Reptiles

1 - 6 ***Puppigerus camperi*** (Grey, 1933). Turtle remains.

1. Humerus. Anterior and internal views (x1)
2. Neural bone. Ventral and dorsal views (x1).
3. Costal bone. Profile and dorsal views (x0.75)
4. Dorsal vertebra. Ventral, anterior & lateral views. (x1)
5. Dentary bone. Lingual and anterior views (x1).
6. Carapace marginal bone. Profile and ventral views (x1)

RANGE: Middle Eocene - Oligocene.

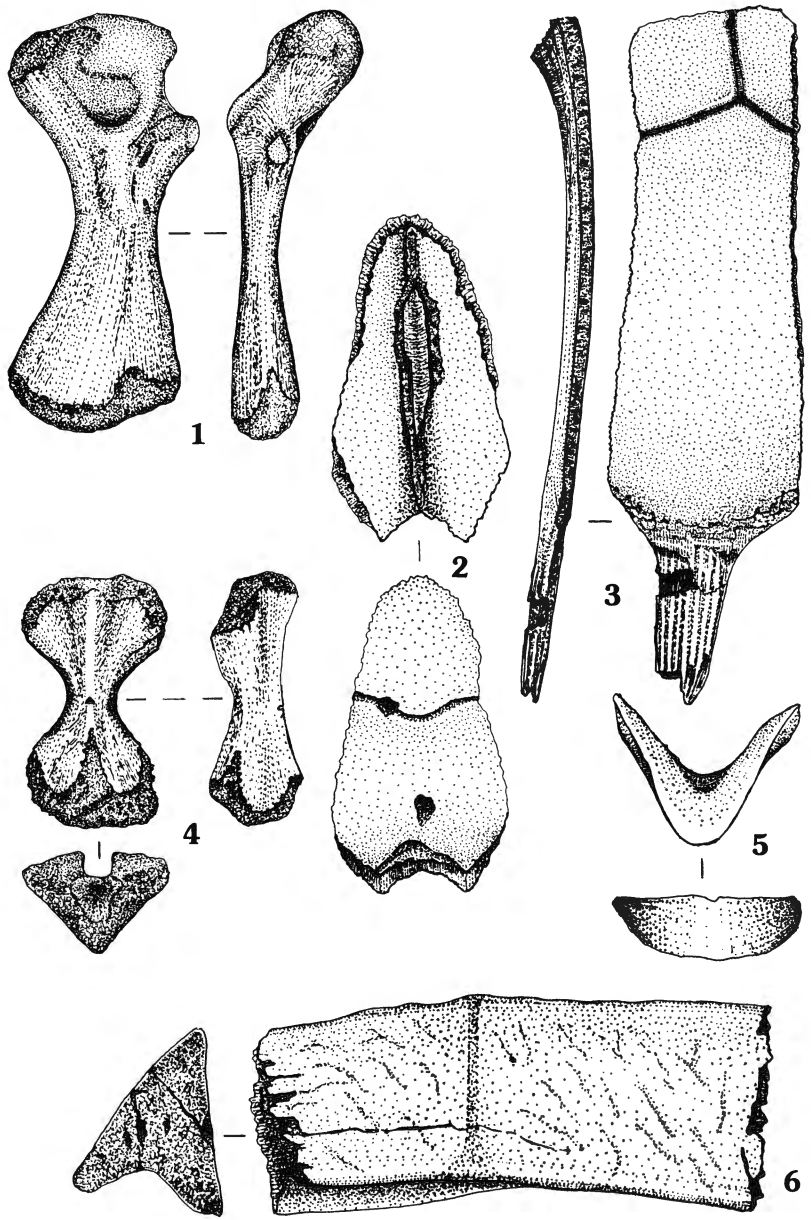


Plate 20

Reptiles

1. ***Argillochelys* sp.** Neural bone (x1). Dorsal view.
   RANGE: Eocene.
2. **Indet. crocodile** Femur (x0.6). Anterior and lateral views.
   RANGE: Triassic - Recent.
3. ***Allaeochelys* sp.** Neural bone (x1). Dorsal view.
   RANGE: Eocene.
4. **Indet. crocodile** tooth (x1). Lateral and basal views.
   RANGE: Triassic - Recent.
5. ***Gavialis dixoni*** Dixon, 1850. Tooth (x1). Lateral and basal views.
   RANGE: Middle Eocene.
6. **Indet. crocodile** Dermal scute (x0.8). Outer surface.
   RANGE: Triassic - Recent.
7. ***Diplocynodon* sp.** Dorsal vertebra. (x0.75). Posterior view of rolled centrum.
   RANGE: Middle Eocene - Oligocene.

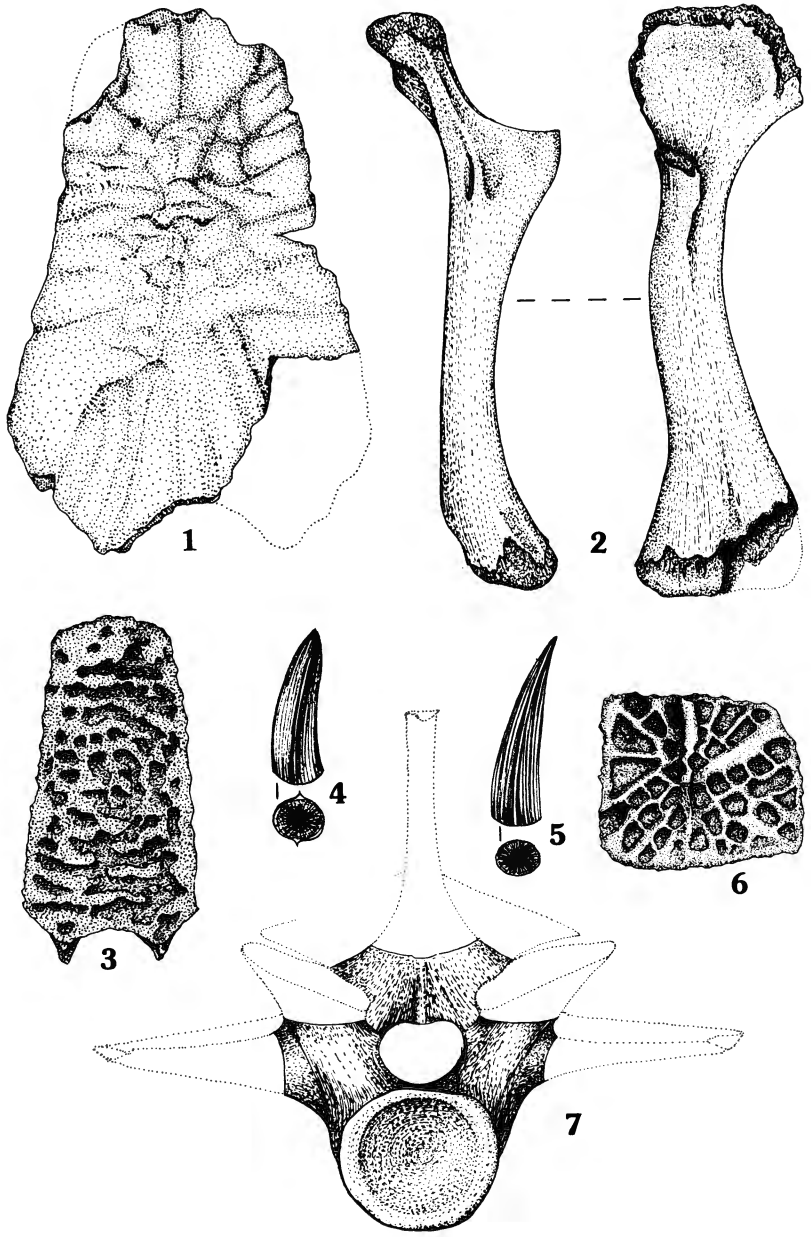
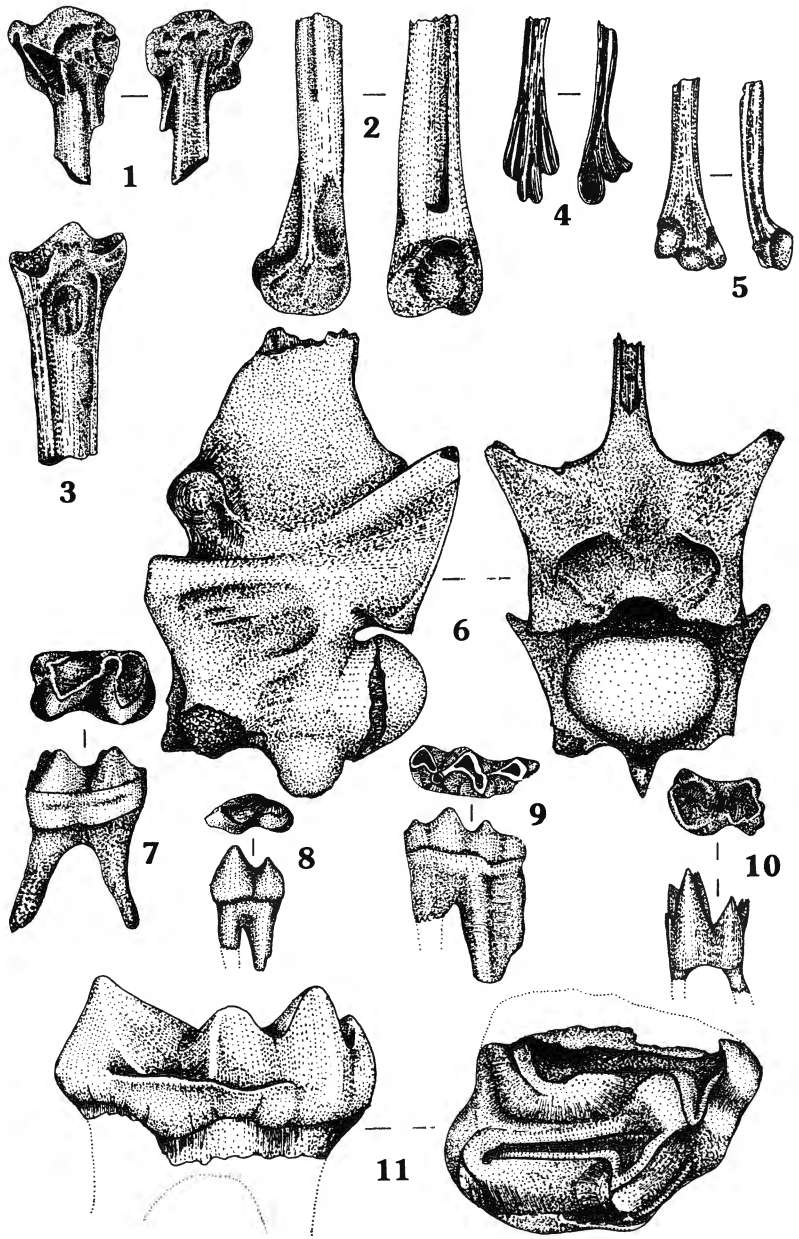


Plate 21

Birds, reptiles and Mammals

1. ***Milvoides kempi*** Harrison & Walker, 1979. Bird, carpometocarpus (x1). Palmar and anconal views.
   RANGE: Middle Eocene.
2. ***Latipons gardeneri*** Harrison & Walker, 1979. Bird, tibiotarsus (x1). Lateral and posterior views.
   RANGE: Middle Eocene.
3. ***Percolinus proudlocki*** Harrison & Walker, 1979. Bird, tarsometatarsus (x1). Anterior view.
   RANGE: Middle Eocene.
4. ***Litoripes medius*** Harrison & Walker, 1979. Bird, tarsometatarsus (x1) Anterior and lateral views.
   RANGE: Middle Eocene.
5. ***Parvirallus gracilis*** Harrison & Walker, 1979. Bird, humerus (x1). Anterior and lateral views.
   RANGE: Middle Eocene.
6. ***Palaeophis typhaeus*** Dixon, 1850. Snake, vertebra (x1.2). Lateral and anterior views.
   RANGE: Middle Eocene.
7. ***Propalaeotherium* cf *parvulum*** (Laurillard, 1849) Mammal, lower molar tooth (x2). Occlusal and labial views.
   RANGE: Middle Eocene.
8. ***Propalaeotherium* cf. *parvulum*** (Laurillard, 1849) Mammal, premolar tooth (x2). Occlusal and labial views.
9. ***Propalaeotherium* cf *parvulum*** (Laurillard, 1849) Mammal, upper molar tooth (x1.5). Occlusal and labial views.
10. **Didelphidae undet**. Mammal, molar tooth (x2). Occlusal and labial views.
11. ***Lophiodon* cf. *cuvieri*** Filhol, 1888. Mammal, upper molar tooth (x1). Lateral and occlusal views.
    RANGE: Middle Eocene.



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