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THE MEDITERRANEAN LOWER CRETACEOUS

BULGARIAN ACADEMY OF SCIENCES

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LE CRETACE INFERIEUR MESOGEEN

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Тодор Г. Николов

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THE MEDITERRANEAN LOWER CRETACEOUS

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In this monograph the Lower Cretaceous of the Mediterranean palaeogeographic Region is considered. The Lower Cretaceous sediments in this large area are developed in various facies and are rich in fossils. On the background of a broad, almost global panorama the author considers the foundation of stratigraphy of the Lower Cretaceous in the Mediterranean Region, the regional stratigraphic features of the development of the Series in local areas, the evolution and palaeobiogeography of the Early Cretaceous marine organisms in the Mediterranean, as well as the basic features of the geological evolution of these areas during Early Cretaceous.

The book is the first synthesis of this kind on the Lower Cretaceous of such a large area and represents a long-term research of the author in Bulgaria and in many other countries as well.

The monograph is designed to be of interest for a broad circle of specialists — geologists, geophysicists and students of corresponding professional fields.

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PREFACE

The idea for this study arose several years ago, when the author had to investigate the Bulgarian Lower Cretaceous in a wide (almost global) stratigraphic and palaeographic panorama. Even at that time a picture emerged, representing — figuratively speaking — an "Alpian-Himalayan" mixing of various processes and phenomena, with different interferences in the concrete regions and provinces. Parallel with this, there appeared the contours of definite trends of great significance for the Early Cretaceous geological evolution of one of the most dynamic areas in the Earth's crust.

In view of the level of present-day knowledge on the Lower Cretaceous in Bulgaria, it may be assumed that its investigation over a wider area would contribute to the further development of the theory and practice of Lower Cretaceous stratigraphy.

Another impetus for this difficult work is the practical lack of a generalization of the Lower Cretaceous in world literature. After Kilian's synthesis in Lethaea Geognostica (Kilian, 1907-1913) concerning the Lower Cretaceous in Southern France, only Eristavi (Эриставн, 1962) has made an attempt at a generalization of the Lower Cretaceous in the Alpine Zone, though his work is rather schematic.

The Mediterranean Region is part of the Tethys Ocean (Tethys Belt in palaeobiogeographic sense of the term). The Tethys is known to have comprised vast ancient marine aquatoria which crossed theMegagea from the Proto-Atlantic to the west, to the Proto-Pacific to the east (Stille, 1946). It covered vast areas of Northwestern Africa, Southern Europe, the Caucasus, Asia Minor, Iran, Afghanistan, the Himalayas and Indo-China to the Caroline corner in the Proto-Pacific. The Tethys Ocean was the conflict space between several lithospheric plates. It generated the Alpian-Himalayan Mountain Belt, while its fragments are the Mediterranean Sea, the Black Sea, the Caspian Sea, the Persian Gulf and the seas of the Malayan Archipelago (Biju-Duval, 1974; Biju-Duval et al., 1976).

The Mediterranean Region comprises Northern Africa, Southern Europe, the Caucasus and Asia Minor. It is characterized by specific development of the Lower Cretaceous, in contrast to the other adjacent regions and provinces (Volgian, Boreal, Himalayan, Malgash, Andian). Various facies are developed in this region: from deep-sea to continental. Rich fossil associations belonging to different groups of organisms are found.

The present monograph is based on the results of the studies on the Lower Cretaceous in Bulgaria, carried out by the author since 1957. In addition, between 1960 and 1984 the author had the opportunity to investigate and collect materials from different countries in the Mediterranean Region (Algeria, France, Switzerland, Italy, Yugoslavia, Greece, Hungary, Romania, Czechoslovakia, Poland and the Soviet Union).

The study of the Lower Cretaceous over such a vast area came up against many difficulties, especially with respect to some countries where the series has been insufficiently investigated. On the other hand, generalizations always conceal the potential danger of a superficial survey. This is why, the author's intention has been to comprise as fully as possible the general trends in the development of the Lower Cretaceous, by presenting the factual material serving as a starting point. In an attempt at concise presentation of the material, detailed characterization of the series in the individual countries has been avoided. The interpretations reflect the author's theoretical views and his concept about the stratigraphy of the Lower Cretaceous.

When examining the Lower Cretaceous in such a vast area, considerably more attention has been devoted to the Lower Cretaceous in Bulgaria. With this the author's aim has been to offer a better opportunity to foreign readers to become familiar with the stratigraphic investigations of the Lower Cretaceous in this country, because the relevant literature published so far is mainly in Bulgarian. On the other hand, the monograph also contains relatively brief information about Greece, Turkey and the Middle East, both due to the limited Lower Cretaceous outcrops there and to the small number of specialized studies. The area to the east of the Caspian Sea and Iran manifests faunistic (and mainly ammonite) elements, which are alien to the Mediterranean Lower Cretaceous.

The author is indebted to a number of colleagues and friends who have helped him in different ways and who have contributed to the successful outcome of the present studies.

Profound gratitude is due to the author's teacher, Academician Ekim Bončev, who suggested the investigation of the Lower Cretaceous.

The author has carried out joint studies of the Lower Cretaceous according to different groups of organisms, joint stratigraphic and lithological studies, or studies of stratigraphically related (transitional) levels together with a number of colleagues over different periods. In this connection the author would like to acknowledge gratefully the cooperation with Mrs. D. Bakalova, Prof. M. Stojanova-Vergilova, Dr. A. Goranov, Mrs. L. Dodekova, Mrs. P. Jovčeva, Dr. T. Kovatcheva, Dr. B. Monov, Dr. I. Nachev and Dr. Kh. Khrischev.

Special gratitude is due to Dr. N. Ruskova for the lithological studies of the Lower Cretaceous rocks used in the present study, as well as for the joint investigations of the Lower Cretaceous in Northern Bulgaria.

Most cordial thanks also to the colleagues Dr. G. Mandov, Dr. I. Sapunov and Dr. J. Tenčov for the discussions and valuable suggestions in connection with the present work. The author is closely linked with Dr. I. Sapunov and Dr. G. Mandov by years of joint fruitful work, which is highly appreciated.

In the course of his work over many years, the author has had the opportunity and the privilege to discuss various problems concerning Lower Cretaceous stratigraphy with many colleagues from abroad. Many of them kindly provided literature not available in Bulgaria, as well as plaster casts or original ammonites from the collections of various institutes and/or museums abroad. Therefore it is a pleasant duty to acknowledge the cooperation of Dr. V. P. Egoyan (Krasnodar), Prof. G. Y. Krimholz (Leningrad), Dr. I. A. Mihaylova (Moscow), Dr. B. T. Yanin (Moscow), Dr. I. G. Sazanova (Moscow), Academician J. Fülöp (Budapest), Dr. R. Busnardo (Lyon), Prof. M. Durand Delga (Toulouse), Prof. Ch. Pomerol (Paris), Dr. J.-P. Thieuloy (Grenoble), Dr. R. Casey (London), Dr. P. Rawson (London) and Prof. J. Wiedmann (Tübingen).

The author also remembers with gratitude the joint work on Lower Cretaceous terrains in Algeria with the colleagues Dr. D. Kožuharov, Dr. Tz. Tzankov, Dr. P. Tchoumatchenco, Dr. Z. Nikolov, Dr. N. Zidarov and Mr. I. Slavov. Research in France was facilitated by the colleagues Prof. M. Durand Delga, Prof. P. Rat, Dr. R. Busnardo, Dr. J.-P. Thieuloy, Dr. G. le Hégarat, Dr. G. Thomel, Dr. J.-P. Masse, Prof. S. Fabre-Taxy, Prof. J. Sornay, Prof. Ch. Pomerol; in Switzerland — by Prof. J. Remane, Dr. H.-P. Funk, Mr. M. Gazay, Mr. M. Lanterno; in Hungary — by Academician J. Fülöp: in Czechoslovakia — by Dr. Z. Roth; in Poland — by Dr. F. Szymakowska; in Romania — by Prof. L. Contescu, Prof. D. Patrulius and Prof. G. Raileanu.

The author is particularly obliged to many Soviet specialists who not only shared their knowledge and experience, but also provided the opportunity for him to work on Lower Cretaceous sections in the southern regions of the USSR. In 1960 the author had the privilege of being member for six months of the Complex Southern Geological Expedition of the Academy of Sciences of the USSR, which worked in the Crimea, in the Caucasus and in the southern periphery of the Russian Platform. Deep gratitude and respect is due to the late Prof. V. P. Rentgarten, to Prof. N. P. Luppov and Prof. V. V. Drushchitz for providing information on the problems of Lower Cretaceous stratigraphy in the USSR.

The author is grateful especially to Dr. N. Ruskova and Dr. I. Sapunov for reading the manuscript of the book and for many good suggestions.

The completion of the present work would have been impossible without the assistance of my colleagues from the Department of Palaeontology at Sofia University. Mrs. N. Motekova and Mrs. M. Kehajova offered valuable assistance in compiling the bibliography. Mrs. E. Džonžurova has drawn most of the figures, Mrs. C. Duškova has typed parts of the manuscript. Mr. A. Vitanov facilitated the settlement of a number of technical matters.

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Sofia, October 1984

Part One

INTRODUCTION

I. GENERAL REMARKS ABOUT THE LOWER CRETACEOUS

1. NOMENCLATURE

The Cretaceous System was differentiated for the first time by Omalius d'Halloy in 1822, in order to unify a complex of beds situated in the upper part of the Mesozoic Erathem in the Paris Basin. These beds are formed of chalk with tuffs, sandstones, marls and clays, and they comprise a section of the continental equivalents of the Berriasian Stage to the white chalk of the Senonian inclusive.

Later this Cretaceous ensemble was subdivided into a number of stages from which, if we exclude the various synonyms and homonyms, the following stage terms are in current use today: Berriasian, Valanginian, Hauterivian, Barremian, Aptian, Albian, Cenomanian, Turonian, Coniasian, Santonian, Campanian, Maastrichtian and Danian. At the end of the 19th and at the beginning of the 20th century different authors proposed these stages to be grouped in two or three series. Thus, De Lapparent (1883, 1906) divided the Cretaceous System into two: Lower or Infra-Cretaceous which comprises the ensemble from the Berriasian to the Albian Stages included, and Upper Cretaceous or Cretaceous sensu stricto for the sequence from the Cenomanian to the Senonian included. This subdivision of the Cretaceous System has been accepted by most specialists, because it corresponds best to the law-governed regularities in the vertical distribution of ammonite faunas in Cretaceous rocks. The division was officially recognized by the Third International Congress of Geology in Berlin (1885).

In 1911 E. Haug proposed a new subdivision of the Cretaceous System into three series: Eocretaceous or Neocomian (Eocrétacé ou Néocomien) comprising from the Valanginian to the Aptian included; Mesocretaceous (Mésocrétacé) comprising the Albian, Cenomanian and Turonian; Neocretaceous (Néocrétacé ou Sénonien) for the sequence from the Coniasian to the Danian included (in modern classifications of the Phanerozoic Danian beds are included in the Tertiary). This classification, however, has few adherents and it is currently very seldom used. There also exists another grouping of the stages in the Mesocretaceous, to which some authors attribute only the Albian and the Cenomanian.

Terms such as "Mesocretaceous stratigraphy", "Mesocretaceous events", etc., are often used in recent literature, although there is no conventionally accepted concept of Mesocretaceous.

2. BOUNDARIES OF THE LOWER CRETACEOUS

In the present monograph the Lower Cretaceous is considered to be the series which comprises approximately the lower half of the Cretaceous System. It includes the beds formed during the Early Cretaceous, in which there is a chain of ammonite successions from the Berriasian (*Pseudosubplanites grandis* Zone) to the Albian (*Stoliczkaia dispar* Zone) included at the top. The Lower Cretaceous includes marine, lacustrine-swamp and continental sediments.

2.1. Lower Boundary

One of the most debatable problems in Mesozoic stratigraphy concerns the boundary between the Jurassic and the Cretaceous Systems, i. e. the lower boundary of the Lower Cretaceous. Over the past twenty years this problem has been discussed at several specialized symposia (Lyon, 1963; Lyon—Neuchâtel, 1973; Moscow, 1975; Sofia—Elena, 1977; Munich, 1982). According to a number of authors, the boundary between the Jurassic and the Cretaceous Systems should pass along the boundary between the ammonite zones *Paraulacosphinctes transitorius* (*Malbosiceras chaperi* Subzone in Southeastern France) and *Pseudosubplanites grandis*. In this way the Berriasian is at the basis of the Lower Cretaceous. According to other researchers, the Jurassic System should include the Berriasian as well, while the Cretaceous should start from the Valanginian Stage.

This problem will not be discussed in detail here, because there is abundant relevant literature. Only some essential points will be outlined.

At the end of the Jurassic the progressive differentiation both in the palaeogeographic environment and in the faunistic provinces became very clear (Uhlig, 1911; Arkell, 1956). This objective picture of clearly manifested provincialism at the end of the Jurassic and at the beginning of the Cretaceous Period is reflected in the definitions of the stages during this interval, resulting in numerous difficulties in the correlation and synchronization of the sediments from the different provinces. Therefore, there exist two parallel stratigraphic classifications of the boundary beds between the two systems in the Tethys and Boreal Realms (Arkell, 1956). The problem is further complicated also by the circumstance that in a number of regions there exist continental formations at the Jurassic-Cretaceous (Purbeckian-Wealdian) boundary.

On the basis of the evolution of the ammonite faunas and of some intrinsic trends in the geological development of the Tethys (Arkell, 1956; Nikolov, 1967; 1982; Sapunov, 1977; Hallam, 1969; Ager, 1981), the boundary between the *Paraulacosphinctes transitorius* Zone (*M. chaperi* Subzone) below and the *Pseudosubplanites grandis* Zone above is assumed to be the boundary between the Jurassic and the Cretaceous Systems, i. e. the lower boundary of the Lower Cretaceous.

2.2. Upper Boundary

The upper boundary of the Lower Cretaceous coincides with the boundary between the standard ammonite zones of *Stoliczkaia dispar* below and *Mantelliceras mantelli* above.

2.3. Radiometric Data

Numerous analyses of radiometric data about the Early Cretaceous have been published over the past 25 years (Kulp, 1961; Casey, 1964; Nachev, Lilov, 1975; Van Hinte, 1976; Harland et al., 1982, and others).

Kulp (1961) elaborated a radiometric scale of the Cretaceous, which was subsequently specified by a number of authors.

Table 1

Radiometric Data for the Lower Cretaceous (after Полевая et al., 1960; Casey, 1964; Nachev, Lilov, 1975)

Locality and formation	Stage / Substage	Mineral	Age (m. y.)
Fore-Caucasus (marls)	Albian	glauconite	119
North Caucasus, Bolshaya Laba river (marls)	Albian	glauconite	100
Fore-Caucasus, Belaya river (marls)	Albian	glauconite	125
Caucasus, Bacsan river (marls)	Aptian	glauconite	107
Malo Peštene, NW Bulgaria (Malo Peštene Formation)	Albian	glauconite	100
Sanadinovo, Northern Bulgaria (Svištov Formation)	Albian	glauconite	105
Sanadinovo, Northern Bulgaria (Svištov Formation)	Albian	glauconite	106
Sprucfield, Alberta (Can.) (Manville Formation)	Middle Albian	glauconite	108
Salzgitter, W. Germany	Albian-Aptian	glauconite	102
La Grulla, Northern Baja Calif, Mexico (granodiorite)	?Albian-Aptian	monazite	115, 99
North Caucasus, Bolshaya Laba river (marls)	Aptian	glauconite	100
North Caucasus, Bolshaya Laba river (marls)	Aptian	glauconite	103
Churt, Surrey, England (Lower Greensand)	Middle Aptian (Gargasian)	glauconite	110
Brook, Surrey, England (Lower Greensand)	Lower Aptian	glauconite	115
Ingluri river, Georgia, USSR	Barremian	glauconite	89
Speeton, Yorks., England (Speeton Clay)	Barremian	glauconite	109
Razgrad, Northern Bulgaria (Razgrad Formation)	Barremian	glauconite	124
Razgrad, Northern Bulgaria (Razgrad Formation)	Barremian	glauconite	125
Trăstenik, Northern Bulgaria (Razgrad Formation)	Barremian	glauconite	126
Teke Dere, Šumen, NE Bulgaria (Razgrad Formation)	Hauterivian	glauconite	125
Teke Dere, Šumen, NE Bulgaria (Razgrad Formation)	Hauterivian	glauconite	122
Stojan Mihajlovski, NE Bulgaria (Razgrad Formation)	Hauterivian	glauconite	127
Speeton, Yorks., England (Speeton Clay)	Hauterivian	glauconite	114
Khabarovsk, USSR (porhyry)	"Neocomian"	glauconite	112
Lenin Hills, Moscow	"Neocomian"	glauconite	131
Norfolk, England	Rjasanian	glauconite	131
Armenia, USSR (granitoids)	"Post-Jurassic-pre-Cenomanian"	biotite	121
Magadan, USSR (gabro-diorite)	"Jurassic-Cretaceous boundary"	biotite	132,136

The geochronological scale of Casey (1964) is theoretical and it postulates equal duration of the different ages in the Cretaceous. The extreme complexity of the geological processes and phenomena forming the geological chronology is well known. There is every reason to assume that the natural geochronology of the Early Cretaceous includes ages with different duration, though the difference may not be very great. However, the ages in the Early Cretaceous could not have been at any rate of equal duration. In this respect the analysis of Harland et al. (1982) deserves attention, because both their radiometric data and their interpretation are most feasible (Table 1).

Table 2

The Early Cretaceous Time Scale

Epoch	Age	Boundary and duration in m. y.		
		after Casey, 1964	after Van Hinte, 1976	after Harland et al., 1982
Late Cretaceous	Cenomanian	6	8	97.5
		100	100	
Early Cretaceous	Albian	6	8	15.5
		106	K_1^{Alb}	
	Aptian	6	108	
			7	K_1^{Alb}
		112	K_1^{Apt}	113
	Barremian	6	115	6
		118	6	K_1^{Apt}
			K_1^{B}	119
	Hauterivian	6	121	
		124	5 K_1^{H}	6 K_1^{B}
				125
	Valanginian	6	126	
			5 K_1^{V}	6 K_1^{H}
		130	131	131
	Berriasian	6	4 K_1^{Ber}	
			135	7 K_1^{V}
		136		138
Late Jurassic	Tithonian			6 K_1^{Ber}
				144

According to the different authors, the duration of the Early Cretaceous is between 36 and 46 million years. The average duration of the Early Cretaceous is about 6 million years, the maximum duration being 15.5 million years (for the Albian Age).

Irrespective of some difficulties connected with the application of radiometric methods, they define along general lines the time interval of the Early Cretaceous and provide data for a number of interpretations. For example, according to the studies of Polevaya et al. (Полевая et al., 1960), in the section of the Lower Cretaceous along the Bolshaya Laba river the glauconite from two samples (samples 2603 and VIII) is divided by a marl formation about 300 m thick. These samples differ by 3 million years in age, which suggests sedimentation rate of about 0.1 mm/year.

N a c h e v, L i l o v (1975) have obtained interesting data about the Lower Cretaceous in Bulgaria. On the basis of K-Ar determinations in glauconites, these authors have determined the absolute age of Lower Cretaceous rocks from several main sections in Northern Bulgaria. The results obtained are comparable with analyses made in other countries. There is particularly precise coincidence for the Albian glauconites, whereas for the Barremian and partly for the Hauterivian, the absolute ages according to glauconite are considerably greater compared with averaged data (Table 2).

According to the Commission for the Absolute Age of Geological Formations at the Academy of Sciences of the USSR, the Jurassic-Cretaceous boundary is dated to be 137 $\pm$ 5 million years using the K-Ar method, the Albian-Cenomanian boundary being 105 $\pm$ 5 million years.

3. MATERIAL

The material serving as the basis of the present work has been gathered in the course of the author's work for more than 25 years on the stratigraphy of the Lower Cretaceous in Bulgaria (since the beginning of 1957).

In order to solve the stratigraphic problems and to create a modern basis for the Lower Cretaceous stratigraphy, it was necessary to build the lithostratigraphy of the rock complexes related to the Lower Cretaceous in Bulgaria, and to study the ammonite associations and their successions in Lower Cretaceous sections in the country. The study of other groups of organisms by different researchers started after 1965. This gave grounds for a complex biostratigraphy of the Lower Cretaceous.

During the 1960-1982 period the author had the opportunity to travel to the USSR (1960, 1973, 1978), Romania (1964), Czechoslovakia (1957, 1980), Hungary (1972, 1978), Algeria (1972), France (1968, 1974, 1982), Italy (1974), Greece (1977), Switzerland (1979), Poland (1979) and Yugoslavia (1982), where extensive material on the development of the Lower Cretaceous was collected, as well as fossils from various groups of organisms (mainly ammonites).

Extensive literature has been used in the regional stratigraphic characterization of the Lower Cretaceous, comprising all major publications on the stratigraphy of this series.

II. STAGES, SUBSTAGES AND BIOSTRATIGRAPHIC ZONES IN THE LOWER CRETACEOUS

1. GENERAL REMARKS

The differentiation of the Lower Cretaceous into stages was achieved around the mid-19th century (1840-1847) in France and Switzerland. It is connected with the names of many outstanding scientists, such as A. d'Orbigny, H. Coquand, E. Desor and E. Renevier, who defined all stage terms of the series used. These difinitions were based on sections of marine sediments developed in the southeastern part of the Paris Basin, in Southeastern France and in Western Switzerland. The Aptian, Albian, Valanginian, Barremian, Berriasian and Hauterivian Stages were successively differentiated. However, not all of these units received a clear definition and completely satisfactory differentiation; some of them were based on sections of shallow-water sea sediments, which created difficulties in their correlation with deep-sea ammonite-bearing deposits. Later this resulted in different interpretations of the already defined stages and led to the appearance of many new names which are synonyms or homonyms of well-known stage terms.

Stratigraphic practice has substantiated the global development of the above-indicated stages, which correspond to the main phases in the development of the ammonite successions in the Lower Cretaceous. These stages were later divided into substages, and after 1890 the respective ammonite zones were defined in them. The 1890-1913 period is characterized precisely as the time when the foundations were laid for the ammonite zonal differentiation of the Lower Cretaceous in the type region of its stages.

In stratigraphic research we should be free from the hypnosis of the stratotypes, but nevertheless we should bear in mind their significance for the stability of the nomenclature. The revisionist spirit of every new generation is well known, but the strife for constant innovations threatens stability in stratigraphy. This is why, the existence of "reference standards", such as the stratotypes, is an essential prerequisite for the development of stratigraphy.

2. GENERAL CHARACTERISTIC OF THE STAGES

2.1. Berriasian

The stage term Berriasian was created by C o q u a n d (1871) to define the deep-sea sediments at the base of the Cretaceous System in Southeastern France, previously designated as "couches de Berrias à *Terebratula diphyoides*" or "couches à ciment".

The stratotype of the Berriasian is found to the north of Berrias village, Ardèche (Southeastern France), from where P i c t e t (1867) described the classical fauna in text and figures. Pictet's opinion was clearly formulated and he definitely emphasized that the fauna in the Berrias area belongs to the base of the Cretaceous System.

Before defining the Berriasian Stage, Coquand repeatedly used expressions such as "couches de Berrias", "faune de Berrias", etc., finally stating his opinion as follows: "ammonite-bearing limestones from Berrias and from Gange are in relation with the Valanginian beds with *Natica leviathan,* whose base they form" (C o q u a n d, 1869, p. 102).

The status of the Berriasian has been the object of long and arduous discussions which last to this day. In 1965 the main problems related to this status were discussed (N i k o l o v, 1965b), therefore only some basic aspects will be given here.

Opinions concerning the place of the Berriasian Stage may be united in four groups:

1. The Berriasian belongs to the Cretaceous, and it is a substage of the Valanginian. This is the original view of Pictet and Coquand who differentiated the Berriasian.

2. The Berriasian and the Valanginian are independent stages at the base of the Cretaceous System. This view is founded on the specific ammonite characteristics of the two units, which, although manifesting some common elements, possess clearly differentiable associations.

3. The Berriasian is independent of the Valanginian, but it is transversed by the Jurassic-Cretaceous boundary and its lower part belongs to the Jurassic System. This view is often expressed by the concept "transient stage" or "transient beds", but it is not based on serious scientific arguments.

4. Recently some authors have suggested that the Berriasian should be attributed to the Jurassic System as the upper part of the Tithonian Stage, on the ground

that there exist close ammonite affinities between the Berriasian and the Tithonian. One should not forget, however, that these affinities are not weaker with the Valanginian either. On the other hand, from the viewpoint of the law-governed trends in the ammonite evolution around the Jurassic-Cretaceous boundary, it is more natural to include the *B. jacobi* Zone (= *M. chaperi* Subzone of the *Paraulacosphinctes transitorius* Zone) from the Tithonian in the Berriasian, because this Zone marks the beginning of a very sharp generic and specific renovation in the ammonite content.

The Berriasian has been the object of numerous detailed studies, among which notably the work of Le Hégarat (1973) who created the modern ammonite zonal pattern of the Berriasian Stage.

2.1.1. Biostratigraphic Zones

Kilian (1895) laid the foundations of ammonite zoning of the Berriasian. Today, parallel with the ammonite zonal scheme, zones are also differentiated according to calpionellids and nannofossils. This provides good opportunities for detailed stratigraphy of the stages (Table 3).

Ammonite Zones

P. grandis **Zone.** It is based on the *Pseudosubplanites grandis, P. combesi* and *P. ponticus* Range-zones. Its lower boundary, which is the lower boundary of the Berriasian Stage and accordingly the Jurassic-Cretaceous boundary, is placed by the disappearance of *Paraulacosphinctes, Haploceras, Protacanthodiscus*, and the apearrance and / or mass development of *Pseudosubplanites grandis* (Maz.), *P. combesi* Le Hég., *P. ponticus* (Ret.), *P. lorioli* (Zitt.), *P. berriasiensis* Le Hég., *P. euxinus* (Ret.), *Parapalassiceras bochianensis* Le Hég., *P. paramacilentus* (Maz.).

T. occitanica **Zone.** It is based on the *Tirnovella* Acme-zone, accompanied by the mass development of *Delphinella, Berriasella, Dalmasiceras* (*Elenaella*). Its lower boundary is marked by the disappearance of *Pseudosubplanites* (*P.*) and *Parapallasiceras*, and by the appearance of *T. occitanica, J. subalpina* and *Neocosmoceras*.

The following ammonites are particularly characteristic of the *T. occitanica* Zone: *Pseudosubplanites* (*H.*) *paramacilentus* (Maz.), *B.* (*B.*) *privasensis* (Pict.), *Malbosiceras stephanovi* Nik., *T. subalpina* (Maz.), *T. occitanica* (Pict.), *Delphinella sevenieri* Le Hég., *Jabronella* (*E.*) *subisaris* (Maz.).

Le Hégarat (1973) differentiated three subzones in this zone: *T. subalpina, B. privasensis* and *D. dalmasi*, which are well characterized, but have been identified so far only in France and Bulgaria, where Berriasian sediments are particularly rich in ammonites.

F. boissieri **Zone.** It is based on the *Fauriella boissieri* Range-zone. Its lower boundary is marked by the appearance of *F. boissieri, Berriasella* (*B.*), *B.* (*Picteticeras*), *Jabronella, Neocosmoceras* and *Euthymiceras*.

The zone is characterized by the following species: *F. boissieri* (Pict.), *F. rarefurcata* (Pict.), *F. gallica* (Maz.), *F. simplicicostata* (Maz.), *B.* (*B.*) *calisto* (d'Orb.), *B.* (*P.*) *picteti* (Kil.), *B.* (*P.*) *moesica* (Nik., Mand.), *B. (Str.) tzankovi* Nik., Mand., *Tirnovella alpillensis (Maz.), Neocosmoceras sayni* (Sim.), *Malbosiceras paramimounum* (Maz.), *Euthymiceras euthimi* (Pict.).

Three subzones are differentiated in the zone: *M. paramimounum, B.* (*P.*) *picteti* and *B.* (*B.*) *calisto*, which are characterized very comprehensively in France and in Bulgaria (Le Hégarat, 1973; Nikolov, 1982).

Table 3

Biostratigraphic Zones in the Berriasian and the Valanginian (based on different authors)

Stage		Ammonite (after different authors)		Calpionellids (after different authors)			Nannofossils (after Thierstein, 1975)	Foraminifera (after Busnardo et al., 1979)
Valanginian	Upper	*S. verrucosum*	*S. verrucosum*				*Calcicalathina oblongata*	*Lenticulina hauteriviana*
			B. campylotoxus					*Lenticulina busnardoi*
	Lower	*K. roubaudiana*	*T. petransiens*	E		*Calpionellites*		*Lenticulina nodosa nodosa*
			T. otopeta				*Cretarhabdus crenulatus*	
Berriasian		*F. boissieri*	*B. callisto*	D	3	*Calpionellopsis*		
			B. picteti		2			
			M. paramimounum		1			
		T. occitanica	*D. dalmasi*	C		*Calpionella*	*Nannoconus colomi*	
			B. privasensis					
			T. subalpina	B				
		P. grandis					?	
Tithonian	Upper	*P. transitorius*	*M. chaperi* (*B. jacobi*)	A	3	*Crassicollaria*	*Conusphaera mexicana*	
			M. microcanthum		2			
					1			
	Middle					*Chitinoidella*		

Table 4

Calpionellid Zones

Stage		Standard Zones (Roma, 1970)	Remane, 1969		Pop, 1974b-1976		Catalano, Liguori, 1971	Allemann, Grün, Wiedmann, 1975		Trejo, 1980	
Valanginian	Upper				?		?				?
Valanginian	Lower	*Calpionellites*	E		*Calpionellites darderi*					*Tintinnopsella*	*Tintinnopsella carpathica*
											Calpionellites darderi
Berriasian		*Calpionellopsis*	D	3	*Calpionellopsis*	*Lorenziella*	*Calpionellopsis simplex — Calpionellopsis oblonga*	*Calpionellopsis*	*R. dadayi — C. oblonga*		*Remaniella dadayi*
				2		*Calpionellopsis oblonga*			*Calpionellopsis simplex*		*Calpionellopsis oblonga*
											Calpionellopsis simplex
				1		*Calpionellopsis simplex*					*Remaniella cadischiana*
		Calpionella	C		*Calpionella*	*Calpionella elliptica*	*Calpionella elliptica*		*Calpionella elliptica*		*Calpionella elliptica*
			B			*Remaniella*	*Calpionella alpina*		*Calpionella alpina*		*Calpionella*
Tithonian	Upper	*Crassicollaria*	A	3	*Crassicollaria*	*Crassicollaria brevis-parvula*	*Crassicollaria intermedia*				*Crassicollaria*
				2		*Crassicollaria intermedia*					
				1							

Table 5

Nannoplankton Zones in the Lower Cretaceous

Stage	Thierstein, 1973	Manivit, 1971	Worsley, 1971	Cepek, Hay, 1969
Cenomanian	*Eiffellithus turriseiffeli*	*Staurolithites orbicolofenestrus*	*Staurolithites orbicolofenestrus*	*Staurolithites orbicolofenestrus*
Albian	*Eiffellithus turriseiffeli* *Prediscosphaera cretacea* *Parhabdolithus angustus*	*Staurolithites orbicolofenestrus* *Staurolithites matalosus* *Corollithion rhombicum* *Hayesites albiensis* *Parhabdolithus angustus*	*Staurolithites matalosus* *Watznaueria diaphanae*	
Aptian	*Parhabdolithus angustus* *Chiastozgus litterarius*	*Parhabdolithus angustus* *Prediscosphaera columnata*	*Watznaueria diaphanae*	
Barremian	*Micrantholithus hoschulzi* *Lithraphidites bollii*		*Watznaueria diaphanae*	
Hauterivian	*Calcicalathina oblongata* *Cretarhabdus crenulatus*		*Ellipsochiastus quadriserratus*	
Valanginian	*Calcicalathina oblongata* *Cretarhabdus crenulatus*		*Diadorhombus rectus*	
Berriasian	*Nannoconus colomi*		*Nannoconus steinmanni*	

Calpionellid Zones

Calpionellid zoning in the Tithonian-Valanginian interval introduced an essentially new content into biostratigraphy (Tables 3 and 4). The following calpionellid zones are found in this sequence: *Crassicollaria, Calpionella, Calpionellopsis* and *Calpionellites* (Table 4). The Berriasian comprises the upper part of the *Calpionella* Zone (*C. alpina* and *C. elliptica* Subzones) and the lower part of the *Calpionellopsis* Zone. *T. carpathica* Subzone is separated in the upper part of the standard *Calpionella* Zone in the Vocontian trough (Southeastern France) and in Bulgaria, being approximately equivalent to the *C. elliptica* Subzone from the standard scale.

***Calpionella* Zone**. It is based on the *C. alpina* Acme-zone. Its lower boundary is marked by the mass development of *C. alpina* and by the appearance of small and middle-sized spheric forms of this species.

The association of this zone abounds in representatives of genus *Calpionella*, with predominance of *C. alpina* in the lower part, and of *C. elliptica* and *Remaniella cadischiana* in the upper part. The large forms of *Tintinnopsella carpathica* and *T. longa* are characteristic. *Crassicollaria parvula* disappears at the end of the zone (R e m a n e, 1974).

***Calpionellopis* Zone**. It comprises the Berriasian *F. boissieri* Ammonite Zone and the base of the Valanginian *K. roubaudiana* Ammonite Zone (*T. otopeta* Zone according to B u s n a r d o et al., 1979). It is based on the *Calpionellopsis* Range-zone. Its lower boundary is marked by the disappearance of *Calpionella elliptica* and the appearance of *Calpionellopsis simplex,* and later of *C. oblonga* and *Lorenziella hungarica. T. carpathica* also occurs frequently.

Nannoplankton Zones

Nannoplankton successions outline two zones related to the Berriasian (T h i e r s t e i n, 1973) (Table 5).

***N. colomi* Zone**. It is based on the Range-zone of the index species. Its lower boundary is in the upper part of the Tithonian Stage and is traced by the appearance of *N. colomi, N. bronnimanni,* etc. The zone comprises a considerable part of the Berriasian.

The zone is characterized by *Nannoconus colomi* (de L a p p.), *N. bronnimanni* T h i e r s t., *Lithraphidites carniolensis* D e f l., *Polycostella senaria* T h i e r s t., *Cruciellipsis chiasta* (W o r s l.), etc.

***C. crenulatus* Zone**. It is based on the Range-zone of the index species. Its lower boundary is in the upper part of the Berriasian, being determined by the appearance of *C. crenulatus* and *V. stradneri.*

The zone is characterized by *Cretarhabdus crenulatus* B r a m l., M a r t., *Vagalapilla stradneri* R o o d., H a y, B a r n., *Tubodiscus verenae* T h i e r s t., *Reinhardtites fenestratus* (W o r s l.), etc.

The upper part of the zone comprises the base of the Valanginian.

2.2. Valanginian

The Valanginian was differentiated by D e s o r (1853) for the so-called "couches de Valangin" — marine cretaceous beds of neritic type, included between the "Purbeckian" and "marnes d'Hauterive".

The stratotype of the stage is found near the Valangin castle (Germ. Valendis), Dep. Neuchâtel (Switzerland).

The Valanginian near the Valangin castle is related to the following lithostratigraphic units (in descending order):

5. Yellow marls with bryozoans, and marls with *Olcostephanus astieri* and *Saynoceras verrucosum* (*Astieria*-Schicht=couches de Villers);
4. Reddish limestones with *T. thurmanni* ("calcaires roux d'Auberson");

Table 6

Concurrent-Range-Zones in Valanginian of Southeastern France (after Busnardo et al., 1979)

Substage	Concurrent-Range-Zones				
	Ammonites	Foraminifera	Ostracods	Calpionellids	Nannofossils
Upper Valanginian	*Teschenites callidiscus*	*Haplophragmoides vocontianus*	*Tethysia chabrensis inflata*		*Calcicalathina oblongata*
	Himantoceras trinodosum	*Lenticulina eichenbergi*			
	Saynoceras verrucosum	*Lenticulina hauteriviana*			
Lower Valanginian	*Busnardoites campylotoxus*	*Lenticulina busnardoi*	*Tethysia chabrensis chabrensis*	... *Calpionellites darderi*	
	Thurmanniceras pertransiens	*Lenticulina nodosa nodosa*		*Lorenziella* ... *hungarica*	*Cretarhabdus crenulatus*
	Thurmanniceras otopeta			... *Calpionellopsis oblonga*	

3. Blueish and yellowish marls with spongia and brachiopods (marnes d'Arzier);

2. Zoogenic limestones with *Natica leviathan* and *Nerinea* (marbre batard);

1. Grey marls and oolitic limestones with *Toxaster granosus*, bivalvs and gastropods (Mergel und Kalkzone).

Only the upper part of this formation belongs to the Valanginian, the lower part being Berriasian.

Ammonites occur very seldom in the stratotype of the Valanginian. Therefore, in order to facilitate correlation, B u s n a r d o et al. (1979) characterized in detail the so-called hypostratotype of the Valanginian at Angles and at Barret-le-Bas (Southeastern France). In this region the Valanginian is connected with pelagic deposits containing many ammonites, calpionellids, belemnites, ostracods, foraminifera and nannofossils (Table 6).

On the basis of the successions in this section, B u s n a r d o et al. (1979) identified eight ammonite zones with twenty subzones, as well as zones according to foraminifera, ostracods, calpionellids and nannoflora.

The ammonite zones found in the so-called hypostratotype of the Valanginian are of local significance. Some of the zones are based on species and/or associations which are more widespread in other countries. For example, the appearance of *Thurmanniceras pertransiens* (S a y n) in Valanginian sections in Bulgaria marks the base of the Valanginian. *Busnardoites campylotoxus* (U h l.) and *Saynoceras verrucosum* (d'O r b.), which are given as index species for the middle zones of the Valanginian, are widespread in the upper part of the stage in Bulgaria.

2.2.1. *Substages*

The Valanginian is subdivided into two substages. The differentiation is based on the ammonite distribution. The Lower Valanginian is characterized by the mass propagation of the genera *Kilianella, Thurmanniceras* and *Sarasinella*, which are less represented in the Upper Valanginian and have sharply changed species composition. Ammonite genera *Neocomites, Olcostephanus, Bochianites, Saynoceras, Luppovella, Busnardoites* and *Neohoploceras* are extensively represented in the Upper Valanginian.

2.2.2. *Biostratigraphic Zones*

Ammonite Zones

Two zones should be accepted as standard zones in the Valanginian. In some regions the space of this stage may be subdivided into more zones, which, however, have limited distribution.

The Lyon Colloquium (1963) adopted two standard zones of the Valanginian: lower — *Kilianella roubaudiana* Zone, and upper — *Saynoceras verrucosum* Zone, which correspond to the Lower and Upper Valanginian, respectively.

***K. roubaudiana* Zone.** It is based on the Range-zone of *Kilianella roubaudiana.* Its lower boundary is marked by the disappearance of *Berriasella, Fauriella, Tirnovella,* and by the appearance of *Kilianella, Thurmanniceras* and *Neocomites.*

The zone is characterized by *K. roubaudiana* (d'O r b.), *K. lucensis* (S a y n), *K. ischnotera* (S a y n), *Thurmanniceras thurmanni* (P i c t., C a m p.), *T. pertransiens* (S a y n), *T. salientinum* (S a y n), *T. crassicostatum* N i k., *T. otopeta* T h i e u l., *Clavithurmannia foraticostata* T h i e u l., *Sarasinella trezanensis* (L o r y), *S. eucyrta* (S a y n), *S. walkeri* (U h l.), *Neocomites beaumugnensis* S a y n and *Spiticeras* (*K.*) *gratianopolitense* D j a n.

***S. verrucosum* Zone.** It is based on the Range-zones of *Saynoceras* and many species of *Thurmanniceras, Busnardoites* and *Neocomites*. The lower boundary is determined by the disappearance of *K. roubaudiana, K. pertransiens* and *Sarasinella* spp., and by the appearance of *Saynoceras verrucosum*.

The zone is characterized by *Saynoceras verrucosum* (d'O r b.), *Luppovella superba* (S a y n), *Busnardoites campylotoxus* (U h l.), *B. subcampylotoxus* N i k., *B. makariopolskii* N i k., *Himantoceras trinodosum* T h i e u l. and *Teschenites callidiscus* T h i e u l.

Calpionellid Zones

***Calpionellopsis* Zone.** Only the uppermost part of this zone belongs to the Valanginian.

***Calpionellites* Zone.** It is based on the Range-zone of the index genus. Its lower boundary is marked by the appearance of *C. darderi*. Another characteristic form is *C. coronata*. *T. carpathica* also occurs frequently. Gradual impoverishment of calpionellids takes place in this zone.

Ostracoda Zones

In the pelagic development of the Valanginian D o n z e (1958) has found successions of ostracods which indicate the *Tethysia chabrensis chabrensis* and *T. chabrensis inflata* Zones which correspond to the Lower and Upper Valanginian, respectively.

B a r t e n s t e i n and B r a n d (1951) have demonstrated the possibility to differentiate three ostracod zones in the Valanginian in the northwestern part of the Federal Republic of Germany. Evidently, the study of ostracods may contribute greatly to Lower Cretaceous stratigraphy.

Foraminifera Zones

Foraminifera manifest clear successions, especially in deeper marine facies. In pelagic facies from the peripheral Alpine Zone in France, M o u l l a d e has differentiated five foraminifera zones: *Lenticulina nodosa nodosa, L. busnardoi, L. hauteriviana, L. eichenbergi* and *Haplophragmoides vocontianus* (Table 6).

It seems, however, that the foraminifera zones connected with the Valanginian in the Mediterranean Region are not more than four, as indicated for the first time by S i g a l (1977). For the time being, three zones are well identified:

***L. guttata* Zone.** It is based on the Acme-zone of the index species. Its lower boundary is determined by the appearance of *Lenticulina guttata* D a m. It corresponds to a considerable range of the Lower Valanginian.

***L. busnardoi* Zone.** It is based on the Acme-zone of the index species, whose appearance marks the lower boundary of the zone. It comprises the upper part of the Lower Valanginian and the base of the Upper Valanginian (including the *L. hauteriviana* Zone of M o u l l a d e).

***L. gr. eichenbergi* Zone.** It is based on the Acme-zone of *L. gr. eichenbergi*. This zone does not seem to be well substantiated and therefore it should be considered as one zone together with the *L. ouachensis bartensteini* Zone, because they jointly outline better a common zone based on the concurrent-range-zones of several frequently occurring species, such as: *L. gr. eichenbergi* B a r t., B r a n d, *L. ouachensis bartensteini* M o u l l., *Dorothia hauteriviana* M o u l l., *Coscinoconus* (*Tr.*) *alpina* L e u p., *C.* (*Tr.*) *elongata* L e u p., *Quinqueloculina antiqua* F r a n k e, *Patellina subcretacea* C u s h., A l e x., etc.

Nannoplankton Zones

Recently rich associations of nannoplankton microflora have been found among Lower Cretaceous sediments. This made it possible for T h i e r s t e i n (1973) and M a n i v i t (in B u s n a r d o et al., 1979) to distinguish two nannoplankton zones in the Valanginian: *Cretarhabdus crenulatus* and *Calcicalathina oblongata* (Tables 5 and 6).

C. oblongata **Zone**. It is based on the Range-zone of the index species. Its lower boundary passes in the upper part of the Lower Valanginian, determined bilaterally. The upper part of this zone comprises the base of the Hauterivian.

The zone is characterized by *Calcicalathina oblongata* (W o r s l.), *Micula infracretacea* T h i e r s t., *Podorhabdus dietzmanni* (R e i n h.), *Nannoconus bucheri* B r o n n., *Zygodiscus diplogrammus* (D e f l., F e r t.), etc.

The nannoplankton microflora is a very promising fossil group for biostratigraphy (Table 6).

2.3. Hauterivian

The Hauterivian was differentiated by R e n e v i e r (1874) who defined it as follows: "I introduce the term Hauterivian ('marnes d'Hauterive') in order to define the stage usually referred to as Neocomian or Middle Neocomian in Switzerland."

The stratotype of the Hauterivian is found at Hauterive — Mail, in the northeastern part of Neuchâtel railway station. The outcrop of this section is rather obscure today, therefore the characterization of the stage in its type region was complemented by H a e f e l i et al. (1965) with several auxiliary sections at Landeron, Twan and Russel.

According to the revision introduced by H a f e l i et al. (1965), in its stratotype region the Hauterivian includes the following lithostratigraphic units (in descending order):

4. Pierre-jaune-zone (=Pierre-jaune de Neuchâtel of R e n e v i e r).
3. Margel-und-Kalk-Zone } (=zone marnocalcaire of B a u m b e r g e r,
2. Knollenmergel-Zone } M o u l i n 1898).
1. Mergel-Zone (=Marnes d'Hauterive of R e n e v i e r).

Owing to B a u m b e r g e r (1903-1910), many Hauterivian ammonites are known from the Neuchâtel region, but they originate almost exclusively from the lower part of the stage. The upper part of the Hauterivian is not well characterized palaeontologically in the type region. Moreover, the neritic facies of Hauterivian sediments in the type region of the stage contain facies-determined faunistic successions, which complicate the correlation with other regions. Therefore, as a whole, the foundations of the detailed stratigraphy of the Hauterivian were laid with the investigation of ammonite successions in the Vocontian trough (Southeastern France).

2.3.1. Substages

The law-governed trends in the evolution of the faunas, especially of ammonites, permits the division of the Hauterivian into two substages: Lower and Upper Hauterivian.

The Lower Hauterivian is distinguished from the Valanginian by the disappearance of *Thurmanniceras, Busnardoites, Sarasinella, Saynoceras* and *Luppovella,* as well as by the appearance of *Crioceratites* and *Acanthodiscus.* It is characterized by predominance of different species from the genera *Acanthodiscus, Crioceratites, Lyticoceras, Distoloceras, Leopoldia, Olcostephanus, Eleniceras, Spitidiscus,* etc.

The Upper Hauterivian is poorer in ammonites. It is characterized by the development of *Balearites, Crioceratites, Subsaynella* and *Pseudothurmannia, Acrioceras, Astieridiscus, Plesiospitidiscus, Phyllopachiceras,* etc. appear.

In addition to the ammonites, the Hauterivian is also characterized by many belemnites belonging to the genera *Hibolites, Duvalia* and *Pseudobelus.* The first representatives of *Curtohibolites* appear in the Upper Hauterivian.

2.3.2. Biostratigraphic Zones

The biostratigraphic differentiation of the Hauterivian is difficult due to the absence of successions manifesting wide spatial stability.

Ammonite Zones

K i l i a n, L o r y, P a q u i e r and S a y n started the ammonite zoning in Southeastern France. On the basis of their studies the following ammonite zonal scheme is proposed (in descending order): *Pseudothurmannia angulicostata* Zone, *Subsaynella sayni* Zone, *Crioceratites duvali* Zone and *Acanthodiscus radiatus* Zone.

A new zone at the base of the stage, referred to as *Lyticoceras* l. s. sp. Zone, was defined in the decisions adopted at the Lyon Colloquium (1963). French stratigraphers substantiated this decision with an abundant *Lyticoceras* population in which there are some rare primitive *Crioceratites* which define the Hauterivian. The differentiation of this "zone" cannot be well substantiated due to the fact that joint finds of *Lyticoceras* and *Acanthodiscus radiatus* are known from a number of localities in the Mediterranean Region (in France included).

M o u l l a d e and T h i e u l o y (1967) distinguished the following ammonite zones in the Hauterivian of the Vocontian trough: *A. radiatus, L. castelanensis, C. duvali-loryi, O. jeannoti, "N" nodosoplicatus, S. sayni — C. duvali, P. ligatus, P. angulicostata.* These ammonite zones are divided by two biointerval zones of the type of barren interzones. This shows that the ammonite zones mentioned by M o u l l a d e and T h i e u l o y are of local character (local range-zones). Similar are also the zones in the Hauterivian of the Western Balkanides, characterized in detail by M a n d o v (М а н д о в, 1976).

Although the ammonite zonal standard of the Hauterivian needs further specifications, it seems that the differentiation of four zones in this stage is most substantiated (Table 7).

***A. radiatus* Zone.** This biostratigraphic unit is based on the Range-overlap-zones of *A. radiatus, S. meneghini* and *L. cryptoceras.* The lower boundary of the zone is determined by the disappearance of the Valanginian ammonite genera and the appearance of *Crioceratites* and *Acanthodiscus radiatus.*

It is characterized by *A. radiatus* (B r.), *A. vaceki* N e u m., U h l., *A. karakaschi* (U h l.), *Leopoldia biassalensis* (K a r.), *L. leopoldi* (d'O r b.), *L. renevieri* B a u m b., *"L." castelanensis* (d'O r b.), *Distoloceras hystrix* (P h.), *Lyticoceras ambligonium* (N e u m., U h l.), *L. cryptoceras, Eleniceras nikolovi* B r., *Lyticoceras* spp., *Olcostephanus* spp. and *Crioceratites* sp.

***O. cultrata* Zone.** It is based on the Acme-zone of the index species. Its lower boundary is determined by the disappearance of *Leopoldia, Acanthodiscus* and *Distoloceras,* as well as by the appearance of *Oostrella cultrata* (d'O r b.), *O. cultratiformis* (U h l.) and *Olcostephanus jeannoti* (d'O r b.).

The zone is characterized by *O. cultrata* (d'O r b.), *O. cultratiformis* (U h l.), *Crioceratites majoricensis majoricensis* (N o l.), *C. bituberculatus* (d'O r b.), *C. matsumotoi* (S a r k.), *Endemoceras enode* T h i e r m., *Eleniceras tschechitevi* B r., *Olcostephanus variegatus* (P a q.), *O. psilostomus* (N e u m., U h l.), *O. rigidus* (B a u m b.), *O. elongatus* (T z.), *Spitidiscus incertus* (d'O r b.), *Aegocrioceras seeleyi* N e u m., U h l., *Speetoniceras versicolor* T r a u t s c h., *S. subinversum* M. P a v l. and *Crioceratites* spp.

***S. sayni* Zone.** It is based on the Acme-zone of the index species. Its lower boundary is determined bilaterally by the disappearance of the characteristic elements for the zonal association of the previous zone and by the appearance of *Subsaynella sayni.*

Table 7

Ammonite Zones in the Hauterivian

<table>
<tr><th>Kilian, Lory, Paquier, Sayn</th><th>Lyon Colloquium, 1963</th><th>Друщиц, Михайлова, 1966</th><th>Moullade, Thieuloy, 1967</th><th>Мандов, 1976</th><th>Nikolov (this book)</th></tr>
<tr><td rowspan="2">Pseudothurmannia angulicostata</td><td rowspan="2">P. angulicostata</td><td rowspan="2">P. angulicostata — Simbirskites decheni</td><td>P. angulicostata</td><td rowspan="2">P. angulicostata</td><td rowspan="2">Pseudothurmannia angulicostata</td></tr>
<tr><td>Plesiospitidiscus ligatus</td></tr>
<tr><td rowspan="2">Subsaynella sayni</td><td rowspan="2">S. sayni</td><td rowspan="2">Craspedodiscus philipsi — Lamelaptychus angulicostatus</td><td>S. sayni — C. duvali duvali</td><td>Crioceratites rodighieri — C. lusitanicus</td><td rowspan="2">Subsaynella sayni</td></tr>
<tr><td>Barren interzone</td><td rowspan="4">Oostrella cultratiformis — Crioceratites loryi</td></tr>
<tr><td rowspan="2">Crioceratites duvali</td><td rowspan="2">—</td><td rowspan="2">C. duvali — Speetoniceras versicolor</td><td>"N" nodosoplicatus</td><td rowspan="3">Oostrella cultrata</td></tr>
<tr><td>Olcostephanus jeannoti</td></tr>
<tr><td rowspan="3">Acanthodiscus radiatus</td><td rowspan="2">A. radiatus</td><td rowspan="3">A. radiatus</td><td>C. duvali — C. loryi</td></tr>
<tr><td>Barren interzone</td><td rowspan="2">Spitidiscus meneghini — Lyticoceras</td><td rowspan="2">Acanthodiscus radiatus</td></tr>
<tr><td>Lyticoceras l. s. sp.</td><td>A. radiatus — "Leopoldia" castelanensis</td></tr>
</table>

The zone is characterized by *S. sayni* (P a q.), *Crioceratites rodighieri* D i m., *C. nolani* (K i l.), *C. krenkeli* S a r k., *C. villersianus bituberculatus* (S a r k.), *C. lusitanicus* (C h o f.), *Olcostephanus klaatschi* (W e g n.), *A.* (*Aspinoceras*) *dilatatum* (d'O r b.), *Spitidiscus intermedius* (d'O r b.), *Craspedodiscus philipsi* N e u m., U h l. and *Speetoniceras speetonense* Y o u n g, B i r d.

***P. angulicostata* Zone**. This zone is greatly discussed, probably owing to the distribution of the index species and of some elements having Barremian affinities in its upper part. Its differentiation is based on the range-zones of many *Pseudothurmannia* species. Its lower boundary is marked clearly by the disappearance of *S. sayni* and by the appearance of *Pseudothurmannia*.

The zone is characterized by *P. angulicostata* (d'O r b.), *P. mortilleti* (P i c t., L o r.), *P. catulloi* (P a r.), *P. belimelensis* D i m., *P. biassalensis* D i m., *P. simionescui* S a r k., *Abrytusites julianyi* (H o n. - B a s t i d e), *Crioceratites quenstedti* (O o s t.), *Balearites* spp., *Plesiospitidiscus ligatus* (d'O r b.), *Simbirskites decheni* L a h., *S. umbonatus* L a h., *S. kowalewskii* P a v l. and *Craspedodiscus discofalcatus* L a h.

Foraminifera Zones

Foraminifera are widely represented among Hauterivian sediments, but it is difficult to establish stable marker beds in the successions. It seems that two foraminifera zones may be identified in this stage, based on the concurrent-range-zones (S i g a l, 1965). However, the characterization of these zones still requires considerable specifications.

In 1977 S i g a l distinguished four foraminifera zones in the Hauterivian of the Mediterranean Region: *Haplophragmoides vocontianus* Zone, *Dorothia ouachensis* Zone, *Caucasella gr. hauterivica — kugleri* Zone and *Conorotalites bartensteini* s. str. — *Gavelinella gr. djaffaensis — sigmoicosta* Zone. However, these zones are not substantiated outside the Vocontian trough.

Nannoplankton Zones

The Hauterivian comprises a considerable part of the *Calcicalathina oblongata* Zone which starts with the upper part of the Valanginian and was characterized earlier in the present work (Table 6).

***L. bollii* Zone**. It comprises the upper part of the Hauterivian and the base of the Barremian. The zone is characterized by *Lithraphidites bollii* (T h i e r s t.), *Discorhabdus biradiatus* (W o r s l.), *Cruciellipsis cuvillieri* (D e f l., M a n.), *Bipodorhabdus roeglii* T h i e r s t. and *Calcicanaliculathina oblongata* (W o r s l.).

Dinoflagellates

As indicated by the studies of G. D e f l a n d r e, G. A l b e r t i, A. E i s e n a c h and H. G o c h t (see references in A l b e r t i, 1961), as well as by the unpublished data of L. D o d e k o v a, dinoflagellates outline characterisitic successions which may be used very successfully in biostratigraphy. So far, however, there are no well-defined dinoflagellate zones.

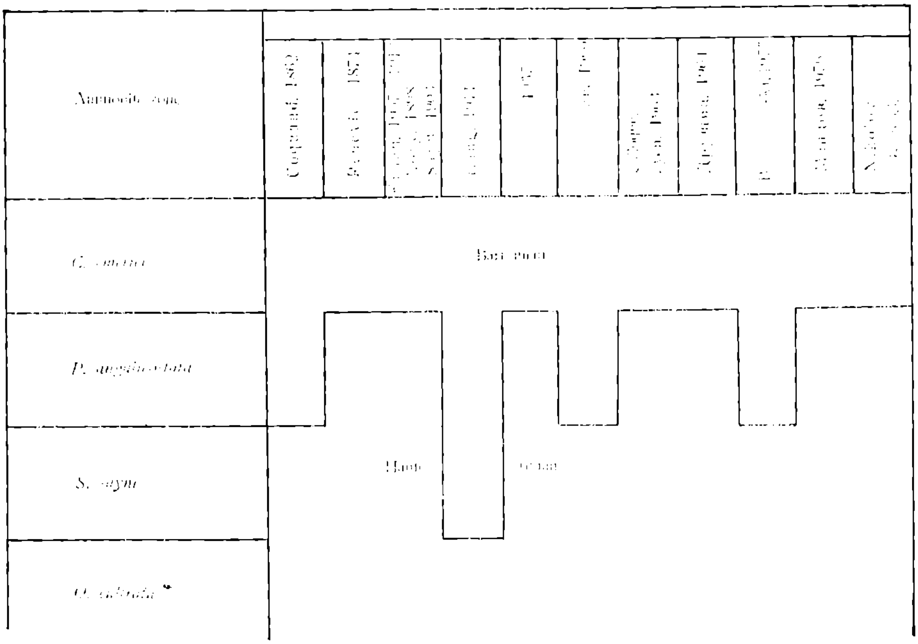
2.4. Barremian

The Barremian was distinguished by C o q u a n d (1862) who did not define it clearly. Moreover, he made a mistake by comparing the Barremian with the "Urgonian" of d'Orbigny. This mistake became later the source of many misunderstandings.

Twelve years later, when R e n e v i e r (1874) differentiated the Hauterivian, he disregarded Coquand's priority and included in the upper part of the new stage beds which had already been referred to the Barremian. Later still, K i l i a n and his followers accepted Renevier's opinion which corresponds better to the intrinsic regularities in the ammonite successions found in Southeastern France

Table 8

The Hauterivian-Barremian Boundary (after various authors)



and specifically studied in detail by Kilian (1888-1895), Lory (1898) and Paquier (1900). In this way the following scheme of the stratigraphy of the Barremian was created:

Upper Barremian — *Heteroceras astierianum* and *Macroscaphites yvani* Zones.

Lower Barremian — *Crioceratites emerici* and *Pulchellia compressissima* Zones.

In this way the lower boundary of the Barremian was marked between the *P. angulicostata* and *C. emerici* Zones, the upper boundary being between the *H. astierianum* and *D. deshayesi* Zones. This situation was accepted by most researchers and was confirmed by the decisions of the Lyon Colloquium (1963).

Coquand named the Barremian after Barrême village (Low Alps, Southeastern France). At present there are no good outcrops of the stage in this region. This is why, Busnardo (1965) studied in detail a very well-exposed section along the road from St. André-les-Alpes to Angles, where he found the following succession: *Crioceratites nolani* — *C. duvali* — *Balearites balearis, Plesiospitidiscus ligatus* — *Pseudothurmannia angulicostata* — *Raspailiceras cassidum* (Hauterivian) — *Holcodiscus kiliani, Barremites vocontius* — *Spitidiscus* — *Barremites difficilis* — *Subpulchellia* — *Pulchellia compressissima* — *Silesites seranonis* — *Hemihoplites feraudi* — *Heteroceras astierianum* — *Macroscaphites* — *Costidiscus* (Barremian) — *Puzosia matheroni* — *Procheloniceras* — *Cheloniceras* (Aptian). There is nothing sensationally new in this sequence, it is known from other sections of the Barremian in the Mediterranean Region as well.

The index species of the two Barremian ammonite zones, which are very characteristic, were unjustifiably changed at the Lyon Colloquium. The argument that

C. emerici has not been found in the neostratotype and that *H. astierianum* is rare, is not substantiated from the viewpoint of biostratigraphic theory.

The lower boundary of the Barremian is very disputable. A number of authors include the *P. angulicostata* in the base of the Barremian (Ренгартен, 1951; Луппов, 1952; Мордвилко, 1960-1962; Эристави, 1960). In Bulgaria this opinion is maintained by Breskovski (1975). The grounds for this view are that in some sections in clayey-carbonate facies from the shelf zone in beds with *P. angulicostata* the first Barremian ammonites appeared (early *Barremites*). In the pelagic facies the successions are clearly differentiated and usually the *P. angulicostata* Zone is characterized by a homogeneous association. However, it is poorer than the synchronous association in the shelf clayey-carbonate facies. Evidently, the difficulties here are objectively conditioned by the factors controlling the ammonite distribution (Table 8).

2.4.1. Substages

On the basis of the intrinsic regularities in the ammonite successions, the Barremian is divided into two substages: Lower and Upper Barremian.

The Lower Barremian is characterized by ammonites from the group of *Crioceratites emerici, Holcodiscus, Haplocrioceras, Acrioceras, Spitidiscus, Salfeldiella, Biasaloceras, Uhligia, Protacrioceras, Anahamulina, Hamulina,* etc.

The Upper Barremian is distinguished by the extensive development of *Barremites, Pseudosaynella, Heteroceras, Imerites, Jaubertites, Karsteniceras, Paraspinoceras, Hamulina, Anahamulina, Pseudohaploceras, Silesites, Pulchellia, Subpulchellia, Carstenia,* etc.

2.4.2. Biostratigraphic Zones

In the Barremian the biostratigraphic zones are identified according to different fossil groups.

Ammonite Zones

There are two standard ammonite zones in the accepted volume of the Barremian, namely: *Crioceratites emerici* and *Heteroceras astierianum* (Table 9).

C. emerici **Zone**. It is based on the Range-zone of the index species. Its lower boundary is marked by the appearance of this species which has ubiquitous distribution.

The main characteristic of the zone is determined by *Crioceratites emerici* Lév., *C. thiollieri* (Ast.), *C. razgradi* (Toula), *Acrioceras tabarelli* (Ast.), *A. silesiacum* (Uhl.), *A. furcatum* (d'Orb.), *Pseudothurmannia pseudomalbosi* (Sar., Schönd.), *P. simionescui* Sar., *Hamulina dissimilis* (d'Orb.), *H. koeneni* Dim., *Holcodiscus perezianus* (d'Orb.), *H. rarecostatus* (Kar.), *H. geronimaeformis* Tz., *H. diversicostatus* (Coq.), *H. sophonisba* (Coq.), *H. caillaudianus* (d'Orb.), *H. ziczac* Kar., *Anahamulina subcylindrica* (d'Orb.), *Barremites difficilis* (d'Orb.), *B. karakaschi* (Sim.), *Spitidiscus seunesi* (Kil.), *S. douvillei* (Nick.) and *Astieridiscus morleti* (Kil.).

H. astierianum **Zone**. It is based on the Concurrent-Range-zones of *Heteroceras astierianum, Pseudosaynella strettostoma, Silesites seranonis* and *B. cassidoides*. Its lower boundary is marked bilaterally by the disappearance of the typical elements of the *C. emerici* and *P. strettostoma*, etc.

The zone is characterized by a very rich association: *H. astierianum* d'Orb., *H. bifurcatum* d'Orb, *Imerites varnensis* Nik., *I. giraudi* Kil., *I. densocostatus* Renng., *Colchidites securiformis* Sim., *C. colchicus* Dj., *C. intermedius* Dj., *Jaubertites dubius* Sark., *Matheronites barremensis* (Uhl.), *M. hammatoptychus*

Table 9

Ammonite Zones in Barremian
(the double line marks the Hauterivian-Barremian boundary)

Kilian, Lory, Raquier, Sayn	Эристави, 1960	Lyon Colloquium, 1963	Друщиц, 1964	Breskowski, 1975	Nikolov (this book)
Heteroceras astierianum — Macroscaphites yvani	*Barremites strettostoma — Imerites giraudi*	*Silesites seranonis*	*H. astierianum — Colchidites securiformis*	*Pseudosaynella strettostoma*	*Heteroceras astierianum*
Crioceratites emerici — Pulchellia compressissima	*Holcodiscus caillaudianus*	*Nicklesia pulchella*	*H. caillaudianus — C. emerici*	*C. emerici*	*Crioceratites emerici*
Pseudothurmannia angulicostata	*P. angulicostata — Craspedodiscus subphilipsi*	*P. angulicostata*	*P. angulicostata — Simbirskites decheni*		*Pseudothurmannia angulicostata*
			Craspedodiscus phillipsi — Lamellaptychus angulicostatus		
Subsaynella sayni	*Speetoniceras inversum — Crioceratites duvali*	*S. sayni*	*C. duvali — Speetoniceras versicolor*	*S. sayni*	*Subsaynella sayni*

(U h l.), *M. soulieri* (M a t h.), *M. ridzewskyi* K a r., *Barremites fegurensis* D i m., *B. muerensis* B r., *Pseudosaynella strettostoma* (U h l.), *Pulchellia hoplitiformis* S a y n, *Silesites seranonis* (d'O r b.), etc.

Foraminifera Zones

G u i l l a u m e and S i g a l (1965) marked for the first time clear foraminifera successions in the Mediterranean development of the Barremian. This stage comprises two foraminifera zones whose boundaries do not coincide exactly with the stage boundaries, though they are very close. Different authors designate them with different index species, and some authors examine them as subzones.

Lower Zone. It is based on the Concurrent-Range-zones of *Lenticulina ouachensis paucistriata* M o u l l., *L. meridiana* B a r t., B e t t., K o v., *L. subaperta* (R e u s s), *Hastigerinella* spp., *Gavelinella sigmoicosta* (D a m.). Its lower boundary is placed bilaterally: by the disappearance of some and by the appearance of other species, especially of *Conorotalites bartensteini* (B e t t.), *Gavelinella sigmoicosta* (D a m.), *Frondicularia inversa* R e u s s, etc.

The main characteristic of this feature is determined by the association of the following species: *Conorotalites bartensteini* (B e t t.), *Gavelinella sigmoicosta* (D a m.), *Frondicularia inversa* R e u s s, *Lenticulina subaperta* (R e u s s), *L. meridiana* B a r t., B e t t., K o v., *L. ouachensis paucistriata* M o u l l., *Astacolus incurvatus* (R e u s s), etc.

Upper Zone. It is based on the Concurrent-Range-zones of *Epistomina caracolla* (R o e m.), *E. hechti* B a r t., B e t t., B o l l i, *Flabellammina alexanderi* C u s h m., *Astacolus scitulus* (B e r t h.). Its lower boundary is marked bilaterally: by the disappearance of some and by the appearance of other species (especially of *F. alexanderi, A. scitilus, Lamarckina lamplughi,* etc.).

The zone is characterized by the association of *Epistomina spinulifera* (R e u s s), *E. hechti* B a r t., B e t t., B o l l i, *Flabellammina rugosa* A l e x., S m., *F. alexanderi* C u s h m., *Lamarckina lamplughi* (S c h e r b.), *Ammomarginulina loricata* L o e b l., T a p p., *Gaudryina borimensis* K o v., *Conorotalites intercedens* (B e t t.), *Astacolus planiusculus* (R e u s s), *A. schloenbachi* (R e u s s), etc.

These foraminifera zones are well manifested in the Barremian of Bulgaria, France, etc. (B a r t e n s t e i n, B e t t e n s t e d t, K o v a t c h e v a, 1971; M o u l l a d e, 1966; K o v a t c h e v a, 1976) (Tables 11 and 12).

Nannoplankton Zones

The Barremian comprises the upper part of the nannoplankton Zone *Lithraphidites bollii*, which was characterized earlier in the present work, and the entire *Micrantholithus hoschulzi* Zone (Table 6).

***M. hoschulzi* Zone.** It is based on the Concurrent-Range-zones of several species. Its lower boundary is marked by the appearance of the index species, and/or *Chiastozygus litterarius* (G o r.), and / or *Rucinolithus irregularis* T h i e r s t.

The association of this zone is very similar to the underlying *L. bollii* Zone, but without *Calcicalathina oblongata* (W o r s l.). *Nannoconus bermudezi* B r o n. occurs seldom, while *N. kamptneri* B r o n. appears in this zone.

2.5. Aptian

This stage was identified by d'O r b i g n y (1840) who used it originally as adjective for defining the beds in the so-called Neocomian in the environs of Apt (Southeastern France). In Prodrome d'O r b i g n y (1850) presented a rather full list of the basic ammonite species which originate from La Bedoule-Cassis and Gargas. The inaccurate definition of d'O r b i g n y gave rise to prolonged discussions about the boundaries of the Aptian.

The lower boundary of the Aptian is marked by clear renovation of ammonite faunas, manifested by the appearance of *Procheloniceras, Ancyloceras, Audouliceras* and *Kutatissites,* as well as a little later by *Cheloniceras, Prodeshayesites* and *Deshayesites.*

2.5.1. Substages

The Aptian is divided into three substages: Lower (Bedoulian), Middle (Gargasian) and Upper (Clansayesian), which have specific ammonite associations.

The Lower Aptian (Bedoulian) was differentiated by a rather general definition of T o u c a s (1888), who defined as stratotype the section at La Bedoule-Cassis (to the east of Marseilles). The present-day range of the substage is much greater than the original definition of T o u c a s, comprising both its Bedoulian and the so-called Rhodanian (the upper part of the Urgonian in Southern Provence). It is characterized by the development of *Procheloniceras, Cheloniceras, Deshayesites, Prodeshayesites, Paradeshayesites, Kutatissites, Dufrenoya, Ancyloceras,* etc.

The Middle Aptian (Gargasian) was determined by K i l i a n (1886) for the marls with pyritized ammonites from the environs of Gargas and Apt (Southeastern France) — "marnes aptiensis" or "marnes de Gargas". It is characterized by *Cheloniceras* (*Epicheloniceras*) spp., *Aconeceras* spp., *Parahoplites, Gargasiceras, Colombiceras, Acanthohoplites, Hamiticeras,* etc. Before the Clansayesian was included in the Aptian, the Gargasian was considered to be the Upper Aptian.

The Upper Aptian (Clansayesian) is the object of discussions to this day owing to its peculiar "buffer" position between two stages and its incomplete original characteristics (Н и к о л о в, 1970).

Clansayesian was defined as a term of the stage group by B r e i s t r o f f e r (1947) for determining the glauconite sands with phosphoritic concretions ("Horizon de Clansayes"), characterized by a rich ammonite association. On its basis, J a c o b (1907) was the first to distinguish and characterize the *Diadochoceras nodosocostatum* Zone.

B r e i s t r o f f e r (1947) divided the Clansayesian into two subzones, only the lower subzone being developed at Clansayes. The upper part of the Clansayesian is characterized according to data from the profile at Algermissen-Wöhrun (C o l l e t, 1907). The complete volume of the Clansayesian was well studied later in a number of countries, especially in the Crimea, the Northern Caucasus and Mangishlak.

A number of authors include to this day the Clansayesian at the base of the Albian. However, the Aptian belonging of the Clansayesian beds is determined by its ammonite characteristics. The relation between Clansayesian ammonite faunas and Gargasian faunas is prominent, as well as their marked difference from Albian faunas. Moreover, the pattern is determined not only by quantitative, but also by qualitative-genetic differences. The most widespread and most characteristic Clansayesian ammonites (*Acanthohoplites, Diadochoceras, Hypacanthoplites, C.* (*Epicheloniceras*) are branches of the unified phylogenic tree of the typical Aptian families Deshayesitidae, Parahoplitidae and the subfamily Cheloniceratinae (Н и к о л о в, 1970).

2.5.2. Biostratigraphic Zones

Ammonite Zone

The Aptian is subdivided into a number of zones by different authors, but it seems to comprise five zones having general importance for the Mediterranean Region (Table 10).

Table 10

Ammonite Zones in Aptian
(the double line marks the upper boundary of the Aptian)

Kilian, 1907-1913	Lyon Colloquim, 1963	Друщиц, 1964	Sornay, 1968	Nikolov (this book)
Douvilleiceras nodosocostatum	*Diadochoceras nodosocostatum*	*Hypacanthoplites jacobi*	*Diadochoceras nodosocostatum*	*Diadochoceras nodosocostatum*
		Acanthohoplites nolani — Diadochoceras nodosocostatum		
Douvilleiceras buxtorfi — D. subnodosocostatum	*Cheloniceras subnodosocostatum*	*Parahoplites melchioris*	*C. subnodosocostatum — C. buxtorfi*	*Cheloniceras subnodosocostatum*
		Cheloniceras subnodosocostatum		
Hoplites furcatus — Oppelia nissus	*Aconeceras nissum*	*Dufrenoya furcata — D. subfurcata*	*A. nissum — D. furcata*	*Aconeceras nissum*
Parahoplites deshayesi	*Deshayesites deshayesi*	*Deshayesites dechyi — D. deshayesi*	*Deshayesites deshayesi*	*Deshayesites deshayesi*
Parahoplites weissi — Douvilleiceras albrechtiaustriae		*Deshayesites weissi — Procheloniceras albrechtiaustriae*		*Procheloniceras pachystephanum*

***P. pachistephanum* Zone.** It is based on the Range-zone of the index species and on the Concurrent-Range-zone of the species of *Kutassites, Ancyloceras* and *Audouliceras*. This zone was noted for the first time by K i l i a n (1907-1913). Its lower boundary, which is also the lower boundary of the stage, is clearly marked.

The zone is characterized by associations from the following species: *Procheloniceras pachistephanum* (U h l.), *P. albrechtiaustriae* (H o h.), *P. sporadicum* R o u c h., *P. pschechense* (L u p.), *Kutatissites simionescui* A v r., *Ancyloceras matheronianum* (d'O r b.), *A. rochi* D i m., *A. manteli* C a s., the first *Deshayesites* from the *weissi* and *dechyi* groups, rare *Colchidites*, etc.

***D. Deshayesi* Zone.** It is based on the Range-zone of the index species and on the Concurrent-Range-zones of a number of species belonging to *Deshayesites, Cheloniceras, Dufrenoya,* etc. Its lower boundary is marked bilaterally by a clear change in the ammonite content, and especially by the mass population explosion of *Deshayesites.*

The zone is characterized by a very rich association: *Deshayesites deshayesi* (L e y m.), *D. terminalis* B o g d., *D. strigosus* C a s., *D. forbesi* C a s., *D. kiliani* C a s., *D. callidiscus* C a s., *D. planus* C a s., *D. gracilis* C a s., *D. grandis* S p a t h, *D. saxbyi, Paradeshayesites tenuicostatus* (K o e n.), *Cheloniceras* (*C.*) *cornuelianum* (d'O r b.), *C.* (*C.*) *crassum* S p a t h, *C.* (*C.*) *kiliani* (K o e n.), *C.* (*C.*) *seminodosum* (S i n z.), *Sanmartinoceras* (*Sinzowia*) *trautscholdi* (S i n z.), *Aconeceras nissoides* (S a r.,) *Prodeshayesites bodei* (K o e n.), *Dufrenoya furcata* (S o w.), *D. formosa* C a s., *D. mackensoni* C a s., etc.

***A. nissum* Zone.** It is based on the Range-zone of the index species and the Concurrent-Range-zones of some species belonging to *Cheloniceras* (*Epicheloniceras*), *Colombiceras* and *Parahoplites*. Its lower boundary is marked clearly by the appearance of *Epicheloniceras* and *Parahoplites.*

The zone is characterized by an association of the following basic species: *Aconeceras nissum* (d'O r b.), *Cheloniceras* (*Epicheloniceras*) *gracile* C a s., *C.* (*E.*) *debile* C a s., *C.* (*E.*) *martinoides* C a s., *C.* (*E.*) *tschernychowi* (S i n z.), *C.* (*E.*) *martini orientalis* (J a c.), *C.* (*E.*) *claudi* C a s., *Colombiceras subpeltoceroides* (S i n z.), *C. subtobleri* (K a s.), *Hamiticeras philadelphium* A n d., *Gargasiceras aptiense* (R o c h), *Dufrenoya* sp., etc.

***C. subnodosocostatum* Zone.** It is based on the Range-zone of the index species and on Concurrent-Range-zones of the species *Gargasiceras, Colombiceras* and *Acanthohoplites*. Its lower boundary is determined by the disappearance of *C.* (*Cheloniceras*), *Aconeceras nissum, Dufrenoya,* as well as by the mass explosion in the populations of *Acanthohoplites* and *Gargasiceras.*

The following species determine most frequently the association of this zone; *Acanthohoplites aschiltensis* (A n t h.), *A. laticostatus* S i n z., *A. subangulicostatus* S i n z., *A. stephanoides* K a s., *A. bigotiincivilis* G l a s and *Parahoplites melchioris* (A n t h.).

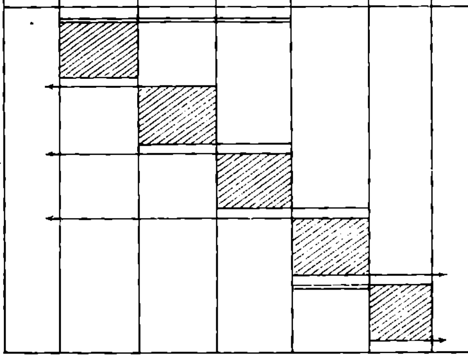
***D. nodosocostatum* Zone.** It is based on the Range-zone of the index species and on the Concurrent-Range-zones of some species belonging to *Acanthohoplites, Hypacanthoplites* and *C.* (*Epicheloniceras*). Its lower boundary is marked bilaterally by the disappearance of the characteristic species from the upper Gargasian ammonite zone, and by the appearance of *Diadochoceras nodosocostatum, Acanthohoplites bigoureti, Hypacanthoplites nolani,* etc.

The zone is characterized by the following association: *Diadochoceras nodosocostatum* (d'O r b.), *D. inaqualis* E g., *Acanthohoplites trautscholdi* S i n z., *A. multispinatus tenuicostatus* S i n z., *A. bigoti bigoti* (S e u n.), *A. abichi* A n t h., *A. nolani* (S e u n.), *A. bigoureti* S e u n., *A. bergeroni* S e u n., *Hypacanthoplites jacobi* C o l l., *H. tscharlokensis* G l a s., *H. nolaniformis* G l a s., *H. compressus* K a s., *C.* (*Epicheloniceras*) *clansayense* (J a c.), etc.

Table 11

The Foraminifera-Zones in the Barremian and Aptian of Northern Bulgaria (after K o v a t c h e v a, 1976)

Lower Cretaceous								Series
Haut.	Barremian		Aptian				Alb.	Stage
Upper	Lower	Upper	Lower	Middle		Upper	Low.	Substage
	[illegible]	[illegible]	*D. deshayesi*	*A. nisum*	*C. subnodosocostatum*	*D. nodosocostatum*		Ammonite-zone
	Georgsdorfensis			*Spinosa*				Foraminifera zone
	Sigmoic.-Georg.	*Bulgar.-Barrem.*	*Djaff.-Colomi*	*Crepid.-Interm.*		*Spin.-Rober.*		Foraminifera-subzone



Triplasia georgsdorfensis
Gavelinella sigmoicosta
Conorboides bulgaricus
Gavelinella barremiana
Marginulinopsis djaffaensis
Epistomina colomi
Planularia crepidularis
Gavelinella intermedia
Saracenaria spinosa
Ticinella roberti

Stratigraphic distribution of the index species

Foraminifera Zones

The foraminifera distribution in the Aptian offers better possibilities for zonal differentiation, compared with the lower stages of the series. Various authors divide the Aptian differently on the basis of foraminifera (M o u l l a d e, 1966; B a r t e n s t e i n, 1979; K o v a t c h e v a, 1976; S i g a l, 1977). The foraminifera successions permit the differentiation of two zones related to the Aptian, with subzones in some countries, which have a more limited distribution (Tables 11 and 12).

Nannoplankton Zones

The Aptian is connected with two nannoplankton zones (T h i e r s t e i n, 1973) (Table 5).

***C. litterarius* Zone.** It is based on the Range-zone of the index species. Its appearance marks the beginning of the zone, which coincides with the lower boundary of the Aptian.

Characteristic association: *Chiastozygus litterarius* (G o r k a), *Rucinolithus irregularis* T h i e r s t., *Rodorhabdus decorus* (D e f l.), *Lithaatrinus septentrionalis* S t r a d n.

***P. angustus* Zone.** It is based on the Range-zone of the index species. Its lower boundary is marked by the appearance of *P. angustus* and / or *L. floralis*. The zone comprises the upper part of the Aptian and part of the Albian.

The zone is characterized by: *Parhabdolithus angustus* (S t r a d n.), *Lithastrinus floralis* S t r a d n., *Flabellites biformis* T h i e r s t., *Corollithion anchylosum* (S t o v.), *Tranolithus gabalus* S t o v., *Cretarhabdus lorieli* G a r t n.

2.6. Albian

The Albian was introduced by d'O r b i g n y (1842), who included in it some lithostratigraphic units developed in the Paris Basin and designated in French and

Table 12

Comparative Table of the Foraminifera Zones in SE France, Bulgaria and Czechoslovakia (after various authors from Kovatcheva, 1976)

Series	Stage	Substage	SE France (after Moullade, 1966) Zones	SE France (after Moullade, 1966) Subzones	N. Bulgaria (after Kovatcheva, 1976) Zones	N. Bulgaria (after Kovatcheva, 1976) Subzones	Czechoslovakia W. Carpathians (after Salaj, Samuel, 1966) Zones	Czechoslovakia W. Carpathians (after Salaj, Samuel, 1966) Subzones
Lower Cretaceous	Aptian	Clansayesian	*bejaouaensis without Pleurostom.*	*O.* aff. *brotzeni without Pleurostomella*	*Spinosa*	*Spinosá — Roberti*	*Hedbergella roberti*	*Haplophragmoides nonioninoides*
				bejaouaensis without O. aff. *brotzeni*				
		Gargasian	*ferreoensis*	*trocoidea—algerianus*		*Crepidularis — Intermedia*		*Epistomina (Brotzenia) charlotae*
				barremiana blowi				*Discorbis wassoewizi*
			cabri					
		Bedoulian	*sigali without eichenbergi*	*sigali — H.* aff. *planispira*	*Georgsdorfensis*	*Djaffaensis — Colomi*	*Planomalina (Globigerinelloides) algerina*	
	Barremian	Upper	*eichenbergi—barremina*	*eichenbergi—aptiensis*		*Bulgaricus — Barremiana*	*Clavihedbergella subcretacea*	
							Planomalina (G.) typica	*Epistomina (Brotzenia) hechti*
		Lower	*sigmoicosta—sigali*	*Clavihedbergella* aff. *simplex*		*Sigmoicosta — Georgsdorfensis*		
				sigmoicosta—sigali without Clavihedbergella	Association of *Lenticulina subaperta, L. macrodisca, E. ornata* etc.			*Anomaliana (G.) sigmoicosta sigmoicosta*
	Hauterivian	Upper						

English literature with the name "Gault". No concrete section was proposed and the original definition is based solely on the palaeontological characteristics given by d'Orbigny (1850) in the second volume of "Prodrome de Paléontology". However, d'Orbigny specifically referred to the strip of outcrops in the southeastern part of the Paris Basin, which is traversed by the Aube river.

In 1979 the French specialists R. Rat, F. Magniez-Jannin, J.-J. Cateauneuf et al. published the results of a comprehensive study of the Albian from the region along the Aube river, which fully characterizes the stage in its stratotype region.

The lower boundary of this stage is clearly marked by the sharp renovation of ammonite faunas. In many respects Albian ammonite faunas seem cryptogenic, without clear phylogenetic connections for a number of genera with Aptian ammonites. The disappearance of *Diadochoceras, C.* (*Epicheloniceras*) and *Acanthohoplites*, as well as the appearance of *Leymeriella, Epileymeriella, Puzosia* and *Beudanticeras*, mark the lower boundary of the stage. The upper boundary of the Albian, which is also the upper boundary of the Lower Cretaceous, is traced between the ammonite zones *Stoliczkaia dispar* and *Mantelliceras mantelli*. It is marked by the disappearance of the genera *Mortoniceras* and *Callihoplites*, as well as of most species belonging to *Anisoceras, Hamites* (*Stomohamites*) and *Mariella*, and by the appearance of genus *Mantelliceras*.

2.6.1. Substages

The Albian is divided into three substages: Lower, Middle and Upper Albian.

The Lower Albian is characterized by *Leymeriella, Epileymeriella, Hypacanthoplites, Bellidiscus, Vnigriceras, Cleoniceras, Anadesmoceras, Arcthohoplites, Douvilleiceras, Kosmatella, Protanisoceras, Otohoplites, Anadesmoceras, Beudanticeras, Puzosia, Rossalites, Euphylloceras, Ammonoceratites*, etc.

The Middle Albian is characterized by *Hoplites, Lyelliceras, Anahoplites, Euhoplites, Dimorphoplites*, etc. The lower boundary of the substage is traced by the disappearance of the genera *Otohoplites* and *Anadesmoceras*, of most representatives of *Douvilleiceras* and *Protanisoceras*, as well as by the appearance of *Hoplites* and *Lyelliceras*.

The Upper Albian is characterized by *Mortoniceras, Epihoplites, Anisoceras, Hysteroceras, Prohysteroceras, Idiohamites, Mariella, Lechites, Hamites* (*Plesiohamites*), *Stoliczkaia* and *Dipoloceras*. Equivalent to this substage is the concept "Vraconian". The lower boundary of the substage is marked by the disappearance of *Dimorphoplites*, of most *Anohoplites*, as well as by the appearance of mass development of *Mortoniceras, Epihoplites, Anisoceras, Idiohamites, Hysteroceras, Prohysteroceras*, etc.

2.6.2. Biostratigraphic Zones

Ammonite Zones

The Albian contains rich ammonite faunas which outline characteristic successions, on the basis of which a number of zones and subzones have been differentiated. Usually 6-10 zones and 20-22 subzones are distinguished. Some zones and most of the subzones are typical local range-zones, without particular significance for wide correlations. Six stable zones are outlined in the Albian space of the Mediterranean Region, which the author of the monograph accepts as being standard for the stage in this region: *L. tardefurcata, D. mammillatum, H. dentatus, E. lautus, M. inflatum* and *S. dispar* Zones (Table 13).

Table 13

Biostratigraphic Zones in the Albian

Ammonites (after various authors)	Foraminifera (after Sigal, 1977)	Nannoplankton (after Tierstein, 1973)
Mantelliceras mantelli (Cenomanian)	*Rotalipora globotruncanoides*	
Stoliczkaia dispar	*Rotalipora appenninica*	
Mortoniceras inflatum	*Ticinella breggiensis*	*Eiffellithus turriseiffeli*
Euhoplites lautus	*Hedbergella rischi*	
Hoplites dentatus		*Prediscosphaera cretacea*
Douvilleiceras mammillatum	*Hedbergella planispira*	
Leymeriella tardefurcata		
Diadochoceras nodosocostatum (Aptian)	*Ticinella bejaouaensis*	*Parhabdolithus angustus*

***L. tardefurcata* Zone.** It is based on the Range-zone of *Leymeriella.* Its lower boundary marks the lower boundary of the Albian.

The zone is characterized by a rich association: *Leymeriella* (*L.*) *tardefurcata* (L e y m.), *L.* (*L.*) *tenuicostata* S a v., *L.* (*L.*) *intermedia* S a v., *L.* (*L.*) *bogdanovitschi* G l a s., *L.* (*L.*) *rencurelensis* J a c., *L.* (*L.*) *densicostata* S p a t h, *L.* (*Neoleymeriella*) *disposita* S a v., *L.* (*N.*) *densicostata* S p a t h, *L.* (*N.*) *intermedia* S p a t h, *L.* (*N.*) *regularis* (B r u g.) d'O r b., *L.* (*N.*) *consueta* C a s., *L.* (*N.*) *renacensis* S e i t z, *L.* (*N.*) *andrusovi* G l a s., etc. The last *Hypacanthoplites* end in this zone and the first representatives of *Douvilleiceras* appear.

The *L. tardefurcata* zone is divided into 2-3 subzones.

***D. mammillatum* Zone**. It is based on the Range-zone of *Douvilleiceras* and *Protanisoceras.* Its lower boundary is marked by the disappearance of *Leymeriella* and *Hypacanthoplites,* as well as by the mass populations explosion of *Douvilleiceras, Protanisoceras, Beudanticeras* and *Kosmatella.*

Characteristic association: *Douvilleiceras mammillatum mammillatum* (S c h l.), *D. mammillatum praecox* C a s., *D. alternans* C a s., *D. orbignyi* H y a t t, *D. scarbosum* C a s., *D. perchoinense* D e s t., *D. paucicostatum* (P a r., B o n a r.), *Protanisoceras* (*P.*) *cantianum* S p a t h, *P.* (*P.*) *moreanum* (B u v i g.), *P.* (*P.*) *lardyi* (P i c t., C a m p.), *P.* (*P.*) spp., *P.* (*Heteroclinus*) spp., *P.* (*Torquistylus*) spp., *Beudanticeras arduenense* B r e i t s t r., *B. dupinianum* (d'O r b.), *B. newtoni* C a s., *Sonneratia dutempleana* (d'O r b.), *S. ciryi* D e s t., *S. daguini* D e s t., *Pseudosonneratia jacobi* C a s., *P. flexuosa* D e s t., *P. palaeodenta* D e s t., *P. crassa* C a s., *Anahoplites* spp., *Knemiceras* spp., *Protohoplites* (*Hemmisonneratia gallicus,* B r e i s t r., *Cleoniceras cleon* (d'Orb.), *C. dimorphum* Cas., *C. floridum* C a s., *Cleoniceras* spp., *Tegoceras gladiator* (B a y l e), *T.* spp. *Otohoplites larcheri* D e s t., etc.

***H. dentatus* Zone.** It is based on the Range-zone of genus *Hoplites*. Its lower boundary is traced by the disappearance of most representatives of *Douvilleiceras* and *Otohoplites*, as well as by the appearance of *Hoplites* and *Lyelliceras*.

The zone is characterized by a rich association: *Hoplites* (*H.*) *pseudodeluci* Spath, *H.* (*Isohoplites*) *eodentatus* Cas., *H.* (*I.*) *steinmanni* Jac., *H.* (*I.*) spp., *Douvilleiceras leightonense pringlei* Cas., *Lyelliceras lyelli* (Leym.), *L. cotteri* Spath, *H.* (*H.*) *baylei* Spath, *H.* (*H.*) *benettianus* (Sow.), *H.* (*H.*) *bullatus* Spath, *H.* (*H.*) *devisens* Spath, *H.* (*H.*) *dentatus dentatus* (Sow.), *H.* (*H.*) *dentatus robustus* Spath, *H.* (*H.*) *dentatus densicostatus* Spath, *H.* (*H.*) *estragnollensis* Spath, *Anahoplites intermedius* Spath, *A. gransdalei* Owen, *A. praecox* Spath, *A. evolutus* Spath, *A.* spp., *Pseudohelioceras catenatum* (d'Orb.), *Protanisoceras* (*P.*) *alternotuberculatum* (Buvig.), *P.* (*P.*) spp., *Beudanticeras* spp., *Hamites* (*H.*) *tenuicostatus* Spath, *H.* (*H.*) *attenuatus* Sow., etc.

In some countries two to five subzones are differentiated in the volume of this zone.

***E. lautus* Zone.** It is based on the Range-zone of the index species and on the Concurrent-Range-zones of *E. nitidus, A. splendens, A. planus*, etc. Its lower boundary is determined by the disappearance of *Hoplites* and by the appearance of *A. splendens*.

The zone is characterized by *Euhoplites lautus* (Sow.), *E. nitidus* Spath, *Anahoplites planus planus* (Mant.), *A. planus gracilis* Spath, *A. daviesi* Spath, *A.* spp., *A. splendens* (Sow.), *Hamites* (*H.*) *tenuis* Spath, *H.* (*H.*) *maximus* Sow., *H.* (*H.*) spp., *Dimorphoplites niobe* Spath, *D. pinax* Spath, *D.* spp., *Pseudohelioceras* spp., *Oxytropidoceras* spp. and *Mojsisoviczia* spp.

In some countries two to three subzones are distinguished in the volume of this zone.

***M. inflatum* Zone.** It is based on the Range-zone of *Epihoplites* and on the Acme-zones of *Mortoniceras* (*Pervinquieria*), *Hysteroceras, Prohysteroceras* (*Coodhalites*) and *Idiohamites*. Its lower boundary marks the lower boundary of the Upper Albian.

The zone is characterized by a rich association: *Mortoniceras* (*Pervinquieria*) *inflatum* (Sow.), *M.* (*P.*) *pricei pricei* Spath, *M.* (*P.*) *pricei intermedium* Spath, *M.* (*Deiradoceras*) *albense* Spath, *M.* (*D.*) spp., *M.* (*Cantabrigites*) *cantabrigense* Spath, *M.* (*C.*) spp., *Prohysteroceras* (*Goodhalites*) *candolianum* (Pict.), *P.* (*G.*) spp., *P.* (*Neoharpoceras*) *coptense* Spath, *P.* (*N.*) spp., *Hysteroceras binum* (Sow.), *H. orbignyi* Spath, *H. subbinum* Spath, *H. pseudocornutum* Spath, *H. carinatum* Spath, *H. bucklandi* (Spath), *H. varicosum* (Sow.), *H.* spp., *Epihoplites compressus* (Par., Bon.), *E.* spp., *Idiohamites androiavensis* Coll., *I. spiniger* (Sow.), *I. subspiniger* Spath, *I. turgidus* (Sow.), *I. tuberculatus* (Sow.), *I. spinulosus* (Sow.), *Beudanticeras* spp., *Hamites* (*H.*) *intermedius* Sow., *H.* (*Stomohamites*) *virgulatus* Brogn., *Anisoceras armatum* Sow., *A. picteti* Spath, *A. pseudoelegans* (Pict., Camp.), *Hengestites* spp., *Dipoloceras cristatum* (J., P. Dest.) and *Dipoloceras* spp.

In some countries this zone is divided into three or four subzones.

***S. dispar* Zone.** It is based on the Range-zone of the index species and of genus *Arraphoceras*, as well as on the Acme-zones of *Lechites* and *Mariella*. Its lower boundary is marked by the disappearance of *M.* (*P.*) *inflatum, M.* (*P.*) *pricei, H. subbinum* and *H. carinatum*, as well as by the appearance of *Lechites, Stoliczkaia, Arraphoceras, Hamites* (*Pleistohamites*), etc. Its upper boundary marks the upper boundary of the Albian.

The zone is characterized by *Stoliczkaia dispar* (d'Orb.), *M.* (*P.*) *rostratum* (Sow.), *M.* (*C.*) *subsimplex* Spath, *Lechites gaudini* (Pict., Camp.), *L. moreti* Breistr., *Arraphoceras substedi* Spath, *Anisoceras armatum*

S o w., *A. pseudoelegans* P i c t., C a m p., *A. picteti* S p a t h, *A. perarmatum* P i c t., C a m p. , *A. saussoreanum* (P i c t.), *A. meiami* P a c k, J o n n e s, *Mariella* (*M.*) *bergeri* (B r o n g n.), *M.* (*M.*) *miliaris* (P i c t., C a m p.), *M.* (*M.*) *nobilis* J u k e s-B r., *Hamites* (*Stoohamites*) *virgulatus* B r o n g n., *H.* (*S.*) *venetzianus* P i c t., *H.* (*S.*) *charpentieri* P i c t., *Beudanticeras* spp., *Callihoplites* spp., *Pseudohoplites* spp., *Leptohoplites* spp., *Discohoplites* spp., etc.

In some countries this zone is divided into two subzones.

Foraminifera Zones

S i g a l (1977) indicated five (planktonic) foraminifera zones connected with the Albian.

T. bejaouaensis **Zone.** It is based on the Acme-zone of the index species *Ticinella bejaouaensis* S i g. Its lower boundary is determined by the disappearance of *Clavihedbergella* s. str. and by the appearance of *Ticinella.* The lower part of the zone coincides with the Upper Aptian (Clansayesian).

H. planispira **Zone.** It is based on the Acme-zone of the index species. Its lower boundary is traced by the appearance of *Hedbergella planispira* (T a p p.). The zone is also characterized by the presence of *Pleurostomella subnodosa* R e u s s and by the appearance of *Favusella* in its lower part.

H. rischi **Zone.** It is based on the Acme-zones of *Hedbergella rischi* M o u l l. and *Ticinella primula* P r. -S i l v a. Its lower boundary is marked by the appearance of these two species.

T. breggiensis **Zone.** It is based on the Range-zone of the index species. Its lower boundary is determined by the disappearance of *Pleurostomella subnodosa* R e u s s, and by the appearance of *Ticinella breggiensis* (G a n d.) and *T. praeticinensis* S i g.

R. appenninica **Zone.** It is based on the Acme-zones of *Rotalipora appenninica* S i g. and *Planomalina buxtorfi* (G a n d.). Its lower boundary is placed by the disappearance of *Ticinella breggiensis* (G a n d.) and by the mass development of *R. appenninica* and *P. buxtorfi.* Its upper boundary coincides with the boundary between the Albian and the Cenomanian, and it is determined by the appearance of *Rotalipora globotruncanoides* S i g. and *R. brotzeni* (S i g.).

Nannoplankton Zones

The Albian is connected with three nannoplankton zones: *Parhabdolithus angustus*, whose lower part coincides with the Aptian, *Prediscosphaera cretacea* and *Eiffellithus turriseiffeli.*

P. cretacea **Zone.** It is based on the Range-zone of the index species. Its lower boundary is marked by the appearance of *Prediscosphaera cretacea* (A r k h a n g e l s k y). The zone is characterized by *P. cretacea* (A r k h.), *Vagalapilla matalosa* (S t o v e r), *Eiffellithus trabeculatus* (G o r k a), *Cretarhabdus coronadventis* R e i n h., *Broinsonia signata* (N o e l), *Tranolithus exiguus* S t o v e r, *T. orionatus* (R e i n h.), etc.

E. turriseiffeli **Zone.** It is based on the Range-zone of the index species. Its lower boundary is marked by the disappearance of *P. cretacea* and by the appearance of *E. turriseiffeli.* The zone is characterized by *Eiffellithus turriseiffeli* (D e h l., F e r t), *Cribrosphaerella ehrenbergi* (A r k h.), *Corrolithion signum* S t r., *Broinsonia enormis* (S h u m e n k o), *Scapholithus fossilis* D e f l., F e r t, etc.

The upper part of this zone coincides with the base of the Cenomanian.

Part Two

REGIONAL STRATIGRAPHY

III. REGIONAL-STRATIGRAPHIC CHARACTERISTICS OF THE LOWER CRETACEOUS

The regional stratigraphy of the Lower Cretaceous has been studied relatively well in the continental part of the Mediterranean Region. After 1968 many data began to be obtained concerning the development of the series within the ocean and sea basins owing to the Deep-Sea Drilling Project (JOIDES, IPOD). The results of this project played a determining role for the formation of the new ideas in geology.

The deep-sea drilling provided extensive data on the Lower Cretaceous in the Atlantic Ocean and in the Mediterranean Sea, which are examined after the characterization of the series in the respective continental region.

The regional-stratigraphic characterization of the Lower Cretaceous starts with the investigation of the series in Bulgaria, as it possesses particularly sections which have been studied in detail and which are at the basis of the present book. Further below the regional stratigraphy is studied according to regions and palaeogeographic zones from west to east and from south to north.

1. BULGARIA

1.1. General Notes

The Lower Cretaceous is of extreme importance for the geological history of Bulgaria. Lower Cretaceous sediments are most widely represented over considerable areas and they play a determining role in the structure of some large tectonic regions.

Four basic areas of development of the Lower Cretaceous are outlined in Bulgaria, each of which manifests specific features:

1. The Moesian Platform where the Lower Cretaceous is represented by carbonate and clayey-limestone sediments of moderate thickness.
2. The Fore-Balkan with predominance of the powerful, mainly terrigenous sediments, determined by a prolonged and deep depression.
3. South Carpathians (Kula region), where specific terrigenous and terrigenous-carbonate sediments of Carpathian type are developed.
4. Southwestern Bulgaria, where a well-expressed depression is developed with terrigenous sediments in the Kraište region, with a relatively calmer foreland to the northeast, with terrigenous-carbonate and clayey-limestone sediments.

Of considerable interest is also the find of Lower Cretaceous Radiolaria among phyllites in part of the so-called diabase-phyllitoid formation in the Eastern Rhodopes.

Among these regions most prominent is the development of the Lower Cretaceous in Northern Bulgaria (Fig. 3).

Table 14

Major Chronostratigraphic and Biostratigraphic Units in the Mediterranean Lower Cretaceous

Stage	Substage	Amonite Zones	Calpionellids	
			Zones	Subzones
Albian	Upper	*Stoliczkaia dispar*		
		Mortoniceras inflatum		
	Middle	*Euhoplites lautus*		
		Hoplites dentatus		
	Lower	*Douvilleiceras mammillatum*		
		Leymeriella tardefurcata		
Aptian	Clansayesian	*Diadochoceras nodosocostatum*		
	Gargasian	*Cheloniceras subnodosocostatum*		
		Aconeceras nisum		
	Bedoulian	*Deshayesites deshayesi*		
		Procheloniceras pachistephanum		
Barremian	Upper	*Heteroceras astierianum*		
	Lower	*Crioceratites emerici*		
Hauterivian	Upper	*Pseudothurmannia angulicostata*		
		Subsaynella sayni		
	Lower	*Oosterella cultrata*		
		Acanthodiscus radiatus		Latest Calpionellidae
Valanginian	Upper	*Saynoceras verrucosum*	*Calpionellites*	
	Lower	*Kilianella roubaudiana*		
Berriasian		*Fauriella boissieri*	*Calpionellopsis*	
		Tirnovella occitanica	*Calpionella* ↓	*Tintinnopsella carpathica*
		Pseudosubplanites grandis	↓	↓

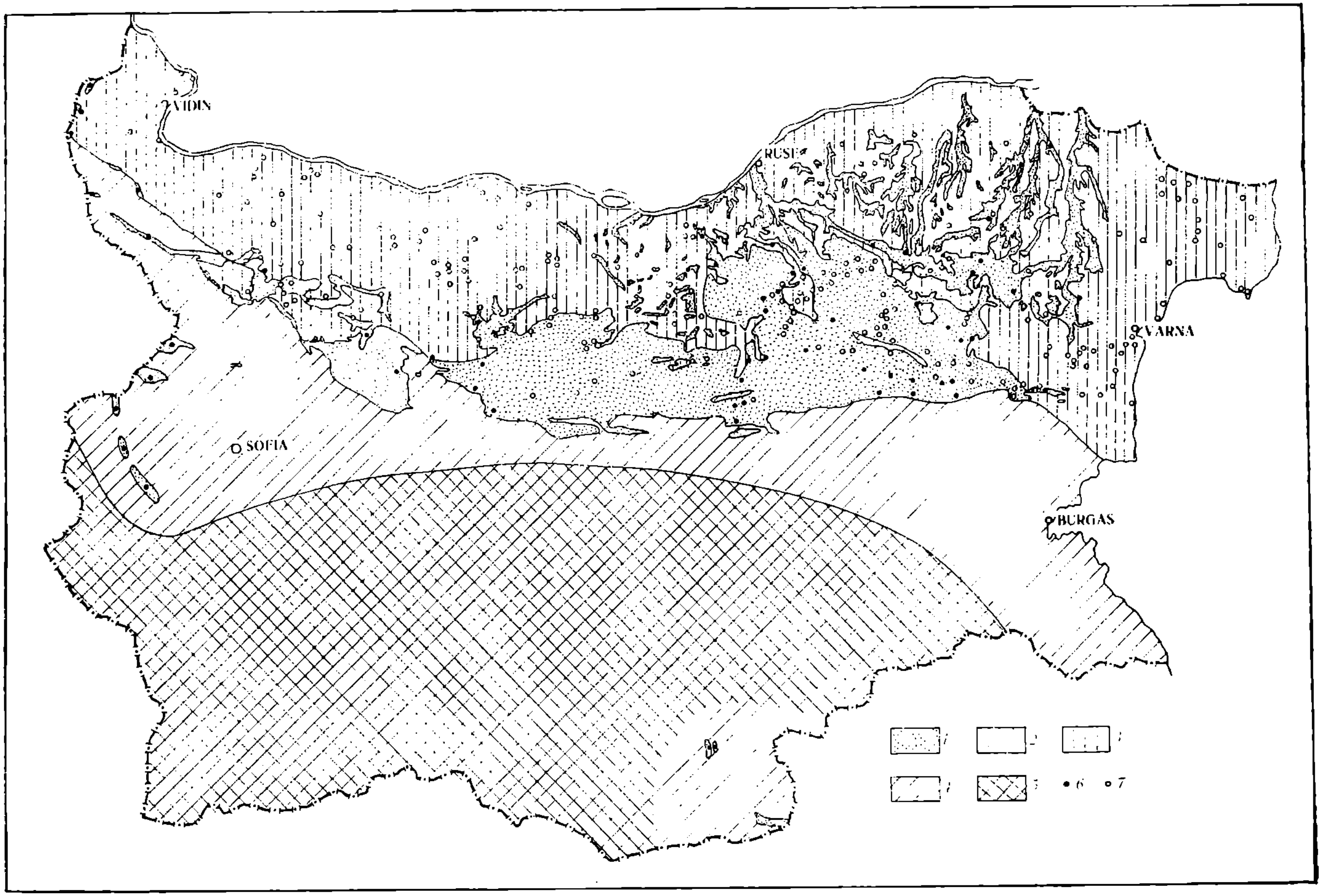


Fig. 3. Map of the distribution of Lower Cretaceous in Bulgaria

1 — outcrops; *2* — areas of distribution proved by boreholes; *3* — areas with probable distribution; *4* — areas with later denuded Lower Cretaceous sediments; *5* — areas of the primary lack of the sediments; *6* — investigated outcrops; *7* — investigated boreholes

1.2. Accepted Stratigraphic Schemes

1.2.1. General Remarks

The model of the stratigraphic classification of the Lower Cretaceous in Bulgaria, which was elaborated in the previous stages, is based on the general inherent trends in the development of this series in the Mediterranean Region and on the results of the studies carried out so far on the lithological and faunistic successions in natural localities and in the boreholes.

The model of the stratigraphy of the Lower Cretaceous, accepted in the present monograph, reveals some differences with respect to the statute, volume and boundaries of some stages and substages. In this book the Berriasian is assumed to be a separate stage at the base of the Cretaceous, unlike some authors who consider it to be part of the Valanginian (Димитрова, 1967). The boundary between the Hauterivian and Barremian is marked between the ammonite zones of *Pseudothurmannia angulicostata* and *Crioceratites emerici,* unlike Breskovski (1975) who includes the beds with *Pseudothurmannia* at the base of the Barremian. The Clansayesian is accepted to be the uppermost substage of the Aptian (Николов, 1970), unlike Dimitrova (Димитрова, 1967) who places it at the base of the Albian.

Lower Cretaceous sediments are divided into stratigraphic units, differentiated in three classification systems: (a) lithostratigraphic (groups, formations, members); (b) biostratigraphic (mainly ammonite oppel-zones); (c) chronostratigraphic (stages, substages).

1.2.2. Bio- and Chronostratigraphic Units

The Lower Cretaceous comprises the following stages: Berriasian, Valanginian' Hauterivian, Barremian, Aptian and Albian. All stages are from the standard International Stratigraphic Scale (Table 14).

1.2.3. Lithostratigraphic Units Related to the Lower Cretaceous in Bulgaria

Until the beginning of the 1960's, the stratigraphic classification of Lower Cretaceous sediments in Bulgaria was represented only by means of chronostratigraphic units.

The wide regional studies and especially the investigation of borehole materials permitted the elaboration of a very comprehensive scheme of the official lithostratigraphic units as a primary matrix of all stratigraphic evidence.

Lower Cretaceous in Bulgaria is connected with the following lithostratigraphic units: Gložene Formation, Slivnica Formation, Brestnica Formation, Kostel Formation, Hănevci Formation, Zlatarica Formation, Černi Osăm Formation, Tiča Formation, Salaš Formation, Kaspičan Formation, Kamčija Formation, Gorna Orjahovica Formation, Mramoren Formation, Razgrad Formation, Vraca Urgonian Group, Loveč Urgonian Group, Trămbeš Formation, Sumer Formation, Svištov Formation, Ruse Formation, Elešnica Formation, Malo Peštene Formation, Roman Formation, Simeonovo Formation and Spasovo Formation (Figs. 4—15).

These are the formal lithostratigraphic units with which the Lower Cretaceous is connected over most of its distribution. In addition to them, there are some informal lithostratigraphic units which participate in the structure of the Lower Cretaceous: terrigenous formation (Carpathian type) revealed near the town of Kula; Urgonian limestones (undivided) in the Western Fore-Balkan and in the Central Fore-Balkan (Straža — Vitite Steni); Paraurgonian formation — developed around the Urgonian complexes in Southwestern Bulgaria and in the Fore-Balkan; marl formation (marls with rare intercalations of sandstones) developed in Zabărdeto, and a probable clayey-marl formation in the Eastern Rhodopes.

1.3. Regional-Stratigraphic Characteristics

The division of the Lower Cretaceous sections in Bulgaria is based on complex lithostratigraphic and biostratigraphic criteria. The biostratigraphic criteria are based on palaeontological data about ammonites, bivalvs, gastropods, calpionellids, algae, foraminifera and ostracods.

The regional-stratigraphic characteristics of the Lower Cretaceous will be examined below on the basis of data from the outcrops and boreholes, from south to north and from west to east, according to the main tectonic regions: Kraištides, South Carpathians, Balkanides, Moesian Platform and the Rhodopes (Eastern Rhodopes).

1.3.1. Kraište

The presence of Lower Cretaceous sediments in this region was proved rather late. V. T z a n k o v et al. (В. Цанков et al., 1960) and S p a s o v (С п а с о в, 1966) report the first finds of Berriasian fossils. On the basis of foraminifera Jovčeva and Vrăbljanski (Й о в ч е в а, В р ъ б л я н с к и, 1963) referred the marls between Košarevo and Banište to the Lower Cretaceous, assuming that the Albian is represented. More systematic studies have been carried out by N a c h e v and N i k o l o v (Н а ч е в, Н и к о л о в, 1968).

In the Kraište Lower Cretaceous sediments are revealed as thin strips to the north and northeast of Trăn, as well as to the southwest between the villages Banište, Stanjovci, Košarevo, Gabrov Dol, Berende and Bornarevo, Radomir region.

The Berriasian is represented by marls, clayey marls, siltstone and sandy marls. Among them there occur clayey limestones and rare intercalations of gritstones, sandstones, siltstones and clastic limestones. At Berende village and to the west of Kopanica village there also appear dark-grey clayey limestones with ammonites and calpionellids, as well as beds of conglomerates up to 5 m thick, formed of fragments of sandstones, quartz, quartzites, limestones, marbles and gneisses (Н а ч е в, Н и к о л о в, 1968).

To the north of Berende village (Stanimirovska hamlet) *Pseudosubplanites* (*Hegaratella*) *subrichteri* (R e t.) has been found in the lower part of the Berriasian. *Retowskiceras* cf. *andrussowi* (R e t.), *Berriasella* sp. indet. and *Himalayites* sp. are found to the southwest of Kopanica village at the base of the section, and in the upper parts — *Phylloceras calypso* (d'O r b.), *Fauriella boissieri* (P i c t.), *F.* cf. *gallica* (M a z.), *Berriasella* sp. indet. *Pseudosubplanites* (*P.*) *grandis* (M a z.) is found in the section at the gorge of Erma river.

These ammonites indicate the lowermost and the uppermost zones of the Berriasian (*P. grandis* and *F. boissieri* Zones). The thickness of the Berriasian sediments in the Kraište is 700-900 m.

The Valanginian is represented by sediments which are lithologically similar to Berriasian deposits. However, marls predominate sharply and define the characteristics of the sections. In the section near Kopanica village there are intercalations (up to 10 cm thick) of gritstones, sandstones, siltstones and clastic limestones among the marls. These intercalations are more frequent and thicker at Berende, and in addition to them there are also intercalations of conglomerates.

The Valanginian was identified for the first time in this region by N a c h e v and N i k o l o v (Н а ч е в, Н и к о л о в, 1968) on the basis of the following ammonite species found at the villages Berende and Kopanica: *Neocomites* (*Eri-*

stavites) cf. *platycostatus* S a y n, *N.* (*N.*) *neocomiensis subquadratus* S a y n, *Neocomites* sp. indet., etc. The thickness of the Valanginian sediments is 500-700 m.

The Hauterivian is proved with foraminifera and ostracods by V r ă b l j a n s k i, J o v č e v a (В р ъ б л я н с к и, Й о в ч е в а, 1969) between Banište and Košarevo villages, Pernik District. The stage is represented by marls and clayey and silty marls. *Trochammina neocomiana* M j a t l. and *Epistomina caracolla* (R o e m.) are found in their lower part. Higher up there are *Ammobaculites trinidadensis* B a r t., B r., single *T. neocomiana* M j a t l., "*Lenticulina eichenbergi* B a r t., B r", and on a mass scale — *E. caracolla* (R o e m.) and ostracods belonging to the species *Dolocytherida hilseana* (R o e m.).

The Barremian and Aptian are not divided in the Kraište, but their presence is indisputable (Н а ч е в, Н и к о л о в, 1968; В р ъ б л я н с к и, Й о в ч е в а, 1969). Between the villages Banište and Košarevo they are represented by marls, clayey marls and silty marls with *Ammobaculites trinidadensis* B a r t., B r., "*Lenticulina subalata* (R e u s s)" (= *L. saxocretacea* B a r t.), *Epistomina chapmani* T. D a m, *E. caracolla* (R o e m.) and *Cytherella ovata* (R o e m.) (after В р ъ б л я н с к и, Й о в ч е в а, 1969). In the same strip there are sandy limestones and oölitic limestones which follow above the Hauterivian sediments in a normal lithological sequence. According to their character, these limestones seem to belong to the Barremian-Aptian. They are covered by slightly aleuritic marls with rather rich foraminifera association typical of Aptian-Albian. This is probably the argumentation for the assumption of V r ă b l j a n s k i and J o v č e v a (В р ъ б л я н с к и, Й о в ч е в а, 1969) that the Albian is also developed in the Kraište.

Sandy limestones and massive limestones of Urgonian type with *Matheronia, Lyma, Orbitolina conoidea,* etc. are revealed in the localities to the north of Trăn, along the road tŏ Bankja village via Goljam Kamăk peak and the Erma river valley near the small tunnel, to the south of the Bogojna neighbourhood of Petkančinci village, at Dragovski Kamăk, Stojnov Kamăk and Cărvanci, as well as at the base of the Gradište to the frontier with Yugoslavia. Their thickness is 80-100 m. These limestones are located over Berriasian sediments. Predominantly detritic and bioconstructed limestones are represented, as well as some oncolitic limestones, sandy limestones and sandy marls with orbitolines. The upper part of this limestone formation is strongly denuded.

1.3.2. Western Bulgaria

The Lower Cretaceous is well developed in Zabărdeto and the lands adjacent to it, but the stratigraphic successions are disrupted by intraformational hiatuses and denudations.

The only indication for the possible presence of the **Berriasian** in the southeastern part of this region is at Beledié Han village, where B a k a l o v a (in N i k o l o v, S a p u n o v, 1977) has found *Gayeuxia kurdistanenesis* E l. — a species known from the Berriasian to the Aptian — in the lowermost part of the Slivnica Formation. Probably here, owing to its low position in the section, it indicates the Berriasian.

As pointed out by M a n d o v (М а н д о в, 1967; 1971), at Dragoman **Hauterivian sediments** transgressively overlie the denuded surface of folded Slivnica limestones. In its base the **Hauterivian** is represented by lense-like beds of breccia conglomerates up to 2.0-2.2 m thick. The fragments consist entirely of limestones, similar to those of the basement. Above them are the clayey calcareous sediments of the Salaš Formation.

The upper part of the Hauterivian near Kalotina is characterized by more terrigenous materials, represented mainly by calcareous sandstones alternating with limestones, clayey and sandy limestones, and marls. The thickness of the Hauterivian between Dragoman and Kalotina is 50-210 m, increasing from the southeast to the northwest.

The Barremian in this region is developed to the southwest of Letnica and to the south of Prekrăste villages, as well as to the west of Kalotina (Мандов, 1971). It is represented by alternation of marls, sandy marls and clayey limestones. Marls gradually increase upwards in the section. The thickness of the Barremian sediments is up to 200 m.

The Aptian is revealed rather extensively near the town of Dragoman: at the villages Nedelište, Višan and Čorul, and between Dragoman and Kalotina village. The section of this stage is particularly characteristic in the Nišava river valley at Kalotina village, described in detail by M a n d o v (Мандов, 1971). Packets of limestones and marls, thin-bedded sandy marls, alternation of calcareous sandstones, sandy limestones and sandy marls, massive limestones with crinoides, oölite limestones, detritic limestones and thick-bedded limestones, are represented. These sediments are the peripheral Paraurgonian facies of the Urgonian massif, developed on Yugoslav territory. The thickness of the Aptian is above 520 m.

To the north the Lower Cretaceous is developed in the Gubeš and Javorec syncline (Николов, Сапунов, 1970; Мандов, 1971; 1972b).

The Berriasian in this zone is connected with the micrite limestones of the Gložene Formation and with the clayey calcareous sediments of the Salaš Formation. Intercalations of sandstones, clayey-calcareous siltstones and aleuritic clayey limestones are included among the clayey-calcareous sediments of the Salaš Formation, from west to east in the sections of the Berriasian Stage in this zone. Sandy beds increase particularly to the east, from Ginci village to the villages of Breze, Zimevica and Bov.

Berriasian sediments in the zone investigated resemble greatly the coeval sediments from the northern part of the Teteven region (the villages Lesidren — Malka Željazna), where the transition between the Černi Osăm and the Salaš Formations occurs.

The Sărbenica tongue which was defined by M a n d o v (Мандов, 1971) for the sandy-marl materials from the lower part of the Berriasian sections in the Javorec syncline, is conditioned by influx of terrigenous material from south-southeast.

The Berriasian in the Gubeš and Javorec syncline is well characterized palaeontologically by M a n d o v (Мандов, 1971; 1972 a), who has demonstrated the presence of the *F. boissieri* ammonite Zone s. l., i. e. *T. occitanica* Zone+*F. boissieri* Zone s. s. The total thickness of the stage in this zone is 30-70 m.

The Valanginian in the Gubeš syncline is also connected with the Salaš Formation. Its lower part is analogous with respect to its facies to Berriasian sediments, whereas the marls increase quantitatively upwards. Sandstones appear among the Valanginian sediments to the south-southeast of Gubeš village.

M a n d o v (Мандов, 1971) has defined a rich ammonite association characterizing both ammonite zones in the Valanginian Stage: *Thurmanniceras thurmanni* (P i c t., C a m p.), *Kilianella salientina* (S a y n), *Sarasinella trezanensis* (L o r y), *Neocomites beaumugnensis* S a y n, *Neocomites* spp., *Olcostephanus* (*O.*) *psilostomus* (N e u m., U h l.), *Saynoceras verrucosum* (d'O r b.), etc. The thickness of the Valanginian sediments is about 100 m.

The Hauterivian is well represented in the Gubeš syncline, where it is connected with the Salaš Formation. The facies of Hauterivian sediments changes to the east-southeast of Gubeš village towards Ginci village. Thick sandstone beds appear (with total thickness of 100-110 m), and in their uppermost part there are also lenses of conglomerates composed of quartz, quartzites and lyditelike flint rocks. In some places the conglomerates manifest good sorting with respect to the size of the fragments. The thickness of the Hauterivian is about 190 m. It is well characterized palaeontologically by M a n d o v (М а н д о в, 1971).

The Barremian is revealed in a strip to the south of the villages Bărlja, Komštica and Gubeš. It is represented in its base by clayey limestones and marls which pass into marls upwards. The vertical lithological sequence is analogous to that of the Salaš syncline. M a n d o v (М а н д о в, 1971) has found a number of characteristic Barremian ammonite taxa from these sediments. The Barremian in the Gubeš syncline is more than 100 m thick, with denuded upper part.

1.3.3. South Carpathians (Kula Region)

The Lower Cretaceous has a specific development, designated as Sinaya type (Б о н ч е в, 1957b), in the Kula region, the Krajna heights and in the southwesternmost part of Vidin District.

According to data of Tz. T z a n k o v (Ц. Ц а н к о в, 1953), Lower Cretaceous sediments lie with a gradual transition over Tithonian limestones. The successions are not very clear, due to the lack of sufficiently good outcrops. T z. T z a n k o v (Ц. Ц а н к о в, 1963) has found a terrigenous-carbonate formation at the base of Lower Cretaceous sections, designated by him as carbonate flysch. It is represented by polygenic breccia-conglomerates, breccias, gritstones, calcareous polymictic sandstones, slightly aleuritic clayey limestones of micritic type, and marls. They are connected by a transition to the Upper Tithonian sediments.

The breccia-conglomerates and the breccias are built mainly of fragments of Upper Jurassic limestones and small quartz grains. Fragments of quartzites, phyllites, schists and granites are less frequent. Sandstones are polymictic, calcareous and inequigranular. Limestomes — clayey, micritic, in some places aleuritic or sandy — predominate in this formation. Marls are slightly aleuritic and occur as thin beds.

These rock varieties form a rhythmic alternation, with graded bedding and a number of other characteristics of flysch formations observed in its phaneromerous varieties. The thickness of this formation is above 400 m.

Palaeontological finds are very scanty: *Pseudobelus bipartitus* B l., *Lamellaptychus didayi* C o g. and unidentifiable calpionellids (Ц. Ц а н к о в, 1963).

Judging by the fact that these sediments are connected by means of a lithological transition to Tithonian sediments, and in view of the available palaeontological evidence, it may be assumed that the described formation in the Bulgarian part of the South Carpathians belongs to the **Berriasian** and **Valanginian**. For the time being, it is difficult to date its upper boundary.

In the region of the Rabiša mound T z. T z a n k o v (Ц. Ц а н к о в, 1963) has described the massive limestones of Urgonian type: biodetritic, zoogenic, oncolitic and cryptocrystalline, referring them justifiably to the **Aptian**. These sediments are of Urgonian type and are not typical of the "Sinaya Cretaceous". Thickness: about 300 m.

Albian sediments are found to the northeast of the Rabiša mound, at Rakovica village and along Neklovec river, to the east of Vrăška Čuka peak (Ц. Ц а н к о в, 1963). Sandy marls with rare intercalations of aleuritic clayey limestones and very seldom of claystones are developed. The contact of these sediments with the Aptian limestones is not clear due to the tectonic disturbance, but they probably overlie a denuded surface above these limestones. At Rabiša mound they form a transition to Cenomanian sediments, whereas at Rakovica village they are covered transgressively and discordantly by palaeogenic sandstones, at Neklovec — by Senonian deposits (Ц. Цанков, 1963).

Among the Albian sediments near Rabiša mound T z. T z a n k o v reports: *Aucellina aptiensis* d'O r b., *Puzosia mayoriana* d'O r b., *Callihoplites atavus* S p., *Hamites sharpentieri* S p., *Hysteroceras orbigny* P i c t., *Scaphites hugardianus* d'O r b. and *Neohibolites minimus* (L i s t.).

In the Neklovec river valley, to the east of Vrăška Čuka peak: *Kosmatella agassiziana* (P i c t.), *Anahoplites praecox* S p., *Puzosia mayoriana* d'O r b., *Neohibolites minimus* (L i s t.) and *Inoceramus concentricus* P a r k.

These taxa define the Middle and Late Albian. There is no palaeontological evidence about the existence of Lower Albian, as assumed by T z. T z a n k o v (Ц. Цанков, 1963).

1.3.4. The Fore-Balkan

Western Fore-Balkan

Lower Cretaceous sediments are particularly widespread in the Fore-Balkan. Most comprehensive are the sections of the series in the Western Fore-Balkan.

The Berriasian is developed everywhere in the base, being connected with the Gložene, Salaš and Brestnica Formations (Николов, Сапунов, 1970; B a k a l o v a et al., 1976) (Fig. 4). In all sections the Berriasian sediments concordantly and with a gradual transition overlie Tithonian sediments. They are well manifested in the Salaš syncline, in Păstrinata hill and the cliff of Belogradčiški Venec, being more limited in the northern limb of the Belogradčik anticlinorium. They are found in all deep boreholes in the region. The following researchers have a considerable contribution to the investigation of the Lower Cretaceous in the boreholes: M o n o v et al. (Моновъ et al., 1970), N i k o l o v, S a p u n o v (Николов, Сапунов, 1970), N i k o l o v, M o n o v et al. (Николов,

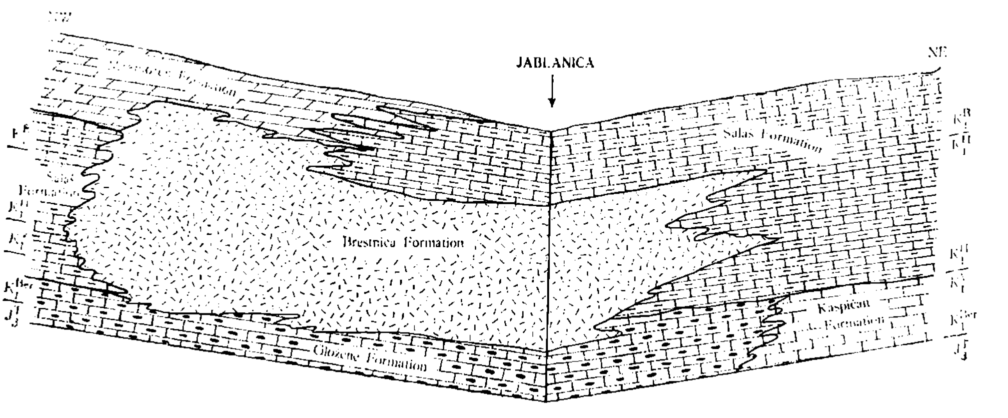


Fig. 4. Relationships of the Brestnica Formation with adjacent lithostratigraphic units

Монов et al., 1972), M o n o v (Монов, 1972; 1973), B a k a l o v a (Бакалова, 1977) etc.

In outcrops in the Western Fore-Balkan Lower Cretaceous sediments have been characterized by M a n o l o v (Манолов, 1962), V r ă b l j a n s k i, T c h o u m a t c h e n c o (Врьблянски, Чумаченко, 1962), N i k o l o v and

Khrischev (Николов, Хрисчев, 1965b), etc. Data obtained more recently will be presented here.

In the Salaš syncline, as well as in Mihajlovgrad District near Blagovo village, Păstrinata hill, the villages Stubel and Pali Lula, in the Čiren, Ponor, Gorno Peštene and Goljamo Peštene areas (Salaš — Čiren zone) the Berriasian is represented at its base by the light grey micritic limestones of the Gložene Formation, and higher up by the clayey-calcareous sediments of the Salaš Formation.

Pseudosubplanites cf. *combesi* Le H é g. was discovered in the upper part of the Gložene Formation, in the valley of the Sugavica river (the southern slope of Păstrinata). This species is characteristic for the base of the Berriasian. This ammonite find, as well as the identified Berriasian calpionellids from the upper part of the Formation found in numerous boreholes (B a k a l o v a et al., 1976), indicate that the upper part of the Gložene Formation is of Berriasian age (Николов, Сапунов, 1970).

In some places in the Salaš syncline the upper part of the Gložene Formation is denuded and Hauterivian sediments overlie the Berriasian (Čeljustnica, Beli Mel and Prevala).

The following ammonite taxa, characteristic of the *Malbosiceras paramimounum* Subzone of the *Fauriella boissieri* Zone: *Malbosiceras paramimounum* (M a z.), *Jabronella* (*Erdenella*) *erdenensis* N i k., *Fauriella boissieri* (P i c t.), *Berriasella* sp., *Spiticeras* spp., etc., are found on the northern slope of Păstrinata hill, in the eastern part of the Erden quarries (to the south of Bojčinovci), at a distance of 40-50 m from the base of the Salaš Formation.

The presence of the Berriasian has also been proved in the sections to the west of Krapčene village, Mihajlovgrad District, as well as to the southwest of Ljuti Dol village and around the Răždavec and Djakovci neighbourhoods, Vraca District. *Leptoceras studeri* (O o s t.), *Berriasella* sp. indet. and *Bochianites* sp. indet. have been identified in the recent outcrops, indicating Late Berriasian

Berriasian microfauna (foraminifera and calpionellids) are found in a number of boreholes in this region.

In the more southern zone (the villages of Zamfirovo — Glavaci — Beli Izvor — Kalen — Veslec — Bešovica — Drašan — Reselec) the Berriasian is connected mainly with the massive micritic, irregular recrystallized, allochemical or biomorphic limestones of the Brestnica Formation, partially with the upper part of the Gložene Formation (R-1 Zamfirovo), or partially with the Salaš Formation as well (e. g. R-17 Beli Izvor), whereas to the north in the boreholes of the Vărbica area — with the transitional sediments of the Brestnica-Salaš Formation (B a k a l o v a et al., 1976).

Interesting calpionellid successions occur in borehole R-1 Reselec, where the following zones and subzones were demonstrated at three levels: in the interval 2965—3038 m (Salaš Formation) — *T. carpathica* Subzone of the *Calpionella* Zone; at 3128-3130 m (Brestnica Formation) — *C. alpina* Subzone of the *Calpionella* Zone; at 3132.40 m — *Crassicollaria* Zone. These findings show that the Jurassic-Cretaceous boundary in this section passes through the lower part of the Brestnica Formation. It should be noted for comparison that the thickness of the Brestnica Formation at R-1 Reselec is 140 m, being 502 m at R-17 Beli Izvor. Consequently, the position of the Jurassic-Cretaceous boundary in the Brestnica Limestone Formation does not depend on the thickness of the Formation, but it is influenced by the position of the section with respect to the body of the Formation, as has been found by S a p u n o v (in B a k a l o v a et al., 1976).

Generally speaking, the Berriasian in the Western Fore-Balkan is relatively homogeneous, connected, on the one hand, with the pelagic facies of the Gložene and Salaš Formations, and on the other — with the carbonate building of the Brestnica Formation.

The Berriasian in the Western Fore-Balkan is 90-450 m thick. The greater thicknesses are related to the Brestnica Limestone Formation.

The Lower Cretaceous section in the zone of the villages Salaš — Čiren is filled upwards by the sediments of the **Valanginian**, with the exception of the area between the villages Čeljustnica — Prevala, where they are absent. In all remaining sections of this zone the Valanginian is connected with the Salaš Formation. It is represented predominantly by micritic limestones, clayey limestones and intercalations of marls.

In the zone of the villages Zamfirovo — Drašan — Reselec the Valanginian is connected with the Brestnica and / or the Salaš Formations. The presence of the Valanginian in the outcrops has been characterized well by N i k o l o v and K h r i s c h e v (Н и к о л о в, Х р и с ч е в, 1965b), N i k o l o v and T z a n k o v (Н и к о л о в, Ц а н к о в, 1971) and M a n d o v (М а н д о в, 1976).

In the locality of Pàstrinata the Valanginian is proved by: *Thurmanniceras* sp., *Busnardoites campylotoxus* (U h l.), *Neocomites* (*N.*) *neocomiensis subtenius* S a y n, *N.* (*Eristavites*) *platycostatus* S a y n, *Saynoceras verrucosum* S a y n, etc.

The two ammonite zones of the Valanginian are proved in the eastern part of the Western Fore-Balkan, in the zone of the transition between the pelagic clayey-calcareous and flysch facies (Salaš — Černi Osăm Formation) (Н и к о л о в, Х р и с ч е в, 1965a).

A characteristic Valanginian ammonite association is found in the transition zone Salaš — Brestnica Formation to the north of Gložene village, in the Vedrovete locality (Н и к о л о в, Х р и с ч е в, 1965a): *Kilianella ischnotera* (S a y n), *Kilianella* sp., *Sarasinella trezanensis* (S a y n), *N.* (*N.*) *neocomiensis* (d'O r b.), *N.* (*N.*) *neocomiensis premolicus* S a y n, *N.* (*N.*) *neocomiensis subquadratus, Thurmanniceras* sp., etc.

No Valanginian macrofauna has been found in the boreholes, with the exception of *Bochianites* sp. in R-3 Čiren (924.50 m).

The differentiation of the Valanginian in the boreholes is made by comparison with the outcrops and according to the microfauna. The thickness of the Valanginian is from several tens of metres to 350 m.

The Hauterivian is well represented in the Western Fore-Balkan, where it is connected with the Salaš and Brestnica Formations. A number of authors have contributed to the investigation of this stage, among whom M a n d o v (М а н д о в, 1976) deserves special credit for his very detailed study of the Hauterivian in the Western Balkanides, comprising mainly natural outcrops.

The following species are found in outcrops of the Salaš Formation in the Salaš syncline, especially near the villages Krapčene and Pali Lula: *Phyllopachyceras winckleri* (U h l.), *Bochianites neocomiensis* (d'O r b.), *Himantoceras trinodosum* T h., *H. acuticostatus* T h., *H. thieuloyi* M a n d o v, *Crioceratites andersoni* (S a r.), *C. nolani* (K i l.), *Crioceratites* spp., *Eleniceras* spp., *Olcostephanus* sp., *Lyticoceras cryptoceras* (d'O r b.) and many others (Н и к о л о в, Х р и с ч е в, 1965b; М а н д о в, 1976).

In the Jablanica area the Hauterivian is proved by: *Crioceratites duvali* L é v., *C. nolani* (K i l.), *Crioceratites* spp., *Balearites balearis* (N o l.), *Subosterella heliaca* (d'O r b.), *Lyticoceras* sp., etc.

In the zone of the Salaš — Čiren villages the Hauterivian is connected with the Salaš Formation. Usually in this zone the lower boundary of the stage is marked at about 100-120 m above the base of the Salaš Formation, whereas the upper boundary is at about 30-40 m below the upper part of this Formation.

In the zone of the villages Žamfirovo — Drašan the Hauterivian is connected predominantly with the Brestnica or with the Salaš Formation.

A number of biostratigraphic proofs of the presence of the Hauterivian have been found in the boreholes as well.

The Hauterivian is heterofacial, connected with the Brestnica and Salaš Formations which are involved in complex interrelations. The thickness of the Hauterivian in the Western Fore-Balkan is 95-700 m.

There exists biostratigraphic evidence about the presence of the **Barremian** both in the natural outcrops and in a number of boreholes.

The following species are found among the marls of the Mramoren Formation from the natural outcrops near the village of Čerkaski, Mihajlovgrad District (М а н о л о в, 1962): *Cymatoceras neocomiense* (d'O r b.), *Phyllopachiceras infundibulum* (d'O r b.), *Barremites* cf. *difficilis* (d'O r b.), *B. subdifficilis* (K a r.), *Silesites vulpes* (C o q.), *Hibolites* cf. *subfusiformis* (R a s p.).

M a n o l o v (М а н о л о в, 1962) reports *Barremites charrierianus* (d'O r b.) from the uppermost part of the Mramoren Formation near Stojanovo village.

The presence of Barremian sediments on Păstrinata hill has been proved by P o p o v and H r i s t a n o v a (П о п о в, Х р и с т а н о в а, 1961) with the following ammonite association: *Crioceratites emerici* L e v., *Anahamulina subcylindrica* (d'O r b.), *Barremites ponticus* (K a r.), *B. charrierianus* (d'O r b.) and *Pseudosaynella strettostoma* (U h l.).

The presence of the Barremian has also been proved with the macrofauna in a number of structural boreholes.

P. J o v č e v a has found characteristic foraminifera associations determining the Barremian at several levels in R-1 Goljamo Peštene (oral communication).

By means of a rich ammonite association found in the outcrops of the Mramoren Formation, immediately below the Urgonian limestones in the Čiren area (Д и м и т р о в а, 1967), the Late Barremian of the upper part of the Mramoren Formation in this region has been proved: *Barremites vocontius* (S a y n), *B. subdifficilis* (K a r.), *B. nabdalsa* (C o q.), *B. sequenze* (C o q.), *B. tenuicinctus* (S a r., S c h.), *Pseudosaynella strettostoma* (U h l.), and *Pulchellia sauvageani* (H e r m.).

K o v a t c h e v a (oral communication) has defined the following characteristic Upper Barremian foraminifera association in R-1 Drašan, in the interval 1669-2284 m: *Lenticulina nodosa* (R e u s s), *Arenobulimina meltae* K o v., *Conorotalites intercedens* (B e t t.), *Gaudryina borimensis* K o v., *Marssonella kummi* Z e d l., *Lamarckina lamplughi* (S h e r l), *Quinqueloculina pseudominima* B a r t., K o v., *Epistomina hechti* B a r t., B e t t., B o l l i, *Choffatella decipiens* S c h l., *Flabellammina urgonensis* B a r t., K o v., *Epistomina caracolla* (R o e m.) and *Trocholina infragranulata* N o t h.

The Barremian in the Western Fore-Balkan is markedly heterofacial. It is connected with the Brestnica, Salaš and Mramoren Formations. Thickness: 100-1000 m.

The development of the **Aptian** in the Western Fore-Balkan is well known from the data of the outcrops. Borehole data provided considerable new information about the comprehensive characteristics of this stage.

There exist numerous biostratigraphic proofs about the presence and completeness of the Aptian and of its three substages: Bedoulian, Gargasian and Clansayesian (В. Ц а н к о в, 1960; Д и м и т р о в а et al., 1961; М а н о л о в, 1962; Н и к о л о в, Х р и с ч е в, 1965b; Н и к о л о в, 1969b; 1970).

The Lower Aptian (Bedoulian) is proved by the following ammonites found to the north of Liljače village: *Deshayesites weissi* (N e u m, U h l.), *D. deshayesi* (L e y m.), *D. bodei* (K o e n), *Deshayesites* sp. and *Cheloniceras* sp.

Requienia zlatarskii P a q., *Matheronia affinis* (M a t h.), *M. aptiensis* (M a t h.) and *M. gryphoides* (M a t h.) are identified from the natural outcrops near Vraca (В. Ц а н к о в, 1960).

Deshayesites deshayesi (L e y m.), *D. weissi* (N e u m., U h l.), *Deshayesites* spp. and *Cheloniceras cornuelianum* (d'O r b.) are reported from the upper part of he Čerepiš Formation near Ponora (Н и к о л о в, 1969).

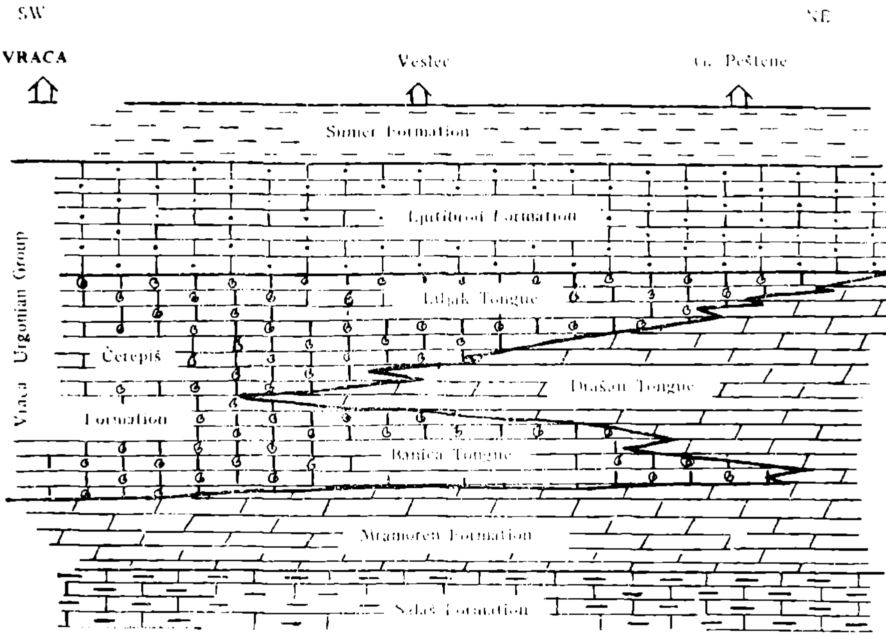


Fig. 5. Section of the Vraca Urgonian Group between Vraca and Goljamo Peštene (after Н и к о л о в et al., 1972)

Matheronia affinis (M a t h.), *M. aptiensis* (M a t h.) and *Requienia zlatarskii* P a q. are known from the same limestones between Ponora and Čiren (В. Ц а н к о в, 1960).

The Lower Aptian is connected mainly with the Čerepiš Formation (Vraca Urgonian Group) (Fig. 5) partially with the Mramoren Formation and with the base of the Roman Formation. This is evidenced by *Deshayesites callidiscus* C a s e y which was found at the base of the Roman Formation near Batulci village.

This substage is also characterized by very rich foraminifera, bivalvs and ostracod fauna.

The Middle Aptian (Gargasian) is demonstrated by ammonite fauna discovered in the outcrops of the Ljutibrod and partly of the Sumer Formations.

Costidiscus nodosocostatus K a r., *Puzosia matheroni* (d'O r b.), *Parahoplites melchioris* A n t h., *P. subcampichei* S i n z., *Acanthohoplites aschiltensis* (A n t h.), *Colombiceras tobleri* (J a c.), *Neohibolites strombecki* (M u l.) and *N. semicanaliculatus* (B l.) are found in the outcrops between the villages Liljače and Goljamo Peštene (Д и м и т р о в а et al., 1961; Н и к о л о в, 1970).

The Upper Aptian (Clansayesian) is proved in the Sumer Formation. *Aucellina caucasica* (v. B u c h), *A. aptiensis* (d'O r b.), *Aucellina* spp. and *Acanthohoplites* *trautscholdi* (S i m., B a c., S o r.) are found in Sumer village, in the valley of Šugavica river.

Hypacanthoplites jacobi (C o l.), *H. tscharlokensis* G l a z., *Acanthohoplites bigoureti* (S e u n.), *A. trautscholdi* (S i m., B a c., S o r.) and *A. nolani* (S e u n.)

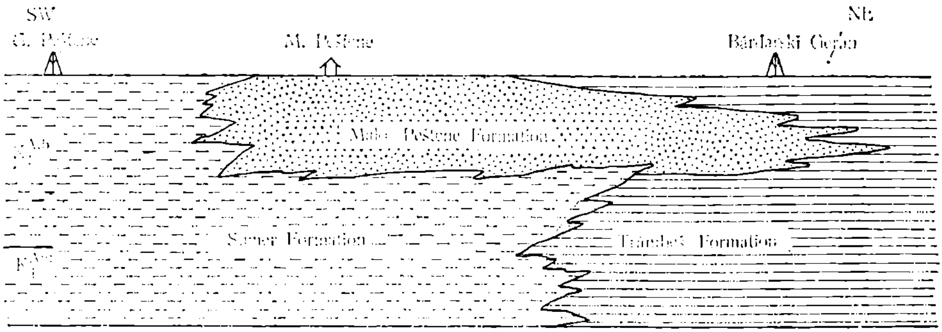


Fig. 6. Relationships between lithostratigraphic units along the Goljamo Peštene — Bărdarski Geran line

are found in the outcrops of the Sumer Formation between the villages Liljače and Goljamo Peštene (Н и к о л о в, 1970).

The chronostratigraphic regularities established for the Aptian according to biostratigraphic evidence from the outcrops were traced and confirmed with new biostratigraphic data in the boreholes.

The Upper Aptian (Clansayesian) is demonstrated with very rich foraminifera association in a number of boreholes (Й о в ч е в а, 1966).

The Aptian is markedly heterofacial, being connected with the Mramoren Formation, the Vraca Urgonian Group, the Roman and Sumer Formations. Thickness: 440-1790 m.

The presence of the **Albian** in the Western Fore-Balkan is proved by many biostratigraphic data (З а х а р и е в а-К о в а ч е в а, 1957; Д и м и т р о в а et al., 1961; М а н о л о в, 1962; Н и к о л о в, Х р и с ч е в 1965b; К а л ч е в а-И л и е в а, 1967; N i k o l o v, 1969; Н и к о л о в, 1970, and others). Here we shall not cite the extremely rich ammonite finds originating from the outcrops of the Albian in the investigated part of the Western Fore-Balkan. Lists of these finds can be discovered in the cited publications.

The studies of I v a n o v (И в а н о в, 1981) on the Albian between the rivers Botunja and Iskăr deserve special reference. They are characterized by their profundity and comprehensiveness, as investigations of this stage in lithostratigraphic, biostratigraphic and palaeontological aspects at a high up-to-date level.

In the southern part (the region of the villages Zamfirovo — Glavaci — Drašan) the Albian is represented by the lower substage and by the base of the middle substage.

The following species are found at boreholes S-2 Zamfirovo:

At 148.50 m: *Hoplites* cf. *divisensis* sp.

At 155-157.50 m: *Leymeriella natskyi* G l a z., *Neosilesites nepos multicostatus* D i m., *Beudanticeras* sp. indet. and *Aucellina aptiensis* (d'O r b.).

This is biostratigraphic evidence about the presence of the Lower Albian and the base of the Middle Albian.

Albian deposits in this region are extremely rich in foraminifera as well (Й о в-ч е в а, 1966).

The upper part of the Middle Albian and the Upper Albian are proved with abundant biostratigraphic data to the north of the studied part of the Western Fore-Balkan, i. e. near the villages Malo Peštene, Bukovec and Suhatče.

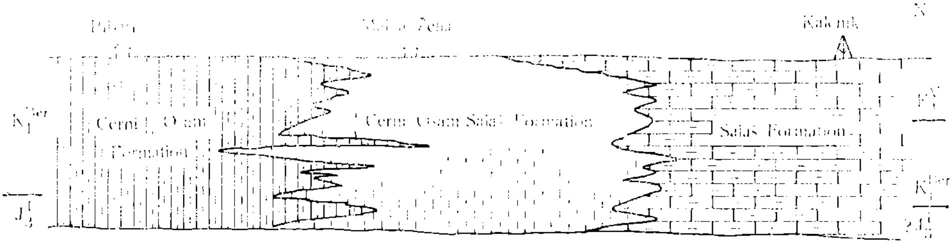


Fig. 7. Relationships between the lithostratigraphic units along the Ribarica — Kalenik line

I v a n o v (И в а н о в, 1981) reports the latest and very detailed data about the biostratigraphic characteristics of the Albian in this region.

The Albian in the Western Fore-Balkan is connected everywhere with the Sumer Formation and with the Malo Peštene Formation (Fig. 6). The thickness of the Albian in this region is 78 -770 m, tending to increase from south to north.

Central Fore-Balkan

The Lower Cretaceous is particularly widely developed in this region.

The Berriasian in the Central Fore-Balkan is well studied in the outcrops (Н и-к о л о в, Х р и с ч е в, 1965a,b; М а н д о в, 1967; N i k o l o v, 1969; N i k o-l o v, S a p u n o v, 1977, and others).

Berriasian sediments from the outcrops are extremely rich in ammonite faunas, lists of which can be found in the cited publications.

The presence of the Berriasian was proved in all deep drillings carried out in the Central Fore-Balkan.

In the southernmost outcrops the Berriasian is represented by the coarse terrigenous sediments of the Kostel Formation — polygenous conglomerates, gritstones, sandstones and aleuritic marls. The mixed rocks of the Hănevci Formation and the flysch-like sediments of the Zlatarica Formation — thick beds of sandstones and marls with intercalations of siltstones, aleuritic marls and aleuritic clayey limestones — are developed to the north. The flysch sediments of the Černi Osăm Formation are developed in the Černi Vrăh anticline and to the north — to localities north of Sevlievo (Fig. 7, 8).

In the boreholes the Berriasian is connected exclusively with the Černi Osăm Formation, whereas in the outcrops to the south, the filling for the Berriasian sections is given not only by this Formation, but also by the Zlatarica, Hănevci and Kostel Formations.

The thickness of the Berriasian in the Central Fore-Balkan is 870 -1200 m.

The Valanginian in the Central Fore-Balkan is well known from the natural outcrops about which information can be found in the publications cited earlier in connection with the Berriasian.

In this region the Valanginian is connected with the sediments of the Hănevci Formation, the upper part of the Zlatarica and Černi Osăm Formations, and with the lower part of the Kamčija Formation.

The presence of the Valanginian in the boreholes is demonstrated by the finding of a number of macro- and microfossils.

In R-1 Sevlievo *Bochianites* sp. and *Neocomites* (*Teschenites*) sp. indet. were found at a depth of 1408 m, and *Olcostephanus* sp. indet. at 1879.25 m. These finds prove the Upper Valanginian and the top of the Lower Valanginian.

In R-5 Sevlievo *Sarasinella trezanensis* (L o r y) and *Neocomites* sp. indet. were found at a depth of 3001.50 -3001.60 m, proving the Lower Valanginian.

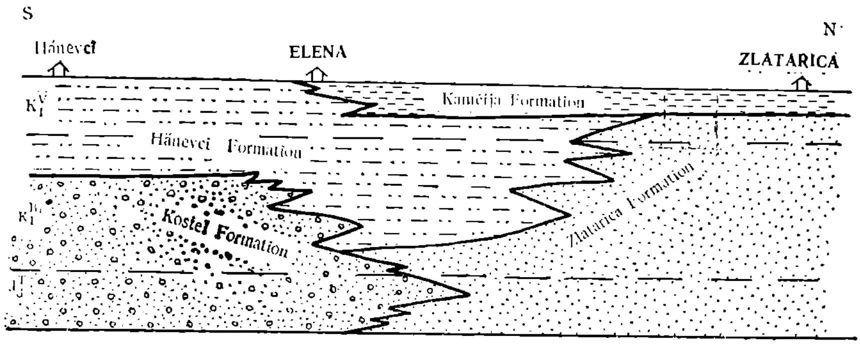


Fig. 8. Relationships between the lithostratigraphic units along Hănevci — Zlatarica line

Busnardoides cf. *campylotoxus* (U h l.), which is a characteristic Upper Valanginian species, was found at 1613.50 m in R-1 Gostilica boreholes.

In the boreholes the Valanginian is connected with the Černi Osăm and Kamčija Formations, while in the outcrops this stage is also proved in the Zlatarica and Hănevci Formations. Thickness: 520-850 m.

The Hauterivian is widely represented in the outcrops in the Central Fore-Balkan (Н и к о л о в, Х р и с ч е в, 1965a, b; М а н д о в, 1967; N i k o l o v, 1969, and others). Its sediments overlie normally and with transitions the Valanginian deposits. In the Jablanica area the Hauterivian is connected with the clayey limestones and marls of the Salaš Formation. To the south, near the village of Džurovo, it is represented by sandstones, siltstones and marls (Kamčija Formation), among which one *Crioceratites* sp. indet. was found in the Beljakovec neighbourhood.

In the northern part of the Teteven area the Hauterivian sections are formed of marls, sandstones and slightly aleuritic clayey limestones. *Crioceratites nolani* (K i l.), *Crioceratites* sp. (cf. *duvali*), *C. quenstedti* (O o s t.), *Crioceratites* spp. and *Olcostephanus* spp. are found among the marls near the villages Bălgarski Izvor, Malka Željazna and Lesidren.

To the southeast of Borima village, in the Suhata Reka river opposite the nursery-garden there are: *Phyllopachiceras infundibulum* (d'O r b.), *Neolissoceras grasi* (d'O r b.), *Crioceratites duvali* L e v., *Subsaynella sayni* (P a q.) and *Duvalia dilatata* (B l.).

In the lower part of the Hauterivian sections (approximately the lower and middle parts of the stage), M a n d o v (М а н д о в, 1967) reports characteristic ammonites which prove the presence of the three ammonite zones of this stage: *A. radiatus, O. cultrata* and *S. sayni.* The uppermost part of the stage is very poor in fossils. This part has been accurately dated only in the section to the west of Jablanica, from where M a n o l o v (М а н о л о в, 1960) reports: *Phylloceras ponticuli* (R o u s.), *Crioceratites duvali* L é v., *Pseudoturmannia angulicostata* (d'O r b.) and *Hibolites subfusiformis* (R a s p.).

To the east of Osăm river Hauterivian sediments are revealed to the south of Dobrodan village and around the villages Beliš, Gumošnik, Mlečevo, Debnevo and Stolăt. One strip of Hauterivian sediments is traced to the north of Debnevo, Berievo and Gradnica. Hauterivian sediments have relatively more limited outcrops at the base of Ostrec peak, to the west of Aprilci, from where L a n d ž e v (Л а н д ж е в, 1940) reports characteristic ammonite taxa.

To the east Hauterivian sediments are traced as a considerably wide strip, passing to the south of Sennik, through Batoševo and Šumata, filling the area between the Gabrovo and Straža synclines to the east of Rosica river, around the villages Găbene, Muzga, Vranilovci, Girgini, Gaetani and Kukata. To the east of Jantra river this Hauterivian strip is connected with the Hauterivian sediments found south of Vărbanovo. In this easternmost part of the Central Fore-Balkan the Hauterivian is represented by the mixed rocks of the Hănevci Formation and by the marly-sandstone deposits of the Kamčija Formation.

In the valley of Jantra river, to the north of Jantra village and to the east of Gostilica village, the Hauterivian is represented by alternation of sandstones and aleuritic marls (Kamčija Formation). Sandstones predominate in the middle part of the sections. Such is the character of Hauterivian sediments to the west of Gostilica village approximetely to the area northwest of Lovni Dol village.

The presence of the Hauterivian in the boreholes is proved mainly through the microfauna, as well as by several rare ammonite finds and by comparison with the outcrops.

In the boreholes the Hauterivian is connected with the Kamčija Formation, in the outcrops — partially with the Hănevci Formation as well.

The thickness of the Hauterivian in the Central Fore-Balkan is 850-1500 m.

The Barremian is very widely developed in the Central Fore-Balkan (М а н о л о в, 1960; Н и к о л о в, Х р и с ч е в, 1965a, b; Х р и с ч е в, 1966; М а н д о в, 1967; К о в а ч е в а, 1968; Н и к о л о в, 1969b).

In the area to the southwest of Džurovo village, near the villages Osikovica and Osikovska Lăkavica, the Barremian is represented by marls and sandstones, while intercalations of sandy organogenic and biodetritic limestones appear in the upper part. *Barremites* sp. is found to the south of Osikovska Lăkavica village. To the west of Jablanica the Barremian is characterized palaeontologically by M a n o l o v (М а н о л о в, 1960).

The following Barremian ammonites are found in the marls to the north of Kirčevo village: *Pseudothurmannia pseudomalbosi* (S a r., S c h.), *Acrioceras morloti* (O o s t.), *A. pulcherrimum* (d'O r b.), *A.* cf. *meriani* (O o s t.), *Barremites* sp. indet., *Anahamulina* sp. indet., and to the northwest of Lesidren village: *Barremites subdifficilis* (K a r.), *B. charierrianus* (d'O r b.), *B. ponticus* (K a r.), *B. tenuicostatus* sp. and *Hamulina* sp. indet.

In the east, in the Trojan area, Barremian rocks are found in a strip to the north of Săevo village, through Borima village, to the north of Dălbok Dol and Dobrodan villages, and from there to Vrabevo and to the north of Debnevo villages.

Characteristic Barremian ammonites are found in the marls to the east of Borima village: *Phyllopachiceras infundibulum* (d'O r b.), *Holcodiscus mediocostatus* T z., *H. irregularis* T z., *H. oosteri* S a r., S c h., *Costidiscus recticostatus* (d'O r b.) and *Crioceratites quenstedti* (O o s t.) and to the north of Debnevo village — *Nicklesia pulchella* (d'O r b.).

In the east, in Sevlievo region, the Barremian is represented by marls with single intercalations of sandstones. A characteristic component of the Barremian sediments in these places are individual lenses and intercalations of organogenic and sandy oölitic limestones. M. A t a n a s o v a-D e l č e v a (oral communication) has found *Barremites* sp. among these sediments between the villages Javorec and Armenite, which proves the Barremian age of the sediments building the base of the Straža syncline.

Biostratigraphic evidence about the development of the Barremian was also found in the boreholes. In R-2 Sevlievo, in the 300-302 m interval, the following foraminifera association characteristic of the Barremian was found by T. K o v a t c h e v a (oral communication): *Epistomina caracolla* (R o e m.), *E. ornata* (R o e m.), *Lenticulina ouachensis ouachensis* (S i g.), *L. meridiana* B a r t., B e t t., K o v., *Gaudryina borimensis* K o v., *Planularia crepidularis* (R o e m.), *Marssonella kummi* Z e d l., *Dentalina communis* d'O r b., *Conorboides bulgaricus* B a r t., B e t t., K o v. The following Barremian ammonites: *Pseudothurmannia pseudomalbosi* (S a r., S c h.), *Barremites difficilis* (d'O r b.), *Barremites* spp. and *Acrioceras* sp. indet., were found in the quarries in the eastern part of Sevlievo. This association dates the Lower Barremian.

The Upper Barremian is connected with terrigenous-carbonate and carbonate (including Urgonian) sediments, which are extensively found in the middle and northern parts of the Central Fore-Balkan. Characteristic fossils are rare here. L a n d ž e v (Л а н д ж е в, 1940) reports *Holcodiscus* sp., *Duvalia* cf. *binervia* (R a s p.), etc., which characterize the Barremian from the Urgonian limestones near the villages Dolna Hirevska Mogila and Gorna Hirevska Mogila.

To the east of Sevlievo, to the north of Bogatovo, to the south of Vetrenci and towards the Jantra river valley, to the south of Veliko Tărnovo, the upper part of the Barremian is built of marls, sandstones, siltstones and limestones. A characteristic Barremian ammonite — *Valdedorsella haugi* B r e s k. — was found among the limestones of the Emen Formation (Mladenci-Debelcov tongue) in the eastern part of Puševo village, Veliko Tărnovo District (Н и к о л о в, 1969b).

The upper boundary of the Barremian in the Northern strip of the Central Fore-Balkan passes through the lower half of the Urgonian complex, while in most sections in the rest of the area it is related to denudation.

The thickness of the Barremian in the Central Fore-Balkan is 1200-1700 m.

The Aptian in the Central Fore-Balkan is represented by Urgonian, Paraurgonian (terrigenous-molasse-like), as well as by marl sediments in the vicinity of the Platform.

In terrigenous and terrigenous-carbonate facies the Aptian is developed predominantly in the Western part of the Central Fore-Balkan, where it is connected with the Roman Formation. This facies fills the Pašalna, Makaravec and Straža synclines, being also found further south, in the Trojan region, to the north of the villages Borima, Dălbok Dol and Dobrodan. Everywhere Aptian sediments are connected by a gradual transition with the Barremian deposits.

Among these sediments there are enormous lense-like bodies of the Urgonian complex — of Dragojca mountain, in the area between Loveč and Veliko Tărnovo, and in the Straža syncline. The stratigraphy of the Loveč Urgonian Group is best studied owing to K h r i s c h e v's consistent and comprehensive studies (Х р и с ч е в, 1966; 1967). This author has demonstrated the structure and the complex spatial interrelations of the Urgonian and terrigenous components of the Loveč Urgonian Group (Fig. 9).

Terrigenous-carbonate sediments of Paraurgonian type are developed to the side of the Urgonian bodies and over them. They represent specific facial fans of the carbonate Urgonian platforms.

Only the Lower Aptian (Bedoulian) is developed in the Central Fore-Balkan.

The Middle Aptian (Gargasian) is developed to the north of Loveč (the villages Goran, Dojrenci and Joglav) and only in the Iskăr river valley the Aptian is represented in its full volume.

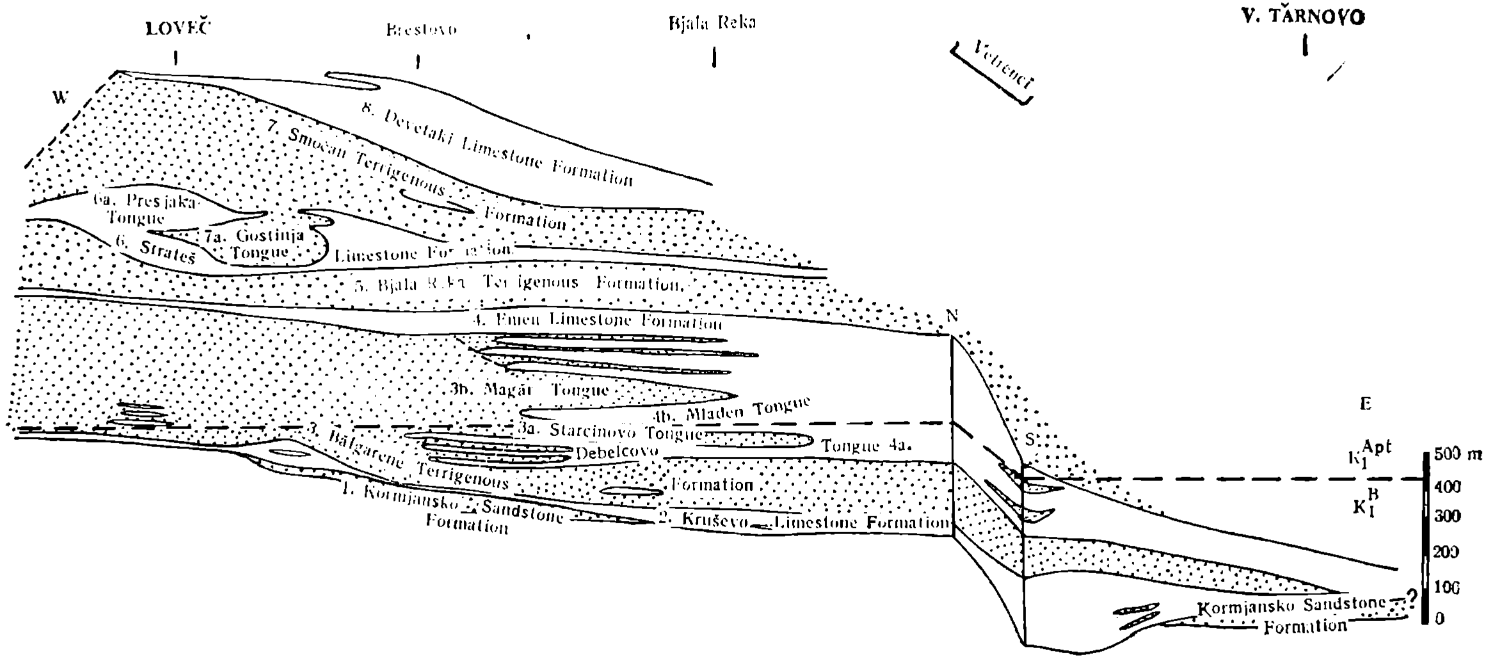


Fig. 9. Section of the Loveč Urgonian Group (after Х р и с ч е в, 1966)

The Aptian is characterized by rich bivalvs and gastropod faunas (Б о н ч е в, 1932; 1937), foraminifera and rare ammonites.

V. T z a n k o v (В. Ц а н к о в, 1960) reports the Lower Aptian *Procheloniceras albrechtiaustriae* (U h l.) from Joglav village, Loveč District. As indicated by K h r i s c h e v (Х р и с ч е в, 1966), this ammonite originates from the upper part of the Smočan Terrigenous Formation. To a lower level belongs *Deshayesites callidiscus* C a s., found near the wall of the Alexander Stambolijski barrage. This ammonite originates from the marls of the Madara tongues of the Bălgarene Formation (Х р и с ч е в, 1966).

T. K o v a t c h e v a (П и м п и р е в, К о в а ч е в а, 1985) has found characteristic Lower Aptian foraminifera associations among the terrigenous-carbonate sediments (Roman Formation) in the Straža syncline:

— At Uzunite village, Gabrovo District: *Gavelinella barremiana* B e t t., *Ammomarginulina loricata* L e o b l., T a p p., *Haplophragmoides nonioninoides* (R e u s s), *Verneuilinoides schizea* C u s h., A l e x., *Ammobaculites torosus* L e o b l., T a p p., *Pseudocyclammina* aff. *cylindrica* R e d m., *Opthalmidium gaultinum* (ten D a m), *Lenticulina subgaultina* B a r t., *Hedbergella infracretacea* (G l a e s s n.);

— Section at Skalsko village, Gabrovo District: *Gaudryina borimensis* K o v., *Haplophragmium subaequeles* (M j a t l.), *Ammobaculites torosus* L e o b l., T a p p., *Choffatella decipiens* S c h l u m b., *Flabellammina urgonensis* B a r t., K o v., *Trocholina apticnsis* J o v., *Haplophragmoides nonioninoides* (R e u s s);

— Section at Mičkovci village, Gabrovo District: *Triplasia georgsdorfensis* B a r t., B r a n d, *Gevelinella barremiana* B e t t., *Arenobulimina meltae* K o v., *Ammomarginulina loričata* L e o b l., T a p p., *Lenticulina subgaultina* B a r t., *L. subangulata* R e u s s, *Ammobaculites torosus* L e o b l., T a p p., *Verneuilinoides schizea* C u s h., A l e x., *Haplophragmoides nonioninoides* (R e u s s).

The facies of the Aptian is most varied in the Central Fore-Balkan. Thickness: 1000-1500 m.

Eastern Fore-Balkan

In the area between Jantra river to the west and Luda Kamčija river to the east, Lower Cretaceous sediments are relatively most widely developed, forming almost entirely the structures in this region. To the east of Luda Kamčija river, along the valley of Armera river, Lower Cretaceous rocks build up the structures of the Predža, Asparuhovo and Gradište anticlines and of the isocline folds in the area to the east of Šerba nature reserve. To the northeast of Armera river the Lower Cretaceous is found in boreholes in the Dolna Kamčija Depression.

The Lower Cretaceous in the Eastern Fore-Balkan has been the object of numerous studies (T o u l a, 1890-1896; З л а т а р с к и, 1907; A c k e r m a n n, 1932; К о е н, 1933; С т е ф а н о в, 1934; М а н д е в, 1942; 1945; Н и к о л о в, 1960, 1962b; Н и к о л о в, Х р и с ч е в, 1965b, etc.).

The Berriasian is developed everywhere in the Eastern Fore-Balkan, being seen on the surface in the cores of the Bujnovci, Elena, Bukak, Omurtag, Preslav and Asparuhovo anticlines, as well as in the northern limb of the Lipovo anticline. Its sediments have been studied in the outcrops in the Fore-Balkan and in all deep drillings. In most boreholes it is difficult to differentiate clearly the Berriasian due to the absence of palaeontological evidence, although its presence in the continuous stratigraphic succession is indisputable.

The Berriasian manifests considerable facies heterogeneity in the Fore-Balkan and in the transition zone to the Moesian Platform, where it is connected with the sediments of the Kostel, Hănevci, Zlatarica and Tiča Formations. Clear facial zonality of the Berriasian sediments is observed from south to north. The complete section of the Berriasian is revealed in the Bujnovci, Elena and Preslav anticlines.

In the Bujnovci anticline the Berriasian is represented by alternation of packets of sandstones, polygenous conglomerates, gritstones and marls (Kostel Formation), and by aleuritic marls and strongly mixed (wacke-type) rocks (Hănevci Formation). The sediments are very well dated and differentiated by means of rich ammonite faunas (N i k o l o v, 1982).

The Berriasian in the core of the Elena anticline is connected with the Zlatarica Formation. It is represented by sandstones, siltstones, slightly aleuritic and aleuritic marls and clayey limestones. Here, too, as in the southern part of the Elena region, marls and sandstones are differentiated in separate packets with average thickness about 20 m, though they also occur in packets up to 80 m thick. Conglomerate intercalations and lenses occur extremely seldom. In addition to the marked macrorhythmic nature, manifested in the alternation of thick packets of marls and sandstones, in some cases a finer rhythmic pattern is also observed.

The section of the Berriasian in the Elena anticline in the gorge of Zlatariška Reka river has been characterized in detail by N i k o l o v (in N i k o l o v, S a p u n o v, 1977) (Fig. 10).

Borehole R-6 Elena, located in the gorge of Zlatariška Reka river, to the south of Panajotova Vodenica, starts from packet No. 15, i. e. from the lower part of the Berriasian (*Pseudosubplanites grandis* Zone). The borehole crosses 2550 m in the Zlatarica Formation. Reducing this thickness in order to take into account the slope of the drilling and the slope of the beds, the actual thickness of the Berriasian in the borehole is 313 m, its total thickness being 978 m together with the naturally exposed part.

Fossils characterizing the lower part of the Berriasian have been found in several intervals in borehole R-4 Omurtag:

— At 1080 m: *Berriasella* (*B.*) *oppeli* (K i l.), *Calpionella alpina cadischi* D o l., *C. elliptica* C a d., *Stenosemellopsis hispanica* (C o l.) and *Lorenziella hungarica* Kn.

— At 1106.50 m: *Calpionella alpina cadischi* D o b., *C. elliptica* C a d. and *Lorenziella pseudoserrata* (C o l.).

— At 1209 m: *Calpionella alpina cadischi* D o b., *Lorenziella pseudoserrata* (C o l.) and *L. hungarica* K n.

Very rich foraminifera associations, known from the Berriasian sediments in other boreholes as well (e. g. R-7 in Veliko Tărnovo), are also found.

The Berriasian is directly established in the boreholes of this Fore-Balkan zone or by correlation with the outcrops from the Elena, Bukak, Omurtag and Preslav anticlines. Everywhere in this zone it is connected with the sediments of the Tiča Formation. The thickness of the Berriasian part of the Tiča Formation in this zone is between 350 and 643 m.

The development of the Berriasian around the villages Mirovo, Tutrakanci, Sultanci, Padina and Junak, is extremely interesting. In this strip it is built of the Tiča Formation, but here it does not contain sandstone intercalations and the limestones are purer. Thin intercalations of light limestones of Kaspičan type are also observed (Padina village). The specific features of the Tiča Formation in the zone of the villages Mirovo — Sultanci — Junak testify to the immediate proximity to the transition to Kaspičan type neritic carbonate sediments.

A number of characteristic calpionellid associations (identified by Prof. J. R e m a n e) and ammonite taxa were established in the boreholes near the villages Sultanci, Hrabrovo, Bozvelijsko, Junak and Padina, which made it possible to identify the Berriasian and to differentiate the Jurassic from the Cretaceous:

— *Berriasella* (*B.*) *subcalisto* — a species characteristic of the lower and middle parts of the Berriasian — is found at borehole R-2 Junak at 982.20 m.

— The upper part of the Berriasian is demonstrated by *Malbosiceras malbosi* (P i c t.), found at 1001.60 m at R-3 Junak.

— *Calpionella alpina* L o r., *Tintinnopsella carpathica* (M u r g., F i l.), *Calpionellopsis* sp., *Calpionellopsis simplex* (C o l.) and *Calpionellopsis oblonga* (C a d.) are found in R-6 Sultanci at 1331.50 m.

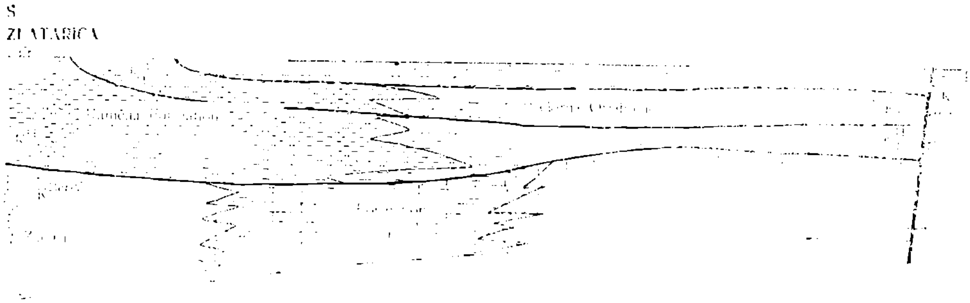


Fig. 10. Relationships between the lithostratigraphic units along the Zlatarica — Čapaevo line

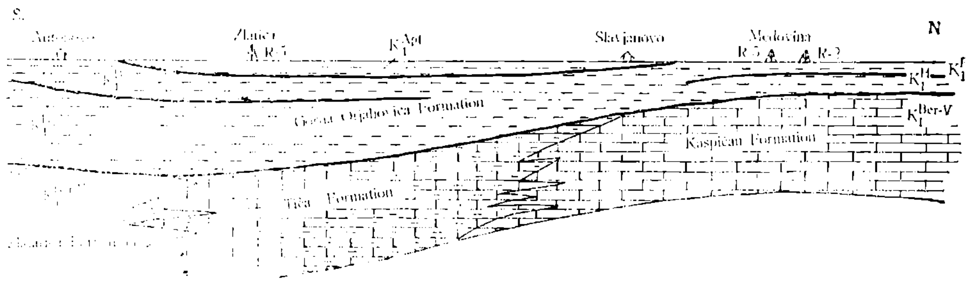


Fig. 11. Relationships between the lithostratigraphic units along the Antonovo — Medovina line

This association characterizes the upper part of the Berriasian (calpionellid zone D 2-3, after R e m a n e, 1963).

The Valanginian in the Eastern Fore-Balkan is represented by terrigenous, clayey-calcareous and mixed rocks (Zlatarica, Hănevci, Tiča and Kamčija Formations).

The differentiation of the Valanginian from the Berriasian is performed by means of many ammonite taxa occurring frequently in the outcrops.

In the southern part of the Elena region the Valanginian is revealed in the northern limb of the Bujnovci anticline, where it is represented by aleuritic marls and mixed rocks (Hănevci Formation), characterized by rich ammonite associations (Н и к о л о в, 1960; N i k o l o v, 1982).

In the north, in the Elena and Bukak anticlines, Valanginian sediments are revealed over comparatively wider areas, enveloping the Tithonian-Berriasian core of the Elena anticline and the Berriasian core of the Bukak anticline. They are represented by sandy-marl rocks (Zlatarica Formation) and by marls (the base of the Kamčija Formation) (Fig. 11).

In the Omurtag and Preslav anticlines the Valanginian is represented by clayey limestones with intercalations of marls and sandstones (Tiča Formation) and of marls (Kamčija Formation).

In the gorge of Vrana river, to the south of Tărgovište, it is difficult to differentiate the Valanginian from the upper part of the Berriasian. It is represented mainly by clayey limestones among which there occur intercalations of micrograined limestones, irregularly distributed, but on the whole rare.

Valanginian sediments in the gorge of Tiča river, south of Preslav, are of the same character, the only difference being the more abundant presence of sandstone beds in the upper part of the Tiča Formation.

To the east of the Preslavska Planina mountain, Valanginian sediments are transversed by the boreholes near the villages Zlatar and Veselinovo, and in the Asparuhovo region.

The following association characteristic of the Valanginian was found at borehole R-9 Veselinivo at 1502 m: *Neocomites* sp. indet. and *Neocomites platycostatus* S a y n.

The easternmost outcrops of Valanginian sediments are in the core of the Asparuhovo anticline, to the south and southeast of Asparuhovo village, where they are represented by alternation of marls and clayey limestones (Tiča Formation). Intercalations of fine-grained sandstones are found in some places.

A definite regularity is observed in the Valanginian section in the Asparuhovo anticline, expressed as predominance of the clayey limestones in the lower part, which decrease upwards at the expense of the marls.

The characteristic Valanginian ammonite *Kilianella roubaudiana* (d'O r b.) was found in borehole S-1 Asparuhovo at 192 m.

Characteristic Valanginian ammonites were also found in the valley of Razkračenica river, south of Asparuhovo village: *Sarasinella walkeri* (U h l.), *S. trezanensis* (L o r y) and *Neocomites* (*N.*) *neocomiensis* (d'O r b.).

The characteristic Upper Valanginian ammonite species *Neocomites* (*T.*) *teschenensis* (U h l.) was found at borehole R-54 Samotino at 3498.50 m.

In borehole R-1 Junak (Fig. 12) the Valanginian is well marked by the presence of *Calpionellites darderi* (C o l o m) at 641.50 m and *Lorenziella hungarica* K n a u e r, N a g y at 904.50 m.

The thickness of the Valanginian sediments in the Eastern Fore-Balkan is 306-840 m.

The Hauterivian in the Eastern Fore-Balkan is represented by marly sandstone sediments of the Kamčija Formation, by the mixed rocks of the Hănevci Formation and by the marls with intercalations of sandstones and siltstones of the Gorna Orjahovica Formation in the transition to the platform.

The area of Veliko Tărnovo, Zlatarica, Ljubenci, Omurtag, Preslav, Veselinovo, Komunari, Asparuhovo, Rudnik, Samotino and Kamčija (R-9) is characterized by the general development of the Kamčija Formation, which is represented mainly by thick packets of marls and sandstones. The Formation is characterized by the lense-like shape of the sandstone packets and beds.

In the southwestern outcrops of the region (Veliko Tărnovo and Elena areas) the Hauterivian is represented by aleuritic marls, mixed rocks, gritstones and conglomerates, the latter being known from the areas along the rivers Belica and Veselina.

In the more northern outcrops of Hauterivian sediments around the villages Kăpinovo, Zlatarica, Dedinci, Rosno and Dlăžka Poljana, the quantity of the sandstones and siltstones is relatively smaller compared with the southern outcrops. Psephites do not occur here, and the marls are less aleuritic. This is particularly characteristic of the more northeastern outcrops from the northern limb of the Bukak anticline. The thickness of the Hauterivian in these places is around 1200 m.

The natural outcrops of the Hauterivian sediments are very rich in ammonite associations (Н и к о л о в, Х р и с ч е в, 1965b; Н и к о л о в, 1969a). Characteristic Hauterivian ammonites have also been found in a number of boreholes from this zone.

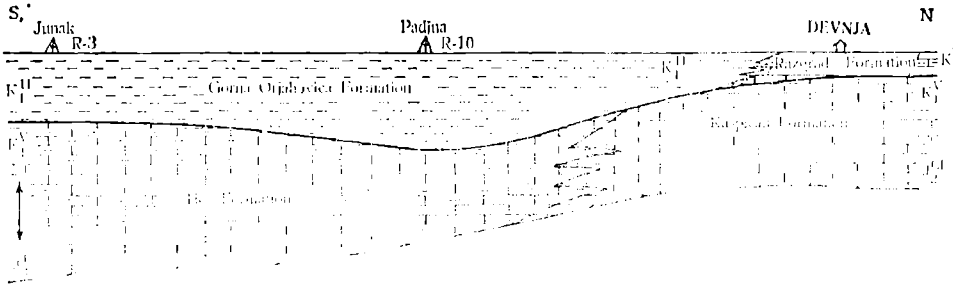


Fig. 12. Relationships between the lithostratigraphic units along the Junak — Devnja line

Characteristic Hauterivian fossils have been found in the outcrops of the Asparuhovo region, and they permit accurate correlation with the borehole sections: *Lyticoceras* spp., *Crioceratites duvali* L é v., *Olcostephanus astierianus* (d'O r b.), *O. guebhardi* (K i l.) and *Duvalia dilatata* (B l.).

The following Hauterivian ammonites have been found in the outcrops close to R-2 Veselinovo: *Lyticoceras* sp., *Crioceratites* spp., *Olcostephanus jeannoti* (d'O r b.). *O. astierianus* (d'O r b.), *O. guebhardi* (K i l.), etc.

The upper boundary of the Hauterivian in the region is denuded — the Hauterivian deposits are usually covered by Quaternary sediments. Only in the Veliko Tărnovo area and in the southwestern part of the Provadija Plateau, as well as in some peripheral parts of the Eastern Fore-Balkan, the Hauterivian is covered normally by Barremian deposits, and in the easternmost parts — by Upper Cretaceous sediments.

The thickness of the Hauterivian sediments in the Eastern Fore-Balkan is 1200-1800 m. Smaller thicknesses are connected with later denudation or with the transition towards the Gorna Orjahovica Formation to the north.

The Barremian is well developed in the Eastern Fore-Balkan. Specific mixed (wacke-type) rocks of the Hănevci Formation are revealed in the southernmost strip, being replaced to the north by marly sandstone sediments (Kamčija and Gorna Orjahovica Formations), widely represented in the middle and northern strips of the Eastern Fore-Balkan. Everywhere Barremian sediments overlie with transitions the Hauterivian deposits.

In the valley of Jantra River and around Veliko Tărnovo, Gorna Orjahovica and Ljaskovec, the Barremian is represented by marls,aleuritic clayey marls and sandstones. These sediments are also found in the southeast — to the south of Malăk Čiflik village and to the west of Dragiževo village. In the area under investigation the Barremian also comprises the lower part of the Urgonian complex.

In this strip of the Fore-Balkan Barremian sediments are transversed only by the drillings in the Veliko Tărnovo area, while the remaining boreholes to the east usually start in older rocks.

In the outcrops Barremian sediments are known from the valley of Jantra river, around Gorna Orjahovica and Ljaskovec, where marls, aleuritic clayey marls and sandstones are developed. These deposits are revealed further east as well — to the south of Malăk Čiflik and to the west of Dragiževo villages. In the Jantra river valley they are covered by Urgonian limestones.

To the southwest and south of Dobri Djal village, around Rodina village and to the east of Džuljunica village, Gorna Orjahovica region, the Barremian is represented by clayey marls with intercalations of thick-bedded sandstones and rarely of limestones. *Crioceratites quenstedti* (O o s t.), *Barremites difficilis* (d'O r b.), *B. hemiptychus* (K i l.), *B. subdifficilis* (K a r.), *B. davidovi* (T r.) and *Pseudosaynella strettostoma* (U h l.) are found among these sediments.

To the northeast of Gorsko Novo Selo village the Barremian section is formed of clayey marls, thin-bedded fine-grained sandstones (5-50 cm) and thick-bedded sandstones (1 - 3.50 m). *Phyllopachiceras infundibulum* (d'O r b.), *Crioceratites* sp., *Barremites difficilis* d'O r b., *Barremites* spp. and *Hamulina* sp. are identified from the marls in this section.

Along the Goljama Reka river the Barremian is represented by calcareous aleuritic clays, clayey marls, marls, sandy and aleuritic marls, siltstones and sandstones. The amount of the terrigenous component increases from below, and sandstones and siltstones are discovered in the upper part of the Barremian. *Barremites* sp. and *Nicklesia* sp. were found among the marls at Ljubenci village.

In the western and southwestern slopes of the Liljak Plateau the Barremian is found to the south of Presijan, to the east of Konak, to the northeast of Dolna Kabda, to the west of Aprilovo, to the south of Zvezda, around Slavjanovo and to the southeast of Svetlen villages. In these places the sections are built of calcareous claystones, aleuritic slightly calcareous claystones, marls, siltstones and sandstones, attributed to the Hauterivian in the past (М а н д е в, 1945; Б о н ч е в, 1957b). Their Barremian age is proved by *Barremites difficilis* (d'O r b.), *Barremites* spp., *Holcodiscus* sp. and *Pseudosaynella strettostoma* (U h l.).

Among the marls around the villages Svetlen and Zvezda S t o y a n o v a-V e r g i l o v a (С т о я н о в а-В е р г и л о в а, 1962) has found the following Barremian belemnite association: *Mesohibolites minaret* (R a s p.), *M. varians* (S c h w.), *M. beskidensis* (U h l.), M. *falauxi* (U h l.), *M. notus* (M i s c h.), *M. tzankovi* (M a n d.), *Hibolites pistiliformis* (B l.) and *Duvalia grasiana* (D u v.-J o u v e).

The strip of outcrops of Barremian sediments is also traced along the northern and eastern ends of the Liljak Plateau, to the south of Gloginka and to the north of Košničari villages, and to the west of the villages Podgorica and Văbel. In these places the section is built by aleuritic calcareous claystones, marls and thin intercalations of sandstones. The latter increase in the section upwards.

In the valley of Stara Reka river and in the area to the north and east of Kipilovo village, Kotel region, the Barremian is represented by mixed rocks, aleuritic clayey marls and fine- to coarse-grained sandstones which contain gravel grains in some places at the base and pass into gritstones. The boundaries of the Barremian stage in the concrete sections in these places cannot be determined due to lack of faunistic data.

Barremian sediments of the same type are revealed to the northeast and east of Tiča village towards the villages Mogilec, Ablanovo, Černookovo, and from there to the east through the area to the south of the villages Vărbica, Nova Bjala Reka, Bjala Reka and Tiševica, through Riš, they continue to the south of the villages Veselinovo and Poljacite to the localities west of Asparuhovo village (Б р е с к о в-с к и, 1974).

Ammonite fauna occurs very rarely in the Barremian sediments along Gerila river and this is probably related to the markedly mixed (unsorted) character of the rocks. *Crioceratites emerici* L é v., *Crioceratites* sp., *Holcodiscus* sp. and *Hamulina* sp. were found.

The thickness of the Barremian sediments may be estimated only approximately, because the lower and upper boundaries of the stage cannot be fixed accurately due to the scarce ammonite fauna. It is of the order of 1000 m. Frequent sand stone intercalations appear in the uppermost part of the exposed section, followe by the Elešnica Terrigenous-Limestone Formation.

Crioceratites emerici L é v., *Barremites difficilis* (d'O r b.) and *Barremites* sp. were identified from the Barremian sediments in this area.

Around Riš and to the south of Veselinovo villages A c k e r m a n n (1932) has found: *Crioceratites emerici* L é v., *Barremites cassidoites* (U h l.), *Barremites difficilis* (d'O r b.), *Pseudosaynella* cf. *strettostoma* (U h l.) and *Barremites* spp.

The Barremian at Jankovo village is represented by medium-grained sandstones at the base of the outcrop. The sandstones are solid, greyish-blue to yellowish. Thin (10-15 cm) layers of clayey siltstones are intercalated. The thickness of these sediments is 15-18 m. Among them there is a 60-70 cm thick layer of clayey marls. They are slightly sandy and easily distinguished from Hauterivian marls. Here the Barremian sediments are in the core of a small anticline. *Barremites* aff. *difficilis* (d'O r b.) and *Nicklesia* sp. were found in them. E. B o n č e v et al. (Б о н ч е в et al., 1957) report also *Crioceratites barremensis* (K i l.).

The outcrop of Barremian sediments at Jankovo village is the only dated find of Barremian deposits in the southern edge of the Provadija syncline. A formation of both friable and solid sandstones is established above them, which are assumed to be Aptian (В. Ц а н к о в, 1942).

The thickness of the Barremian sediments to the south of Veliko Tărnovo is above 200 m, in the area of the villages Rodina, Gorsko Novo Selo and to the south of Džuljunica — 180-220 m, in the valley of Goljama Reka river — up to 200 m. Barremian sediments are with greatest thickness in the southern part of Gerlovo (Vărbica and Bjala Reka villages), where they are above 1000 m thick. To the south of Veselinovo village Barremian sediments are above 600 m thick. Generally speaking, Barremian deposits are the thickest in the middle part of the Eastern Fore-Balkan (Gerlovo), becoming thinner to the west and especially to the east.

The Aptian is extensively developed in the Eastern Fore-Balkan, where it is represented by a varied rock spectrum. There are good outcrops around the towns Veliko Tărnovo, Ljaskovec and Gorna Orjahovica, to the south of the villages Džuljunica, Gorna Orjahovica region (Romana peak), as well as to the east of the villages Tiča—Bjala Reka—Riš until approximately Kumunari—Asparuhovo.

Aptian sediments are widespread in the area between the villages Kozarevec, Džuljunica, Kesarevo, Slivovica, Gorsko Novo Selo, Rodina and Dobri Djal, where they build the upper parts of the heights. Aleuritic calcareous claystones and fine- to medium-grained sandstones are found on the southwestern slope of Romana peak at the base of the Aptian Stage. About 5 m oölitic and organogenic limestones follow above these deposits, further above there are 50 m aleuritic clayey marls with intercalations of sandstones, 3 m solid thick-bedded sandstones, about 47 m aleuritic clayey marls, 5 m cream-coloured organogenic limestones, among which there are numerous remains of corals, bivalvs and brachiopods. On top there is a packet of aleuritic clayey marls covered by a pack of sandstones.

In the quarry to the south of Dobri Djal village the upper part of the Aptian section is exposed, built of organogenic-fragmentary limestones, sandy limestones, sandstones and marls.

There are vast outcrops of Aptian sediments along Goljama Reka river. In the valley of this river, between the villages Mirovo, Braknica, Novo Gradište and Semerci the Aptian is built in its base of a formation consisting of sandstones, clayey and calcareous sandstones, and aleuritic calcareous claystones. These deposits overlie normally Barremian sediments, with the exception of the localities around Ljubenci village, where local disconformity as found. The described deposits were assumed to be Hauterivian by M a n d e v (М а н д е в, 1942). Upwards in the section there are impure calcareous sandstones with Orbitolinidae, orbitolinic sandy limestones, oölitic and granular limestones.

The described calcareous-sandy sediments form the upper part of the Aptian section around the villages Mirovo, Novo Gradište, Ljubenci, Semerci, Dolna Zlatica, Gorna Zlatica and Braknica, to the west of Razdelci and Baba Tonka, and to the south of Gorica. It should be pointed out that, generally speaking, impure calcareous sandstones with Orbitolinidae predominate in the section, dominating completely its uppermost part. M a n d e v (М а н д е в, 1942) reports the following species from these sediments: *Orbitolina lenticularis* (B l u m.), *Terebratula depressa* L a m., *T. biplicata* S o w., *Rhynchonella lata* (d'O r b.), *Trigonia ornata* d'O r b. and *Hibolites semicanaliculatus* (B l.).

At 250 m northwest of the linesman's lodge between Stražica and Asenovo railway stations the height is built of Aptian sandstones. They are calcareous, filled in many places with Orbitolinidae and organogenic detritus. Weathering results in cavities everywhere. Poorly preserved ammonites belonging to genus *Deshayesites* occur. These sandstones are intercalated by clayey marls with up to 0.50 m thickness of the individual beds. The visible thickness of the exposed part of the Aptian is about 170 m. Clayey marls begin to predominate in the east-northeast, and already in the Gjajurkite locality, 1 km southwest of Asenovo village, the southern slope of the plateau is built at the base of slightly aleuritic clayey marls with intercalations of fine-grained sandstones.

They are followed upwards by sandstones with Orbitolinidae and organogenic detritus, which alternate with aleuritic clayey marls, the latter being of subordinate significance here. This is the middle part of the exposed section. The upper part is built of clayey marls (2-3 m thick) which alternate with sandstone beds up to 0.50 m thick, while in the middle part their thickness is often above 1 m.

To the northeast of Asenovo village the Aptian is built in its base of 20-25 m clayey marls, followed above by about 8 m finegrained slightly calcareous thin-bedded sandstones, 50-52 m clayey marls intercalated with calcareous sandstones 5-10 cm thick. *Deshayesites lavaschensis* (K a s.), *Deshayesites* spp. and *Cheloniceras* sp. were found in these sediments.

Above these sediments there is a pack (about 50 m thick) of clayey marls, intercalated with sound calcareous orbitolinic sandstones, among which *Deshayesites* sp. was found. The section ends with a packet (about 60 m thick) of clayey marls, intercalated with fine-grained limestones.

Tracing the changes in the facies of Aptian sediments from the town of Stražica to the north and northeast towards the villages Asenovo, Vodica and Posabina, reveals a new tendency towards reduction of the terrigenous and increase of the carbonate component. Sandstones decrease rapidly or are gradually replaced by limestones, clayey marls increase and begin to predominate in the section. Evidently, the transition from terrigenous to clayey-calcareous type of Aptian sediments takes place in the area between Stražica and Asenovo to the south, and the villages Kamen, Vodica and Posabina to the north.

Along the upper reaches of Černi Lom river and in the Liljak Plateau the Aptian is represented by sandstones with intercalations of aleuritic to almost pure calcareous claystones and marls. Sandstones predominate in the section, being with different grain size: from fine-grained to gravel-type. The latter often contain detritus as well. Bivalv's shells and rare single corals also occur.

To the north and northwest of Zavetno village the Aptian is represented by orbitolinic sandstones and aleuritic clayey marls, among which *Deshayesites* cf. *deshayesi* (L é v.) and *Neohibolites* sp. were found.

The outcrops of Aptian rocks in the plateau north of Zavetno village are the last outcrops in which sediments of the types found in the Fore-Balkan are observed. To the north they rapidly pass into clayey-calcareous sediments typical of the Platform.

In Lisa Planina mountain the Aptian is represented by a terrigenous formation which overlies dated Barremian sediments to the south in the upper reaches of Kamčija river. It is built predominantly of sandstones and mixed rocks. Lenses of gritstones and conglomerates occur among the sandstones. Sometimes the sandstones are characterized by coarse cross-lamination, whereby the cross-series dip to the south. Generally speaking, the Aptian terrigenous formation in these places is very varied with respect to its granulometric composition and it is characterized by frequent wedges of psephite layers and lenses.

Aptian sediments have a more special development southeast of Vărbica, south of Bjala Reka river and towards Riš villages. Mixed rocks are found in these places at the base of the Aptian section, in some places with intercalations of sandstones, followed above by the Elešnica Terrigenous-Limestone Formation. The following species were found in the mixed rocks at the base of the Aptian south of Riš village below the Elešnica Formation: *Deshayesites* cf. *weissi* (N e u m., U h l.), *Deshayesites* sp. indet., "*Crioceratites*" cf. *abichi* (B a c., S i m.), *Ancyloceras waageni* (A n t h.) and *Toxoceratoides* sp. (aff. *royerianus* d'O r b.).

The Elešnica Formation is best developed along Elešnica river to the south of Bjala Reka village. Its composition here is very varied, being built of different limestones, sandstones, conglomerates, siltstones, as well as aleuritic claystones with different quantity of clastic material.

The thickness of the Elešnica Formation in the section along Elešnica river is about 280 m. The described sediments are also exposed to the east near the localities southwest of Riš village.

A relatively narrow strip of Aptian sediments — sandstones and aleuritic clayey marls — is found along the northern limb of the Predža anticline between the villages Kălnovo and Komunari. The best section of this strip is exposed east of Kălnovo village, where the Aptian is represented by sandstones, friable clayey sandstones and aleuritic clayey marls.

Among the Aptian sediments in the eastern part of the Preslav region, B o n č e v et al. (Б о н ч е в et al. 1957) report: *Nerinea astrachanica* R e n g., *Avelina aptiensis* P i c t., C a m p., *Lima tombeckiana* d'O r b., *Pecten* (*Chlamys*) *robinaldinus* (d'O r b.), "*Douvilleiceras*" cf. *cornuelianum* d'O r b. and *Neohibolites semicanaliculatus* (B l.). These are the main outcrops of Aptian sediments in the Eastern Fore-Balkan.

The thickness of the Aptian sediments varies in the different parts of the Eastern Fore-Balkan: 250 to 600 m. Aptian sediments are the thickest in the middle part of the Eastern Fore-Balkan—the area of Lisa Planina mountain and the southern part of Gerlovo, where they are also most coarsely terrigenous.

The Aptian in the Eastern Fore-Balkan is represented only by its lower substage — Bedoulian. Middle and Upper Aptian sediments are absent.

1.3.5. The Moesian Platform

In the Moesian Platform the Lower Cretaceous has ubiquitous distribution. The transitional zone between the Fore-Balkan and the Platform is also included in this area for consideration, because the Lower Cretaceous sediments in it have a closer facies to that of the Platform.

In the northwestern part of the Moesian Platform (the Lom Depression) Lower Cretaceous sediments, especially in the lower part of the series, manifest greater affinities to the sections in the northern strip of the Western Fore-Balkan than to the remaining regions of the Platform to the east of the Kozloduj — Kneža line.

In the Lom Depression the Lower Cretaceous is presented in its full volume from the Berriasian to the Albian included. In this region Lower Cretaceous sediments are connected with a transition both with the underlying (Tithonian) and with the overlying (Cenomanian) sediments. The upper part of the Lower Cretaceous is absent only in Vidin District (Vidin and the villages Gomotarci, Košava, Milčina Lăka, Simeonovo), and Cenomanian marls overlie directly Valanginian limestones beds or Simeonovo Formations (at borehole R-1 Simeonovo).

In Vidin District the Lower Cretaceous is represented by the **Berriasian** and **Valanginian**, which are not differentiated. They are connected with various limestones and with the dolomitized limestones of the type of the Kaspičan Formation. Its upper part is denuded everywhere, being covered by Cenomanian clayey-calcareous (mainly marl) sediments.

The thickness of the Berriasian-Valanginian sediments in this region is 495-622 m.

In the region of the villages Dălgodelci, Gorna Gnojnica, Komoštica, Kovačica and Medkovec, Lom area, the Lower Cretaceous is found in its full volume. At its base is the Berriasian which is represented by dense and partly intraclastic limestones of the Gložene Formation. The presence of the Berriasian in this region has been proved for the first time by J o v č e v a and T r i f o n o v a (Й о в ч е в а, Т р и ф о н о в а, 1964). In borehole R-6 Dălgodelci (depth 3364-3422 m) they have found: *Berriasella* sp., *Calpionella elliptica* C a d., *Tintinnopsella carpathica* (M u r g., F i.) and *Calpionellopsis oblonga* (C a d.), as well as many foraminifera. The thickness of the Berriasian in this region is 58 -70 m.

The sediments of the **Valanginian**, which is connected with the Salaš Formation, lie higher up with gradual transitions. The characteristic Upper Valanginian ammonite *Busnardoides subcampylotoxus* N i k. was found in borehole R-1 Hajredin 2880.80 m). From borehole R-6 Dălgodelci J o v č e v a and T r i f o n o v a (Й о в ч е в а, Т р и ф о н о в а, 1964) report *Calpionellites darderi* (C o l.) — a characteristic Valanginian species.

The thickness of the Valanginian in this region is 75 -125 m.

The Hauterivian is represented by clayey limestones with intercalations of marls (Salaš Formation) and by micrograined, in some places slightly clayey and slightly aleuritic limestones from the peripheral part of the Salaš Formation.

Characteristic ammonites were found in boreholes R-2 Komoštica, R-1 and R-6 Dălgodelci and R-1 Hajredin: *Lyticoceras* sp., *Crioceratites rodighieri* D i m., *C. duvali* L é v., *C. quenstedti* (O o s t.), etc. The thickness of the Hauterivian sediments in this region is 142-280 m.

The Barremian is represented by micrograined slightly clayey limestones. Among them *Barremites difficilis* (d'O r b.) and *B. subdifficilis* (K a r.) were found in borehole R-6 Dălgodelci at 3145 m. The thickness of the Barremian sediments is 105-126 m.

The sediments of the **Aptian** are connected through gradual transitions with the Barremian sediments. The lower and middle parts of the Aptian sections are built of clayey limestones, whereas the upper part is formed of marls to slightly aleuritic clayey limestones (Trămbeš Formation).

Characteristic Upper Aptian bivalvs: *Aucellina caucasica* (B u c h.) and *A. pompechii* P a v l., were found in borehole R-6 at 2823.50 to 2825.20 m.

Rich foraminifera associations are also found among the Aptian sediments in this region. The thickness of the Aptian is 123-309 m.

The Albian is represented by marls which are connected with a gradual transition with the Aptian marls. They are covered by Cenomanian marls with a fast lithological transition.

Characteristic Albian macrofossils were found in a number of intervals in borehole R-1 Kovačica at 1839 -1840 m: *Idiohamites favrinus* (P i c t.), *Idiohamites* sp. indet., *Hamites intermedius* S o w., *Hamites* sp. indet. and *Mortoniceras* sp. indet which define the Late Albian.

In the same borehole the Lower Albian ammonite *Douvilleiceras* ex gr. *D. monile* (S o w.) was found at 1883.50 m, whereas *Uhligella* sp. indet. and *Aucellina* sp. were found at 1886-1887.50 m.

The Albian has also been proved with many foraminifera (Й о в ч е в а, 1966). The thickness of this stage is 122-148 m.

Extensive information about the development of the Lower Cretaceous in Central Northern Bulgaria was obtained in the investigations of the boreholes (Н и к о л о в, 1972; Н и к о л о в, Р у с к о в а, 1972; Н и к о л о в et al., 1974).

The Berriasian is developed ubiquitously in Central Northern Bulgaria. It manifests relative facial stability in the central part of the area, where it is connected with the neritic sediments of the Kaspičan Formation. This stage is characterized by considerable facial heterogeneity in the southern and western parts of the area, where it is connected with the gložene Formation, with the Salaš and Tiča Formations and with the transitions of the Kaspičan-Salaš (or Salaš-Kaspičan) Formation.

It is impossible to differentiate the Berriasian in most boreholes due to the absence of palaeontological data, but in these cases its presence in the continuous stratigraphic succession is indisputable.

The lower boundary of the Berriasian, which is also the boundary between the Jurassic and the Cretaceous, has been determined with certainty only in the boreholes R-1 Kneža and R-1 Bărdarski Geran. Of considerable interest are the palaeontological successions in borehole R-1 Kneža, where many calpionellids are found.

The lower boundary of the Berriasian in borehole R-1 Kneža is marked at 2970 m. The *Calpionella alpina* find at a depth of 3132-3134 m is probably of Upper Tithonian age.

The boundaries of the Berriasian in R-1 Kneža thus outlined connect the stage with the lower part of the Salaš-Kaspičan Formation, which is 406 m thick, i. e. approximately half of the total thickness of the Formation.

Near Bărdarski Geran village the Berriasian is connected with the lower half of the Kaspičan-Salaš Formation, the Berriasian part in borehole R-1 Bărdarski Geran being 350 m thick, the total thickness of the Formation — 817 m.

There exist palaeontological indications of the Berriasian in many other boreholes in the region as well, although it is not possible to outline the boundaries of the stage, due to the lack of a core.

There are reliable data about the Berriasian in borehole R-2 Beglež, where the presence of the *Calpionellopsis* Zone has been found at a depth of 2907 m in the Salaš-Kaspičan Formation. With its stratigraphic position in the section of this borehole this zone dates the upper part of the Berriasian.

In the central, eastern and northern parts of the area, where the Berriasian is connected with the Kaspičan Formation, no reliable palaeontological evidence has been found for its accurate dating and differentiation.

Judging by the law-governed regularities in the development of the Berriasian in the transition zones of the Kaspičan Formation, with comparable thicknesses in the zone of the typical development of the Kaspičan Formation, the Berriasian comprises also the greater part of the lower half of this Formation, which is 300-400 m thick.

In the western, southwestern and southern parts of the area the Berriasian is connected with the deep-sea sediments of the Gložene, Salaš and Tiča Formations. Transient sediments are developed in the strip Kozloduj — Bărdarski Geran — Kneža — Umarevci (Salaš-Kaspičan or Kaspičan-Salaš Formation) (Fig. 13) whereas in the transitional strip between the Fore-Balkan and the Platform the Berriasian is represented by a transitional type of sediments of the Kaspičan-Tiča and Salaš-Černi Osăm Formations. As has already been mentioned, in the larger part (central, northern and eastern) of the area the Berriasian is represented by the neritic carbonate facies of the Kaspičan Formation.

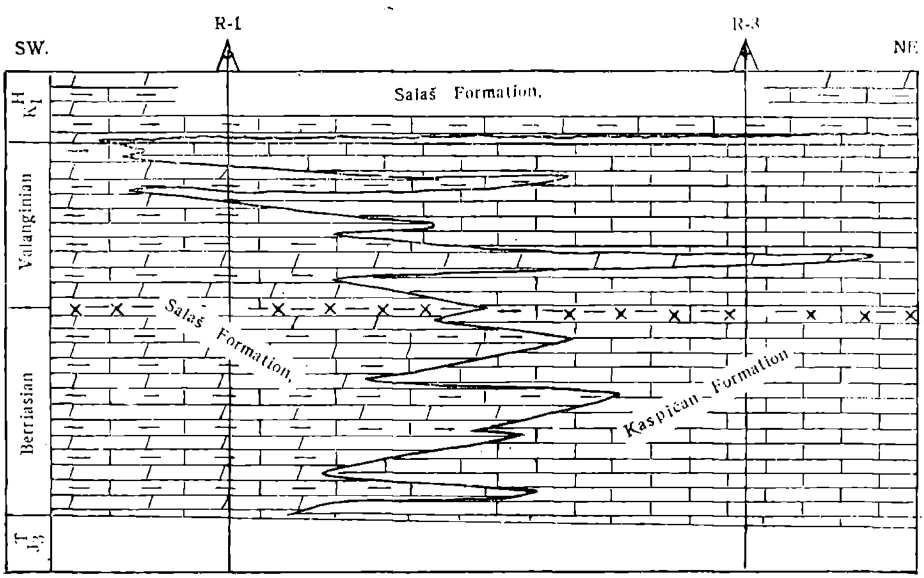


Fig. 13. Relationships between the Salaš and Kaspičan Formations in the Kozloduj — Kneža zone

The Valanginian has general development in Central Northern Bulgaria. It is connected with the Salaš, Tiča and Kaspičan Formations, as well as with the transitional Salaš-Kaspičan and Kaspičan-Salaš Formations. On a large scale the stage seems facially heterogeneous, but with a definite and distinct horizontal facial zonality.

The Valanginian is clearly differentiated in the boreholes R-1 Kneža and R-1 Bărdarski Geran, palaeontological indications about its presence being found in many other boreholes throughout the region. Irrespective of the lack of palaeontological evidence in all boreholes containing a continuous normal section, the presence of the Valanginian is indisputable.

Borehole R-1 Kneža is of special interest owing to the presence of many fossils belonging to different systematic groups, whose vertical distribution coincides. According to ammonites and calpionellids, a concurrent polytaxonic range-zone is outlined within the Valanginian boundaries:

— At 2374-2376 m (calpionellids): *Tintinnopsella carpathica* (M u r g., F i l.).

— At 2551-2554 m (calpionellids from the *Calpionellopsis* Zone): *Tintinnopsella carpathica* (M u r g., F i l.), *Calpionellopsis simplex* (C o l.) and *Calpionella elliptica* C a d.

The characteristic Lower Valanginian ammonite species *Thurmanniceras* ex gr. *T. thurmanni* (P i c t., C a m p.) is found in the same interval at 2552 m. Thus, the Valanginian in this borehole, connected with the Salaš-Kaspičan Formation, includes the 364 m thick interval between 2200 and 2564 m.

The upper boundary of the Valanginian is determined more easily owing to the more frequent fossil finds. Moreover, it is most often bilaterally outlined: on the one hand, by the occurrence of Valanginian species, and on the other — by the palaeontological determination of the base of the Hauterivian.

In the areas where the Valanginian is connected with the Salaš Formation it is 100-120 m thick, whereas in the facies of the Kaspičan Formation and in the zone of its transitions its thickness is 360-400 m.

The Hauterivian is very widely developed in the area, in some places (Kneža) its section is incomplete, while elsewhere (the villages Komarevo, Trăstenik, Brest and Gigen) it is completely absent. It is connected with the Salaš, Gorna Orjahovica and Razgrad Formations, as well as with the upper part of the transitional Salaš-Kaspičan and Kaspičan-Salaš Formations. Close to the transitional zone it also comprises the uppermost several metres of the Kaspičan Formation.

The Hauterivian is found in boreholes near Kneža, the villages Aleksandrovo, Odărne and Grivica, in almost all boreholes of the Gorni Dăbnik region, near the villages Tučenica, Totleben, Slavjanovo, Stežerovo and Resen, as well as close to the towns Polski Trămbeš and Svištov.

The lower boundary of the Hauterivian is provisionally marked in the uppermost part of the Salaš-Kaspičan Formation at 2200 m. The upper boundary is determined by correlation with borehole R-2 Kneža, where it is fixed by macrofossils. The total thickness of the Hauterivian at borehole R-1 Kneža is 75 m, 37 m of which are in the Salaš-Kaspičan Formation (the lowermost part of the Hauterivian) and 38 m are in the Salaš Formation (Upper Hauterivian — partly incomplete from below).

In borehohe R-2 Kneža Hauterivian macrofauna has been found at four levels: at 2311-2311.80 m — *Neolissoceras grasi* (d'O r b.), *Belbekella* sp. and *Chlamys* cf. *archiaci* (d'O r b.); at 2311.80-2317.20 m — *Subsaynella* sp. indet. and *Duvalia* sp. ex gr. *D. dilatata*; at 2317.20-2332 m — *Chlamys* cf. *archiaci* (d'O r b.) and *Plesiospitidiscus* sp. indet.; at 2325.40 m — *Pseudothurmannia* sp. indet.

The macrofossils and more specifically the ammonites are characteristic of the Upper Hauterivian.

Hauterivian fossils have been found in borehole R-1 Loveč at several levels: at 2110 m — *Natica laevigata* D e s h.; at 2449 m — *Neocomites* (*Teschenites*) *teschenensis* (U h l.) and *Lamellaptychus* cf. *subdidayi* T r.; at 2450.50 m — *Neocomites* (*T.*) *teschenensis* (U h l.); at 2453.20 m — *Lamellaptychus* sp. indet.

These fossils determine the lowermost levels of the Hauterivian. Probably the lower boundary of the Hauterivian in borehole R-1 Loveč is about 2480 m.

The new palaeontological data obtained in this study have demonstrated that in addition to the facies of the Salaš, Razgrad and Gorna Orjahovica Formations known so far, the Hauterivian comprises the uppermost part (maximum up to 35-37 m) from the transitional Salaš-Kaspičan and Kaspičan-Salaš Formations. Evidently, close to the transitional zone the Kaspičan type of sedimentation ended at the beginning of the Early Hauterivian. Being provisionally guided by this, without the existence of palaeontological data, the author refers the uppermost beds of the Kaspičan Formation in the transition of the Platform to the Fore-Balkan (Devetaki and Kărpačevo villages and the town of Suhindol) to the base of the Hauterivian. It seems more probable, however, that in this southern zone the lower boundary of the Hauterivian coincides with the upper boundary of the Kaspičan Formation, as is the case in the central, northern and eastern parts of the area.

The Barremian is widely developed in the area, being also known from outcrops in the southern part. It is connected with the Salaš, Mramoren, Razgrad and Gorna Orjahovica Formations, as well as with the base of the Loveč Urgonian Group. Barremian sediments are usually connected with Upper Hauterivian deposits by a gradual lithological transition, while in the Komarevo region they overlie the denuded surface of the Valanginian limestones (Kaspičan Formation). In the north, in the Brest-Gigen region, Barremian sediments are absent. In the remaining boreholes the Barremian is developed in a continuous succession, its presence being accurately proved palaeontologically in many places.

Characteristic Barremian ammonites are found in a number of boreholes (Н и к о л о в et al., 1974).

The Barremian is characterized by rich foraminifera associations by means of which this stage is clearly differentiated in many areas.

In borehole R-1 Dolni Dăbnik at a depth of 1605-1608 m T. K o v a t c h e v a (oral communication) has established characteristic Upper Barremian foraminifera: *Astacolus planiusculus* (R e u s s), *A. incurvatus* (R e u s s), *Lamarckina lamplughi* (S h.), *Lenticulina ouachensis ouachensis* (S i g.), *Frondicularia inversa* R e u s s, *Marssonella subtrochus* B a r t., *Marginulinopsis djaffaensis* S i g., *Gaudryina borimensis* K o v. and *Epistomina caracolla* (R o e m.).

In borehole R-1 Umarevci the Barremian comprises the base of the Loveč Urgonian Group (approximately the lower 100 m) and the upper part of the Gorna Orjahovica Formation, i. e. it is about 600 m thick. At two levels in this borehole K o v a t c h e v a (unpublished data) has found characteristic Barremian foraminifera:

— At 1049-1052 m: *Epistomina hechti* B a r t., B e t t., B o l l i, *Arenobulimina meltae* K o v., *Marssonella subtrochus* B a r t., *Lamarckina lamplughi* S h., *Conorboides bulgaricus* B a r t., B e t t., K o v., *Gaudryina borimensis* K o v., *Planularia crepidularis* (R o e m.) and *Lenticulina nodosa* (R e u s s).

— At 1481-1484 m: *Epistomina hechti* B a r t., B e t t., B o l l i, *E. caracolla* (R o e m.), *Gaudryina borimensis* K o v. and *Lenticulina nodosa* (R e u s s).

In borehole R-37 Komarevo, at a depth of 1071 m T. K o v a t c h e v a has found the following foraminifera at the beds with Barremian ammonites: *Conorotalites intercedens* (B e t t.), *Gavelinella barremiana* B e t t., *Gaudryina praedividens* N e a g u, *G. borimensis* K o v., *Marginulinopsis djaffaensis* S i g., *Lenticulina ouachensis ouachensis* (S i g.), *Trochammina gerochi* B a r t., K o v. and *Marssonella kummi* Z e d l.

The thickness of the Barremian in the southern part of the area (the villages Kalenik — Umarevci — Devetaki) is 600-750 m, in the central part (the town of Gorni Dăbnik and the villages Dolni Dăbnik, Grivica, Slavjanovo and Stežerovo) — 191-453 m, in the northwestern and northern part — 50 to 123 m.

The Aptian is widely developed in Central Northern Bulgaria, occurring in many outcrops. It is extremely facially heterogeneous and it is connected with the following lithostratigraphic units: Mramoren, Sumer, Roman and Trămbeš Formations, as well as the Vraca and Loveč Urgonian Groups.

The Aptian is differentiated in the boreholes mainly according to data on the vertical distribution of the foraminifera. In some boreholes it is indicated by macrofauna as well. The boreholes from the northwestern part of the area are also correlated with the borehole sections from the Western Fore-Balkan and the Lom Depression, where this stage is well characterized palaeontologically.

The complete section of the Aptian is found in a number of outcrops between the villages Kozar-Belene and Sanadinovo, Pleven District, in the valley of Osăm river. In these outcrops, as well as in the east towards the valley of Jantra river between the villages Polski Trămbeš and Cenovo this stage is represented by marls and it is characterized by many molluscs:

— For the Bedoulian: *Cheloniceras* (*C.*) *beltzovensis* D i m., *C.* (*C.*) *crassum* S p., *C.* (*C.*) *seminodosum* S i n z., *Deshayesites deshayesi* L e y m., *D. callidiscus* C a s., *Deshayesites* spp.. etc.

— For the Gargasian: *Cheloniceras (E.) martinoides* C a s., *Cheloniceras (E.)* spp., *Gargasiceras* sp., *Acanthohoplites subtobleri* (K a s.) and *Acanthohoplites* spp.

— For the Clansayesian: *Acanthohoplites abichi* (A n t h.), *A. aschiltensis* (A n t h.), *Colombiceras* sp., etc.

In the northwestern part of the area (Kneža and the villages Bărdarski Geran, Dolni Lukovit, Pelovo and Pisarovo) the Aptian is with relatively moderate thickness: 300-540 m. In the central part of the area Aptian sediments are 700-800 m thick, whereas in the south (the villages Kalen — Beglež), where only the Lower Aptian is developed, the thickness exceeds 1300 m.

The Albian is widely developed in the northwestern, central and northern parts of the area. It is connected with the Sumer, Trămbeš and Svištov Formations, as well as with the Malo Peštene Formation. Albian sediments are connected with Aptian deposits by means of a gradual transition. In a number of sections they pass into Cenomanian deposits above, but most often they are discordantly covered by various younger Upper Cretaceous, Neogene and Quaternary sediments.

Albian sediments are transversed by many boreholes in this area (the villages Dobrolevo, Tărnava, the town of Kneža, the villages Dolni Lukovit, Pisarovo, Bărdarski Geran, Trăstenik, Komarevo, and near Brest and Gigen).

The best natural outcrops of the Albian are observed in the northern part of the area — between the villages Sanadinovo, Novačene and Dekov, as well as around the town of Svištov, where the Svištov Formation is exposed (С т р а ш и м и р о в, С т о я н о в а, 1958; Н и к о л о в et al., 1974).

The basement of the Albian between the villages Sanadinovo and Novačene is represented by whitish, light-grey to beige aleuritic, indistinctly bedded marls from the Trămbeš Formation. The Upper Aptian species *Acanthohoplites aschiltensis* A n t h. has been found in these marls near Trănčovica village, Pleven District (В. Ц а н к о в, Й о в ч е в а, 1961).

According to the studies of I v a n o v, S t o j k o v a and N i k o l o v (И в а н о в et al., 1982), an up to 30 cm thick phosphorite bed is found transgressively over the light-grey marls of the Trămbeš Formation, between the villages Sanadinovo and Novačene. In addition to the phosphorus concretions, in this layer there are also rock fragments, quartz gravel, phosphatized ammonites, bivalvs and gastropods. The following species are identified: *Hoplites dentatus* (S o w.), *Anahoplites intermedius* S p a t h. and *A. planus sulcatus* S p a t h.

Dark-grey to greenish calcareous sandstones with thickness up to 1 m overlie this first phosphorite bed. They contain a little glauconite and rare phosphorite concretions.

Anahoplites intermedius S p a t h and *A. planus sulcatus* S p a t h occur in the lower part of the sandstones.

The following species are found in the upper part of these sandstones: *Anahoplites planus planus* (M a n t.), *A. planus discoideus* S p a t h, *A. planus gracilis* S p a t h, *Anahoplites* spp., *Dimorphoplites tethydis* (B a y l e) and *D. pinax* S p a t h. They are followed by a second phosphorite bed, 50-70 m thick. The bed is formed of phosphorite concretions and phosphatized fossils (ammonites, gastropods and mainly bivalvs). The matrix is calcareous-sandy with glauconite. *Cuculea glabra* (P a r k.), *Anahoplites planus fittoni* (d'A r c h.), *Dipoloceras cristatum* (B r o g n.) and *Euhoplites solenotus* (S e e l.) occur in the lower part of this bed.

The following species are found in the upper part of the same bed: *Hysteroceras orbignyi* S p a t h, *H. symmetricum* (S o w.), *H. subbinum* S p a t h., *H. varicosum* (S o w.), *H. bucklandi* S p a t h, *Prohysteroceras (Goodhallites) goodhalli* (S o w), *Mortoniceras (Pervinquieria) inflatum* (S o w.) and *M. (Deiradoceras)* cf. *bipunctatum* S p a t h.

Slightly calcareous to slightly aleuritic glauconitites are revealed above the second phosphorite bed. The glauconite content in them reaches up to 90 per cent, their thickness — about 2-4 m. *Callihoplites vraconensis* (P i c t., C a m p.) and *Arraphoceras* sp. have been found immediately at the base of this glauconite layer, whereas ammonites of relatively greater size — up to 80 cm — occur higher. *Puzosia mayoriana* (d'O r b.) and *Ostlingoceras puzosianum* (d'O r b.) are identified.

The amount of the glauconite gradually decreases upwards, while the clayey and calcareous substances increase.

Albian sediments are covered by slightly aleuritic light-grey to whitish marls, in the lower part of which the following Cenomanian taxa have been found (Н а ч е в, Н и к о л о в, 1961): *Mantelliceras* cf. *martimpreyi* (C o q.), *M. mantelli* (S o w.), *Neohibolites ultimus* (d'O r b.) and *Inoceramus* sp.

The two Albian Substages — Middle and Upper — are fully developed in the examined section between the villages Sanadinovo and Novačene. Lower Albian is not deposited. All ammonite zones of the Middle and Upper Albian have been identified.

The section near Dekov village differs in a certain respect from the already described section between the villages Sanadinovo and Novačene. At Dekov the Albian sediments lie transgressively, represented at their base by coarse-grained glauconitic sands, filled with many fossils and phosphoritic concretions, which attribute to them a conglomerate appearance. Thickness: 0.80 - 1.00 m. The following species have been identified from this bed: *Anahoplites planus discoideus* S p a t h, *Callihoplites patella* S p a t h, *Prohysteroceras* (*Goodhallites*) *goodhalli* (S o w.), *P.* (*G.*) *candolianum* (P i c t.), *Hysteroceras orbignyi* S p a t h, *H. bucklandi* S p a t h, *Hysteroceras* sp., *Mortoniceras* (*Pervinquieria*) *inflatum* (S o w.), *M.* (*Deiradoceras*) *devonense* S p a t h, *Inoceramus sulcatus* P a r k., *Cucullaea glabra* (P a r k.) and *Natica favrina* P i c t., R o u x.

A coarse-grained dark-green glauconite sandstone, 2-3 m thick, lies above the described bed. The glauconite content in it reaches 70 per cent. Large-sized

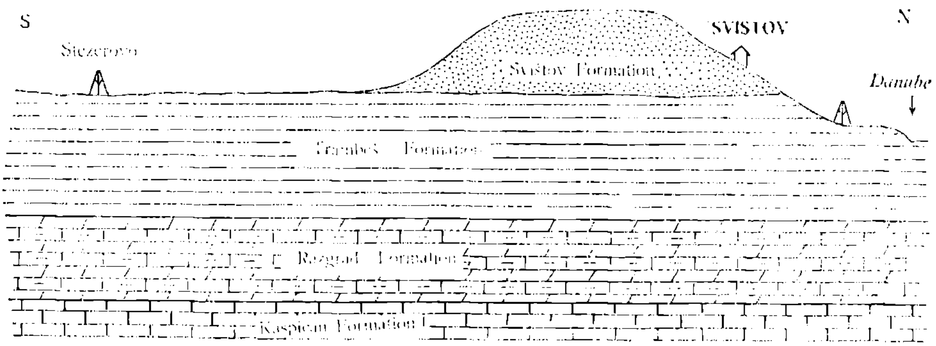


Fig. 14. Lithostratigraphic units related with the Lower Cretaceous between Stežerovo and Svištov

ammonites (0.70-0.80 m) occur in this bed. *Puzosia mayoriana* (d'O r b.) and *Ostlingoceras puzosianum* (d'O r b.) are identified.

The Albian glauconite sandstones are covered on top by Cenomanian marls. The described section near Dekov village comprises only the Upper Albian.

The Albian around the town of Svištov (Fig. 14) is represented by different-grained sandstones which are intercalated in some places by aleuritic marls. Here is the stratotype of the Svištov Formation which is also transected in the boreholes of the Grivica, Pisarovo, Krušovica, Gorni Dăbnik and Dolni Dăbnik areas. The phosphorite-bearing and glauconite beds between the villages Sanadinovo, Novačene and Dekov should be considered as peripheral facies of the Svištov Formation.

The thickness of the Albian sediments varies in the different areas: from 94 m (Trăstenik village) to 687 m (Bărdarski Geran village), depending mainly on the completeness of the sections and on the influence of the post-Albian denudation.

The Lower Cretaceous has most extensive surface outcrops in the northeastern part of the Moesian Platform. In this area it is also revealed by many boreholes. Therefore, the Lower Cretaceous has been relatively best studied in Northeastern Bulgaria. More recent studies to be mentioned in this connection are those of Dimitrova (Димитрова, 1967), Dimitrova, Čembersk i and Kostadinov (Димитрова, Чемберски, Костадинов, 1965), Dimitrova, Češitev and Breskovski (Димитрова, Чешитев, Бресковски, 1972), Breskovski (Бресковски, 1966; Breskovski, 1975), Kostadinov and Breskovski (Костадинов, Бресковски, 1967) and Nikolov (Николов, 1969a). These works contain the entire literature on the stratigraphy of the Lower Cretaceous in the area. In the present book only the latest data on the Lower Cretaceous stratigraphy in Northeastern Bulgaria will be reported.

Berriasian sediments are not exposed in the northeastern part of the Moesian Platform. They are found in all deep drillings transversing the uninterrupted succession of the Kaspičan Formation. However, the accurate differentiation of the Berriasian in the boreholes of this carbonate Formation is impossible, due to the absence of distinct fossil remains of organisms. According to borehole data, the conditionally differentiated Berriasian part of the Kaspičan Formation is represented by dolomites, dolomitized limestones and intercalations of limestones.

In borehole S-30 Kardam (Popovo area) P. Jovčeva (oral communication) has identified foraminifera from several levels. In all probability, the *Trocholina* (*Coscinoconus*) *alpina* Leup. found at 356.70 m and at 389.40 m is in the Berriasian part of the section, because a characteristic Valanginian association has been found higher up (at 320 m).

The Valanginian is generally developed in Northeastern Bulgaria. In the northeastern part of the Moesian Platform it is connected with the Kaspičan Formation. The stage is represented at its base by micrograined dolomites and dolomitized limestones which are replaced upwards by crystalline and granular limestones.

In borehole S-30 Kardam (Popovo area), at a depth of 320 m, P. Jovčeva has found a characteristic microfossil association: *Trocholina* (*Coscinoconus*) *alpina* Leup., *T.* (*Coscinoconus*) *elongata* Leup., *Hechtina praeantiqua* Bart., Br., *Ammodiscus cretaceous* Reuss and *Quinqueloculina infravalangiana* Bart.

In borehole S-11 Kalugerica the Valanginian is proved by foraminifera associations the most characteristic among which is from 167.30 m: *Trocholina* (*C.*) *alpina* Leup., *T.* (*C.*) *elongata* Leup., *Quinqueloculina infravalangiana* Bart. *Cardim imbricatum* Leum. was found in the same borehole at 152-156 m, *Nerinea favrina* Pict., Camp. and *Trigonia ornata* d'Orb. — in the interval 138.70-146.00 m.

Analogous fossil associations are found to the east-northeast in a number of boreholes (S-31 Esenica, S-32 Dolina, S-10 Černookovo and R-1 Tjulenovo).

The upper boundary of the Valanginian in this area is traced along the upper part of the Kaspičan Formation, with the exception of the region to the north of Šumen, Novi Pazar, Devnja and Černevo, where the upper part (probably up to

50-60 m thick) of the Kaspičan Formation belongs to the Hauterivian (Д и м и т р о в а et al., 1968).

The total thickness of the Berriasian and Valanginian sediments in their carbonate development is 320-960 m.

The Hauterivian has general development in the area investigated. Two facial zones in the development of the Hauterivian sediments become outlined: southern zone — in the transitional strip between the Fore-Balkan and the Moesian Platform, where marl deposits with intercalations of sandstones of the Gorna Orjahovica Formation are developed, and a northern zone — within the confines of the Platform, with two subzones: southern — clayey-calcareous (Razgrad Formation) and northern — calcareous (Ruse Formation).

Variegated deposits (Spasovo Formation) are developed in the northeasternmost coastal part of Northeastern Bulgaria.

The Hauterivian is connected everywhere with the Gorna Orjahovica Formation in the strip outlined to the north between the villages Resen and Čapaevo, the town of Tărgovište, the northern part of the Preslav region, the villages Zlatar, Vasil Drumevo and the Provadija region (Mirovo village), the villages Sultanci and Junak, and Varna (Asparuhovo quarter). The Gorna Orjahovica Formation is represented by marls, rather clayey, slightly aleuritic, with very rare and thin intercalations (mainly in the southern part) of calcareous siltstones and fine-grained sandstones.

In this strip the Hauterivian sediments overlie with a sharp boundary the limestones of the Kaspičan Formation in the larger part of the region, or a transitional type of clayey-calcareous deposits of the Tiča-Kaspičan Formation (the northern part of the Preslav, Tărgovište and Provadija (Mirovo) regions), or the sediments of the Tiča Formation (the villages Zlatar, Sultanci, Tutrakanci, Padina, Junak and Bozvelijsko).

The Hauterivian in the investigated strip (Resen — Junak villages) is built at its base by clayey to slightly clayey limestones which pass into marls. Glauconite occurs frequently among the clayey limestones at the base, whereas among the marls higher up there are rare and thin intercalations of clayey-calcareous siltstones and of fine-grained sandstones.

In addition to the outcrops which are rich in ammonite faunas (Н и к о л о в, 1969a), the Hauterivian in the boreholes of this region is characterized by many fossils.

The thickness of the Hauterivian sediments in the examined strip reaches up to 780 m, though it is between 150 and 320 m in most boreholes.

To the north of the strip under investigation, in the region of the town of Polski Trămbeš, Džuljunica village (Ruse District), Popovo, the villages Buhovci and Hitrino, the towns Devnja, Kubrat and Tervel, Severci village and Tolbuhin, the Hauterivian is connected with the clayey-calcareous sediments of the Razgrad Formation (in the southern part of the region) and with the limestones of the Ruse Formation (in the northern part of the region).

In a considerable part of the region the Hauterivian is represented predominantly by clayey limestones with intercalations of marls (Razgrad Formation). In most cases and especially in the lower part, these sediments contain glauconite.

A large lense-like body of sandy limestones, biodetritic limestones and oölitic limestones is discovered in the Hitrino region (Šumen District) among the clayey-carbonate deposits of the Razgrad Formation, in some places (the villages Kamenjak and Vărbak) with thin intercalations of calcareous sandstones. These sediments are known as "Hitrino Limestones" (Б о н ч е в, 1955).

In the Kubrat region the Hauterivian is connected with a transitional type of sediments between the Razgrad and Ruse Formations.

In the northwestern part of the Kubrat region (boreholes R-1 Čerešovo and R-3 Pisanec), in R-2 Preslavci, as well as in the Tervel-Severci and Dulovo regions, the Hauterivian is connected with different limestones belonging to the Ruse Formation. The boundary between the Hauterivian and Valanginian in this region is connected with the lithological boundary between the Ruse and Kaspičan Formations.

The Lower Hauterivian age of the uppermost part of the Kaspičan limestones in the region of Hitrino village, Kaspičan and Novi Pazar, Vetrino village — the town of Devnja, has been proved by the following ammonites (Димитрова, 1967; Николов, 1969a): *Acanthodiscus radiatus* (Brug.), *A. twanensis* Busn., Guill., *A. waceki* (Neum., Uhl.), *A. karakaschi* (Uhl.), *Leopoldia biassalensis* (Kar.), *L. prenocostata* (Felix), *Leopoldia* sp. and *Lyticoceras* sp.

Many characteristic Lower Hauterivian ammonites have been found in the marls above the Kaspičan Limestones. The thickness of the Hauterivian in this strip is 104-373 m.

In the northeasternmost (littoral) part of the area (Spasovo, Kardam and Balčik regions, and the Zlatni Pjasăci) the Hauterivian sediments are developed in a coastal type.

The sediments of the Hauterivian in this region overlie with a sharp boundary the denuded surface of the Kaspičan Formation. They are represented by terrigenous and clayey-calcareous deposits.

The Hauterivian is represented in the Spasovo region by variegated claystones, in some places with carbonized plant detritus. The claystones are intercalated, with limestones: clayey, dense, micrograined and porcelain-like. Intercalations of fine- to smallgrained sandstones also occur.

In the Balčik region the Hauterivian is represented by clayey-aleuritic limestones with a little glauconite.

In the Zlatni Pjasăci area (boreholes R-1[x], R-2[x] and R-3[x] Zlatni Pjasăci) the Hauterivian is built of irregular alternation of sandy marls, sandy and aleuritic limestones, and small-grained, predominantly quartz sandstones.

The Hauterivian sediments in this region are dated by microfauna. The thickness of the Hauterivian sediments in the littoral part is between 0 and 658 m.

The Barremian is very well represented in Northeastern Bulgaria. The facial environment of this stage is very similar along general lines with the Hauterivian.

In the southern part of the Moesian Platform clayey marls with rare intercalations of sandstones (Gorna Orjahovica Formation) and of clayey-calcareous sediments (Razgrad Formation) are developed, being replaced in the north by carbonate rocks, extensively developed in the northern part of the area (Ruse Formation).

In the strip between the villages Resen — Čapaevo — Vasil Drumevo the Barremian is connected with the Gorna Orjahovica Formation. It is represented by marls with intercalations of fine-grained sandstones. In some places there are also thin intercalations of clayey-calcareous siltstones.

Characteristic Barremian ammonites were found in borehole S-22 (Resen area): at 58.10-63.40 m — *Hemihoplites* spp., *Anahamulina* cf. *subcylindrica* (d'Orb.) and *Barremites* spp.; at 243.00-245.70 m — *Barremites* cf. *subdifficilis* (Kar.), *Pulchellia* sp. and "*Leptoceras*" sp.; at 384.60-394.40 m — "*Leptoceras*" sp. and *Barremites* cf. *difficilis* (d'Orb.); at 404.00-416.50 m — *Crioceratites* (*E.*) *emerici* Lév., *Acrioceras tabarelli* (Ast.), *Spitidiscus* sp. indet. and *Barremites* cf. *hemiptychus* (Kil.).

In borehole S-1 Ljubenci, where the Barremian is represented by sediments which are transitional, but probably closer to the Kamčija Formation, Barremian ammonites have been found in two intervals: at 90.00 m — *Holcodiscus* sp. indet.; at 479.00-484.50 m — *Anahamulina subcylindrica* (d'Orb.) and *Holcodiscus* spp.

The thickness of the Barremian deposits in the Resen — Čapaevo — Vasil Drumevo strip reaches 534 m.

In the north the Barremian is represented by the clayey-calcareous sediments of the Razgrad Formation (Polski Trămbeš, Džuljunica — Ruse District, the north-

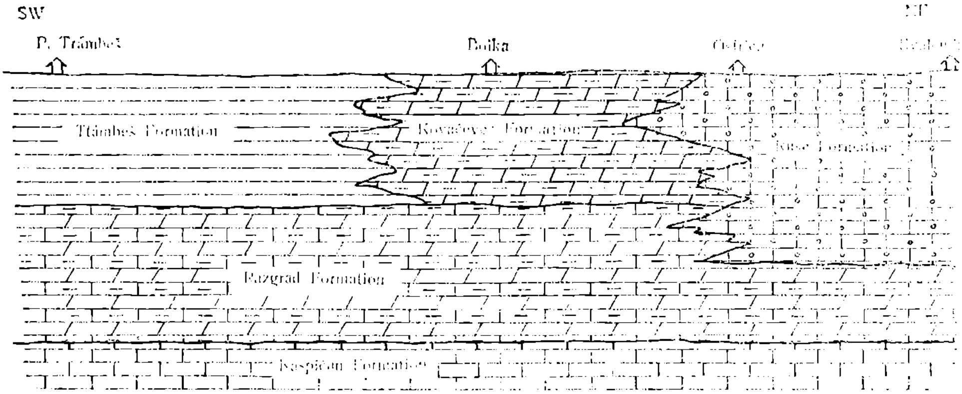


Fig. 15. Relationships between the lithostratigraphic units along the Polski Trămbeš — Svalenik line

ern part of the Popovo region, Buhovci and the Tolbuhin region). In the northernmost part of the area (the northwestern part of the Kubrat region, in borehole R-2 Preslavci, in the Dulovo and Tervel-Sever regions) the Barremian is connected with the limestones of the Ruse Formation. The transition between the sediments of the Razgrad and Ruse Formations is discovered in the boreholes in the southern part of the Kubrat region (Fig. 15).

Barremian sediments are very well characterized faunistically (Н и к о л о в, 1964-1969; Б р е с к о в с к и, 1966-1978).

The upper boundary of the Barremian is denuded in a considerable part of the region. In the places where the Barremian is covered by clayey-calcareous Aptian sediments (the villages Opaka, Sadina and Kacelovo), the boundary between the two stages is traced only by means of ammonites. In the Džuljunica area (Ruse District) the upper boundary of the Barremian coincides with the upper boundary of the uppermost tongue of the Razgrad Formation.

The thickness of the Barremian sediments in the northern part of the area is 101.0 -234.0 m.

The Aptian is widespread in Northeastern Bulgaria. It has a relatively more limited development in the central part of the Northern Bulgarian elevation, whereas in eastern and especially in western direction Aptian sediments are very well represented.

In the southern part of the Platform the Aptian is connected with the Gorna Orjahovica Formation which is represented by marls, aleuritic marls, sandy marls, siltstones, sandstones and sandy limestones with Orbitolinidae. Only the Lower Aptian (Bedoulian) is developed in this zone.

Vast outcrops of the Aptian exist in the valley of Jantra river, where the complete section of this stage can be observed from Saševo village in the south to Cenovo village in the north.

The Lower Aptian (Bedoulian) east of Saševo village is represented by mixed rocks. Slightly aleuritic clayey limestones appear in the upper part of the Bedoulian.

Sanmartinoceras (*Sinzovia*) *trautscholdi* (S i n z.) is found at the base of the outcrop to the east of Saševo village.

Slightly further north, to the east of Radanovo village, the Bedoulian is represented by slightly aleuritic clayey marls with intercalations of calcareous sandstones, micrograined limestones and sandy limestones. The following species are found among them: *Toxoceratoides royerianus* (d'O r b.), *Cheloniceras* (*C.*) *cornuelianum* (d'O r b.), *C.* (*C.*) cf. *dechouxi* (K i l., R e b.), *Aconeceras nisoides* (S a r.) and *Sanmartinoceras* (*Sinzovia*) *trautscholdi* (S i n z.).

In the east, in the area of the villages Kamen, Bojka, Vodica, Kovačevec and Palamarca, the Bedoulian is represented by clayey marls with very rare and thin intercalations of sandstones. Thin-layer slightly aleuritic limestones appear in the uppermost part. The following species are found among these sediments: *C.* (*C.*) *cornuelianum* (d'O r b.), *C.* (*C.*) cf. *pygmeum* (N i k s c h.), *C.* (*C.*) cf. *seminodosum* (S i n z.), *Deshayesites callidiscus* C a s., *D. deshayesi* (L e y m.), *D. planus* C a s. and *D. strigosus* C a s.

Complete sections of the Bedoulian are found in the valley of Černi Lom river, around the villages Zaraevo, Opaka, Krepča, Gărčinovo, Gorsko Ablanovo and Kacelovo, where marls and clayey limestones are developed. These sediments contain many ammonites (Н и к о л о в, 1969a). Thin-bedded and silicified limestones are discovered in the upper part of Bedoulian sections, in some places even chalcedonoliths (Г о р а н о в, 1965).

The following species are collected from these sections: *Procheloniceras albrechtiaustriae* (H o h.), *P. pachystephanum* (U h l.), *Cheloniceras* (*C.*) *cornuelianum* (d'O r b.), *C.* (*C.*) *kiliani* (K o e n.), *C.* (*C.*) *seminodosum* (S i n z.), *Deshayesites stutzeri* R i e d e l, *D. deshayesi* (L e y m.), *D. strigosus* C a s., *D. forbesi* C a s., *D. consobrinus* (d'O r b.) and *D. callidiscus* C a s.

In the valley of Malki Lom river, to the north and northwest of Sadina village, the Bedoulian is represented by clayey limestones which pass into pure limestones. These sediments are also intercalated to the east towards the villages Osenec and Balkanski, Razgrad District, as well as south of Razgrad. The transition between the Razgrad and Ruse Formations takes place in this zone at the level of the Bedoulian.

In the east, in the Vojvoda Plateau and Stanata, the Bedoulian is represented by alternation of marls and clayey limestones passing into granular limestones in the upper part and to the north.

Between the towns of Vălči Dol and Suvorovo the Bedoulian is represented by clayey marls, aleuritic clayey limestones, aleuritic marls, calcareous sandstones and relatively pure limestones with flint concretions. Clayey-sandy limestones containing great amounts of glauconite, glauconite sandstones and clayey-calcareous sandstones, are found near Vojvodino village, Varna District. *Cheloniceras* (*C.*) *cornuelianum* (d'O r b.) and *Deshayesites* spp. are found among these sediments.

In the northernmost part of the area the Bedoulian is connected with the Ruse Formation. Various limestones are developed: granular, oölitic, biodetritic, bivalvial, coral, bryozoal, algal, in some places porcelain-like (micrograined), in other places sandy and orbitolinic limestones. The following species are found among these sediments near the villages Belcov and Batin, Ruse District: *Deshayesites weissi* (N e u m., U h l.), *D. grandis* S p a t h, *D. callidiscus* C a s., *D. forbesi* C a s., *D. strigosus* C a s., *Deshayesites* spp., *Procheloniceras albrechtiaustriae* (H o h.) and *Cheloniceras* (*C.*) spp.

Of particular interest is the section of the Bedoulian to the southeast of Širokovo and near Ostrica villages, Ruse District, where at a distance of about 1 km the transition between the clayey-calcareous sediments of the Razgrad Formation and the limestones of the Ruse Formation takes place.

The thickness of the Bedoulian in the examined sections is 40-140 m.

The Middle Aptian (Gargasian) is developed mainly in the northwestern part of this area. Between the villages Strelec and Orlovec, Ruse District, the Gargasian is represented by microcrystalline limestones, clayey limestones and marls. Flint concretions occur in some places among the limestones.

In the northeast, around the villages Bojka, Koprivec and Drjanovec, the Gargasian sections are formed by alternation of thin-layer silicified limestones, slightly silicified crystalline limestones and clayey slightly aleuritic limestones (Kovačevec Formation). The following species are collected from the lower part of the sections: *Costidiscus microcostatus* (S i m., B a c., S o r.), *Gargasiceras lautus* (G l a s.), *Gargasiceras* sp., *Hamiticeras* sp. and *Epancyloceras* sp.

The upper part of the same sections is characterized by: *Acanthohoplites aschiltensis* A n t h., *A.* sp., *Subacanthoplites* sp. and *Cheloniceras* (*E.*) aff. *debile* C a s.

The Gargasian has vast outcrops in the Bjala region — around the villages Bistrenci, Pet Kladenci, Borovo, Baniska, west of Čilnov, around Cenovo, Stărmen, Dolna Studena, Polsko Kosovo and Bjala. Marls with alternation of clayey and thin-bedded silicified limestones are discovered. They are characterized by many ammonites (Н и к о л о в, 1969a).

The thickness of the Gargasian is 80-150 m.

The Upper Aptian (Clansayesian) is widespread to the west of Baniski Lom river, around Borovo village, north of Bistrenci village, Bjala, Cenovo and Batin villages, Ruse District. It is represented by marls with intercalations of clayey limestones characterized by: *Aucellina caucasica* (B u c h), *A. gryphaeoides* (S o w.), *A. nassibiantzi* S o k., *Acanthohoplites bigoti bigoti* (S e u n.), *A. multispinatus tenuicostatus* (S i n z.), *A. trautscholdi* (S i m., B a c., S o r.) and *Cheloniceras* (*E.*) *clansayense* (J a c.).

The thickness of the Clansayesian sediments is 35-70 m.

The Albian has a limited distribution in this area, being developed mainly around Ruse (Д и м и т р о в а, 1952) and partly in the western part of the Razgrad District. It is represented by clayey marls and glauconite sandstones (Trămbeš Formation).

The Albian sediments are transversed by some structural boreholes (Băzăn village, Razgrad District), as well as during the construction of the bridge across the Danube between Ruse and Giurgiu. The characteristic Upper Albian ammonite *Anisoceras armatum* (S o w.) is found at 56.30 m in borehole R-9 near Băzăn village.

Albian sediments reach up to 60 m in thickness.

1.3.6. Eastern Rhodopes

The development of the Lower Cretaceous in the Eastern Rhodopes was proved by B o j a n o v and L i p m a n n (Б о я н о в, Л и п м а н, 1973) who found a rich association of Radiolaria characteristic of the Lower Cretaceous. They were found among phyllitoid schists around Mečo Uho village in the valley of Kulidžikska river, Kărdžali District. Phyllitoid schists are assumed to be part of the so-called diabase-phyllitoid formation. Most probably these are deep-sea formations of the type of the aspid formations.

In 1982 B o j a n o v, R u s e v a and D i m i t r o v a (Б о я н о в, Р у с е в а, Д и м и т р о в а, 1982) reported the find of Upper Cretaceous (Campanian) foraminifera "in Jurassic-Lower Cretaceous metamorphic rocks" at Sveti Ilija locality, about 2 km northwest of Dolno Lukovo village, Kărdžali District. The foraminifera have been found among tuffites which alternate with sandstones and siltstones.

These finds are of exceptional significance for the geological history of the Eastern Rhodopes and Strandža during the Cretaceous.

2. NORTHWESTERN AFRICA

The Atlantic coast of Africa is of particular interest for the stratigraphy of the Lower Cretaceous.

A formation of shallow-sea sandstones is developed to the south of the Gulf of Guinea near Angola (Cameroon, Gabon and Angola), as well as lagoon-marine sediments of Aptian age. Among these sediments there are also deltaic formations, bituminous and salt-bearing beds intercalated by thin limestone beds with sea fossils.

The Albian is represented predominantly by clayey limestones and marls with ammonites: beds with *Mortoniceras inflatum* (S o w.), *Prohysteroceras wordei* S p a t h, *Prohysteroceras* spp., *Elobiceras* sp. in the Lobito area in Angola (S o r n a y, 1951), beds with *Elobiceras* near Béndoué in Nigeria, "marls and limestones of N'Toum" with *Douvilleiceras monile* (S o w.) and *D. mammillatum* (S c h l.) in Gabon (F u r o n, 1960).

In the north, in Northwestern Africa proper, the Lower Cretaceous has a rather limited development. It is discovered as thin and broken strips along the coastline (Ivory Coast, Ghana), where it is represented by lagoon sediments which are poor in fossils: sandstones, aleuritic-sandy claystones and claystones with lignite coals, up to 800 m thick (F u r o n, 1960). These sediments usually overlie Precambrian rocks.

In **Western Sahara** the Lower Cretaceous is represented by continental sandstones and in some places by sandy claystones with silicified trees and remains of dinosaurs (Continental intercalaire after K i l i a n, 1931).

2.1. Morocco

In Northwest Africa the Lower Cretaceous is most extensively developed in Morocco. Its distribution is connected with the Aaiun — Tarfaya coastal basins, the High Atlas (Agadir — Essaouira, Meseta) and the Moroccan reef.

In the Tarfaya — El Aaiun Basin the Lower Cretaceous starts with continental sandstones and conglomerates, about 1100 m thick, which are provisionally referred to the Barremian (W i e d m a n n et al., 1978). These formations overlie Triassic or Jurassic rocks.

The marine Lower Cretaceous sediments in this basin are of Aptian or Albian age.

To the northeast of Cape Draa, at the base of the sea coast there are marls and aleuritic claystones with *Hypacanthoplites nolani* (S e u n.), *Cheloniceras* (*E.*) cf. *pretosum* (d'O r b.), *C.* (*E.*) ex gr. *debile* C a s. and *Cheloniceras* (*E.*) spp., which define the **Clansayesian** (C o l l i n g o n, 1963). This is the southernmost outcrop of Mediterranean Clansayesian ammonites.

The Albian is represented by its upper substage. The sections are built of greenish claystones and marls, siltstones, dolomitized limestones and clayey limestones, which contain many ammonites: *Beudanticeras beudanti* (B r.), *Hysteroceras carinatum* S p a t h, *H. orbignyi* S p a t h, *Dipoloceras bouchardi* (d'O r b.), *D. cristatum* (D e l u c), *Deiradoceras cunningtoni* S p a t h, *Anisoceras pseudoelegans* (P i c t., C a m p.), *Idiohamites salvani* C o l l., *Mortoniceras inflatum* (S o w.), *M. rostratum* (S o w.), *M. aequatoriale* (K o s s m.). *M. pricei* S p a t h, *M. orientale* (K o s s m.), *Hypengonoceras chouberti* C o l l., *H. tarfayense* C o l l., *Oxytropidoceras bituberculatum* C o l l., etc. This fauna demonstrates the greatest number of common elements with the Albian of the Mediterranean Region, but also with Madagascar, South Africa, Angola and Nigeria (C o l l i n g o n, 1963).

Together with the ammonites, the Albian sediments from Tarfaya are also characterized by concurrent foraminifera zones, as well as by many bivalvs and gastropods. Their thickness varies between 300 and 820 m, tending to increase from east to west. The development of the Lower Cretaceous in this basin is characterized by the numerous intraformational hiatuses. Upwards the Albian sediments are connected with the Cenomanian ones by means of a gradual transition.

The **Agadir-Essaouira (Haha) Basin** comprises two sedimentation zones. In the southern Agadir zone the Lower Cretaceous is very well exposed in the coastal strip between Arhoud, Tarhazoute and Aourir, north of Agadir.

The Berriasian is represented at its base by limestones and dolomitized limestones with remains of neritic fauna (oysters, gastropods, algae and bryozoans), followed upwards by aleuritic marls and clayey limestones with ammonites: *Pomeliceras (M.) broussei* (M a z.), *Tirnovella occitanica* (P i c t.), *T. alpillensis* (M a z.) and *Spiticeras (K.) damesiforme* D j a n. (W i e d m a n n et al., 1978). The foraminifera are represented by benthonic nodosarids and agglutinated forms of *Haplophragmidium, Dorothia praeoxycona* M o u l l., *Lenticulina nodosa* R e u s s, *L. eichenbergi* B a r t., B r., *L. ouachensis* S i g. and *Vaginulina* sp. (B u t t, 1982).

The Lower Berriasian carbonates are typical shallow-sea deposits; they contain calcareous algae, bivalvs, gastropods and neritic foraminifera, which demonstrate subreefogenic conditions in the inner shelf zone. The upper part of the Berriasian built of alternation of marls and clayey limestones with ammonites and benthic foraminifera, is formed under the conditions of the middle shelf area with gradual increase in the depth (B u t t, 1982).

The Valanginian is represented by varied, predominantly aleuritic marls with *Thurmanniceras thurmanii* (P i c t., C a m p.), *Sarasinella longi* (S a y n), *Olcostephanus beticus* (W i e d m.), oysters, *Trigonia, Pinna,* corals, brachiopods and echinoderms. The distribution of the macrobenthos is very uneven, with strong local fluctuations. The foraminifera are benthic: *Vaginulina* sp., *Lenticulina ouachensis* S i g., *L. eichenbergi / L. guttata, Spirilina neocomiana* M o u l l., *Epistomina caracolla / E. ornata,* etc. (W i e d m a n n et al., 1978).

The Hauterivian is represented by a thick complex of aleuritic marls and claystones with a limestone-dolomite formation in the middle part. The Lower Hauterivian is characterized by *Endemoceras noricum* (R o e m.), *Acanthodiscus vaceki* N e u m., U h l. and *Crioceratites strombecki* (K o e n.), typical benthic foraminifera, such as *Planularia crepidularis* (R o e m.), *Dorothia hauteriviana* (M o u l l.), *Vaginulinopsis* sp. Higher up there are *Crioceratites duvali* L é v., *C. hildesiensis* (K o e n.), *C. maghrebiensis* I m m e l and *Crioceratites* sp., as well as the first plankton foraminifera (W i e d m a n n et al., 1978).

The development of dolomites and reef limestones in the middle part of the Hauterivian sections demonstrates local shallowing.

The Upper Hauterivian is represented by aleuritic marls and claystones with *Pseudothurmannia angulicostata* (d'O r b.), *Exogyra* sp., brachiopods, planktonic foraminifera, which are associated with benthos forms. The bio- and lithofacies indicate a relatively deep middle shelf with open sea connections to the northwest (B u t t, 1982).

The Barremian is also represented by aleuritic marls with claystones with *Crioceratites fissicostatus* (R o e m.), *Nicklesia pulchella* (d'O r b.), *Heteroceras* sp., *Hedbergella sigali* M o u l l., *H. infracretacea* (G l a e s s n.) and *Clavihedbergella* aff. *simplex* (M o r r.).

The Lower Aptian is represented by dolomite limestones and sandstones containing *Procheloniceras albrechtiaustriae* (H o h.) and *Deshayesites callidiscus* C a s. Higher up (in the Middle and Upper Aptian) the beds are condensed. *Cheloniceras (E.) martini* (d'O r b.), *Ammonitoceras* sp., *Hypacanthoplites nolani* S e u n., *Acanthohoplites* sp., charophytes and foraminifera: *Ticinella bejaouaensis* S i g., *Globigerinelloides algerianus* (C u s h., D a m.) and *G. ferreolensis* (M o u l l.), occur (W i e d m a n n et al., 1978).

The Albian is built of greenish marls with many planktonic foraminifera: *Planulina buxtorfi* (C a n d.), *Rotalipora apenninica* (R e n z), *Ticinella primula* L u t t and *Ticinella* sp., as well as nodosarids (*Lenticulina*) and ostracods. The macrofauna is scarce. *Douvilleiceras mammillatum* (S c h l.), *Beudanticeras* spp., *Oxytropidoceras* (*O.*) sp., *Hysteroceras orbignyi* S p a t h, *Mortoniceras falax* S p a t h, *Paraturrilites bergeri* (P i c t., C a m p.) and *Stoliczkaia dispar* (d'O r b.) are found (W i e d m a n n et al., 1978). The bio- and lithofacies indicate deepening of the shelf basin.

In the northeastern part of the **Agadir zone** (Tizi region), in the High Atlas, the upper part of the Lower Cretaceous (**Barremian-Albian**) is of regressive type. The Upper Barremian and the Lower Aptian contain predominantly clastic sediments of epicontinental type (reddish aleuritic claystones, sandstones, dolomites and conglomerate lenses). According to B u t t (1982), these sediments are cross-bedded, with core structures and traces of submarine slides. This is evidence of deltaic facies formed in the littoral zone. The organism remains consist of varied detritus, as well as charophytes, small ostracods and agglutinated foraminifera (*Ammobaculites*).

In the same Tizi region the described clastic deltaic facies of the Upper Barremian-Lower Aptian is covered by a typical condensed section of the Upper Aptian and the Albian. Limestones, sandstones, aleuritic marls and in some places dolomites are developed, among which there are ammonites and different foraminifera (*Nodosaria, Lenticulina* and *Hedbergella*), as well as agglutinated forms (*Haplophragmium, Ammodiscus* and *Reophax*). The fauna becomes poorer higher up in the section and only in the uppermost part of the Albian there is an abundance of planktonic foraminifera. The lithological transition to the Cenomanian is gradual.

In the north, in the Essaouira area, the lower part of the series is very similar to the sections in the Agadir zone. Over the shallow-marine Upper Tithonian limestones there are aleuritic marls in alternation with limestones containing Berriasian, Valanginian and Lower Hauterivian ammonites, as well as a rich association of foraminifera, among which the nodosarids are very varied (W i e d m a n n et al., 1978; B u t t, 1982). According to Butt, the foraminifera indicate a deep middle-shelf environment, similar to that of the Agadir zone. A sharp shallowing started during the Early Hauterivian, which is indicated by the development of coloured (mainly red) sediments containing small bivalvs, gastropods and rare agglutinated foraminifera (*Ammobaculites*). This biofacies demonstrates lagoon and brakish epicontinental regressive environment (B u t t, 1982). Marls with ammonites and many foraminifera are developed higher up in the section of the Upper Hauterivian and in the Barremian indicating typically marine environment in the middle shelf. The Lower Aptian is connected with continental sandstones and conglomerates (red beds) which are covered by marls and aleuritic claystones with foraminifera (Gargasian Substage), followed higher up by olive-green and yellow-green aleuritic and sandy marls with ammonites and many foraminifera (Upper Aptian-Albian). The faunistic content and especially the P/B ratio in the foraminifera indicates a relatively deep and calm middle shelf (B u t t , 1982).

The Late Albian marks the start of the deposition of carbonate sediments, among which ammonites and planktonic foraminifera disappear.

In the north, at Safi, the Lower Cretaceous is developed in marine facies (Berriasian-Aptian).

Specificilly good faunistic successions are known from the Ida (Tanan) area, east of Cape Rhir (H a u g, 1908; 1911).

Valanginian: *Thurmanniceras thurmanni* (P i c t., C a m p.), *Neocomites neocomiensis* (d'O r b.), *Olcostephanus* spp., bivalvs, gastropods and brachiopods.

Hauterivian: *Acanthodiscus radiatus* (B r.), *Leopoldia kiliani* (K o e n.), *L. biassalensis* (K a r.). *Olcostephanus astierianus* (d'O r b.), *Pseudothurmannia angulicostata* (d'O r b.), *Duvalia dilatata* (B l.), bivalvs, gastropods and brachiopods.

Barremian: *Pulchellia compressissima* (d'O r b.), *Barremites difficilis* (d'O r b.), *Barremites* spp. and *Heteroceras* sp. Bivalvs and brachiopods are well represented.

The Aptian is developed in its full volume and is characterized by *Cheloniceras* (*C.*) *cornuelianum* (d'O r b.), *Procheloniceras stobiecki* (d'O r b.), *Deshayesites deshayesi* (L e y m.), *Aconeceras nissum* (d'O r b.), *Toxoceras cornuelianum* (d'O r b.), *Gargasiceras* sp., *Parahoplites melchioris* A n t h., *Acanthohoplites aschiltensis* (A n t h.), *A. akuschaense* (A n t h.), *A. bigoureti* (S e u n.), *Colombiceras tobleri* (J a c.), *Diadochoceras nodosocostatum* (d'O r b.), etc.

The upper and middle parts of the Aptian are very well characterized faunistically in the Marrakech valley.

In the **Meseta** area the Lower Cretaceous is developed in a Wealdean-like continental facies, divided by a sea ingression during the Valanginian. Sandstones and red claystones are represented, which are assumed *grosso modo* to be Lower Cretaceous, because they overlie the Upper Jurassic rocks and are covered transgressively by marine Cenomanian deposits. The Valanginian is represented by dolomite limestones containing rich ammonite fauna (W i e d m a n n et al., 1978).

The Moroccan Reef area lies approximately to the north of the Rabat parallel. Its shores are washed by the Atlantic Ocean to the west and by the Mediterranean Sea to the north. The eastern boundary of this area is the valley of the Oued Moulouya river, after which the Tellian Atlas starts.

In the southern part of the Reef the Lower Cretaceous starts with the Berriasian, connected with a lithological transition to the Tithonian. It is represented by fine-grained biomicrites, rich in *Calpionella, Nannoconus, Calcisphaeridium*, radiolaria, smooth-shell ostracods and various detritus; pelletic limestones and core limestones ("Ammonitico-Rosso" type) with many ammonites; microbreccias, in some places with graded bedding and intraclastic limestones. The bio- and lithofacies indicate hemipelagic environment of external shelf (W i e d m a n n et al., 1982).

The beginning of the Valanginian is marked by a sudden transition to clayey-calcareous sediments (calcareous claystones, marls and clayey limestones) with many ammonites, calpionellids and radiolaria. The calpionellid zones *Calpionella, Calpionellopsis* and *Calpionellites* are discovered in the Berriasian-Valanginian (W i e d m a n n et al., 1982).

In the north, in the coastal zone of the Reef (Dorsale rifaine), there are clayey limestones, rich in radiolaria, nannoplankton, calpionellids and aptychi, which permit the differentiation of Lower Cretaceous stages — from the Berriasian to the Barremian included. These sediments overlie Jurassic, most frequently Lower Jurassic rocks. They reach up to 50 m in thickness. Green glauconitic Albian marls are found in the Haouz — Dorsale intern area.

In the allochthonous part of the Reef the Lower Cretaceous is developed in flysch facies which are not stratigraphically divided due to lack of good fossils (D u r a n d D e l g a, 1965b). The Berriasian is represented by clayey-calcareous sediments, such as Tithonian. The sedimentation of turbidites started toward the end of the Berriasian and continued uninterrupted throughout the entire Early Cretaceous.

2.2. Continental Margin of Northwestern Africa

This vast area covered by the waters of the Atlantic Ocean includes the Continental Margin of Northwestern Africa from Senegal to Gibraltar, with the Cape Verde Islands, the Canary Islands and Madeira. The ocean bottom is with strongly differentiated relief (U c h u p i et al., 1976) (Fig. 16).

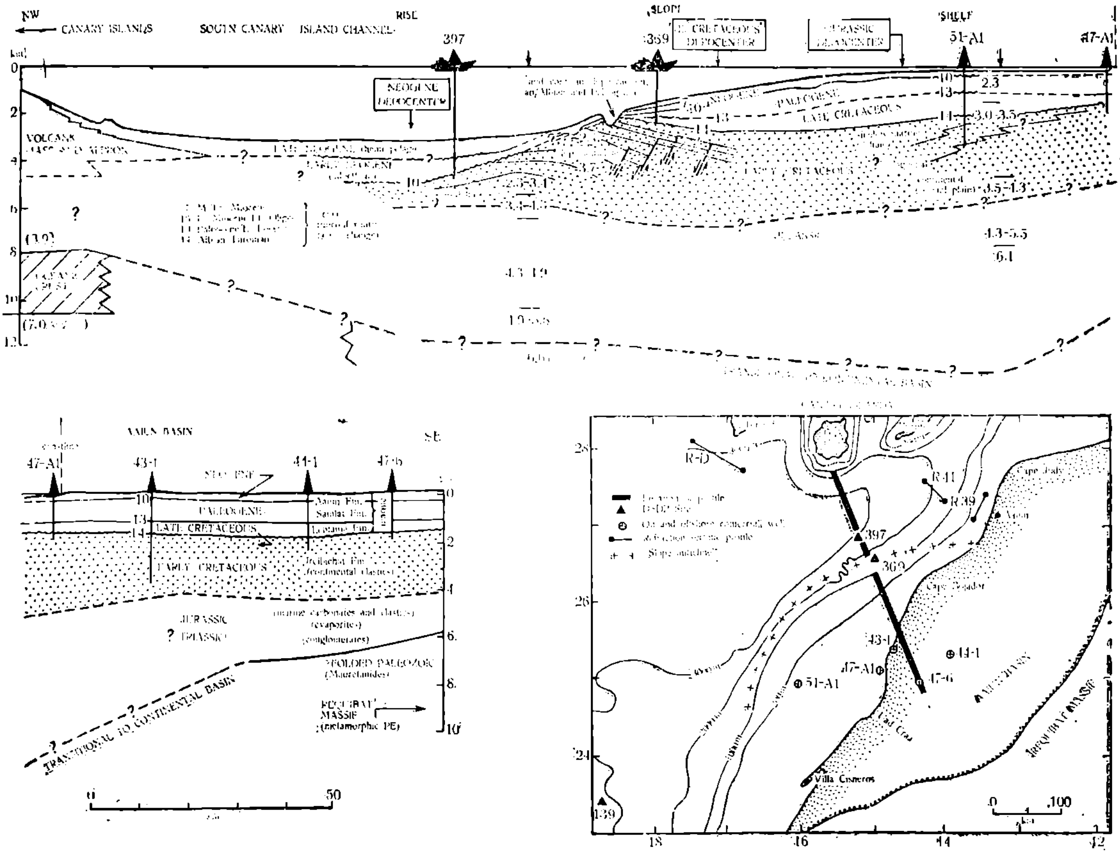


Fig. 16. Schematic section of the Continental Margin of Northwestern Africa (according to data of deep-sea drilling and seismic investigations). Init. Rep. DSDP, **47**, 1, 1977)

The oldest sedimentary rocks are the Upper Jurassic-Lower Cretaceous limestones and siliceous rocks discovered on Maio Island (Cape Verde Islands). The Lower Cretaceous starts with the Berriasian which lies with a gradual lithological transition over Tithonian cherty limestones. The Berriasian, Valanginian and Hauterivian are represented by slightly metamorphosed limestones, 200 m thick, covered by basalt lava which spread at the end of the Hauterivian. The Berriasian-Hauterivian part is dated by scanty foraminifera. The Barremian is represented on top by bituminous marls with *Crioceratites emerici* L é v., *Heteroceras giraudi* K i l., *Lytoceras subfimbriatum* d'O r b., bivalvs and fish remains.

The Aptian-Albian section is built of variegated clayey shales, slightly metamorphosed limestones and basalts. *Phylloceras guettardi* (R a s p.), *Parahoplites* cf. *hitzeli* J a c., *Costidiscus recticostatus* (d'O r b.), etc. are found among the Aptian sediments (F u r o n, 1960).

DSDP Site 367 (Leg 41) revealed Kimmeridgian red argillaceous limestones which overlie basalt, followed upwards by Tithonian-Hauterivian sequence characterized by cherty limestones and grey marls. The Barremian is represented by claystones, the Aptian and Albian — by black shales (J a n s a, W i e d m a n n, in: Von R a d et al., 1982).

Further north, at DSDP Site 368, located to the northwest of the Cape Verde Islands, Miocene diabasic sills are found among Albian-Turonian black shales.

Data about the Lower Cretaceous are particularly numerous in the continental margin of Morocco and near the Canary Islands.

At Site 369 **to the southwest of the Canary Islands,** opposite Cape Bojador, Aptian-Albian silty marls with nannoplankton are found at the base of the section.

Further north, Site 370, situated on the parallel of Madeira Island in the continental foot of the Moroccan Meseta, at 4216 m depth of the water, has passed 1176 m and has revealed a terrigenous Lower Cretaceous (Berriasian-Albian), represented mainly by turbidites with marl intercalations with nannoplankton, siltstones, sandstones and rare conglomerate beds. These sediments are of flysch type. They are dated by foraminifera and nannofossils (B u t t, 1982).

An interesting Lower Cretaceous section is discovered at Site 397 between the Canary Islands and Cape Bojador. The borehole passes 1453 m and reveals in the lower part Valanginian-Hauterivian aleuritic argillites with siderite concretions. They contain abundant remains of fishes, echinoderms, cephalopods and gastropods. The sediments demonstrate a number of deltaic features, which correlate well with the continental part.

In DSDP-Hole 397-A (from Site 397), W i e d m a n n (1979) has identified *Neocomites neocomiensis* (d'O r b.), *Phylloceras* (*H.*) *thetys* (d'O r b.) and *Protetragonites* cf. *crebrisulcatus* (U h l.), which prove the Valanginian, Hauterivian and Barremian.

There are several boreholes in the Mazagan Plateau (DSDP-Leg 79). The borehole at Site 545 reveals a considerable hiatus at the base of the Lower Cretaceous. Yellow-grey dolomite and calcareous sediments dated to the Barremian-Aptian directly overlie the Upper Jurassic carbonate platform, followed upwards by green nannofossil clayey limestones which fill the volume of the Aptian, Albian and Cenomanian (Von R a d et al., 1982).

The Lower Cretaceous at Site 547 is represented by the upper part of the Albian Stage, which covers Upper Jurassic limestone breccias. Greenish nannofossil-bearing claystones and mudstones with common intraformational flat-pebble mudstone conglomerate layers and slump structures are developed. They are dated by foraminifera as Upper Albian-Cenomanian (H i n z, W i n t e r e r et al., 1982).

In the area of the **Canary Islands** (Fuertaventura) the Lower Cretaceous is represended at its base by cross-bedded siltstones (Valanginian-Hauterivian), passing upwards into pelagic radiolarites and limestones (Aptian-Albian), which correlate with the section at Cape Verde Islands (Maio Island) (A r t h u r et al., 1979).

Clear dependences are established between the Lower Cretaceous sections in the investigated part of the Atlantic Ocean and in the outcrops from Northwestern Africa.

Compared with the prodeltaic facies at Site 397, the Barremian-Aptian sediments from the Tarfaya — El Aaiun region and in the shelf of Western Sahara have developed a 1200 m thick complex of terrigenous sediments in deltaic facies (W i e d m a n n et al., 1978; E i n s e l e, Von R a d, 1979). These sediments contain rare fossils (bivalvs, gastropods, echinids, foraminifera). Bio- and lithofacies indicate lagoon and brakish environments. The Aptian-Albian sections from the continent and from its margin demonstrate gradually facial changes from shallow-sea to deep-sea pelagic sediments. A similar dependence is also established for the Agadir — Essaouira Basin and its continuation into the ocean, with the exception of a number of intraformational hiatuses with some alternations of marine and continental sediments. A similar picture is also observed in the continental part of Meseta.

Generally speaking, the Lower Cretaceous in the coastal basins of the continent (Tarfaya — El Aaiun and Agadir — Essaouira) demonstrates a change of marine for non-marine environment, with predominant development of deltaic facies which correlate well biostratigraphically and palaeoecologically with the flysch facies of the boreholes at Sites 370 and 397. Moreover, the thick turbidites in the Moroccan Basin (Site 370) are in sharp contrast to the pelagic carbonates and black shales in the more southern area (Site 367). Interesting is also the development of the black shale facies in the upper part of the Lower Cretaceous, which suggest practically oxygen-free environment.

3. NORTHERN AFRICA

The Lower Cretaceous is developed in marine facies in Algeria and Tunisia, whereas in Libya, Egypt and Sahara it is represented by continental deposits.

3.1. Algeria

The Lower Cretaceous is developed in the Sahara Atlas, the High Plateaux and in the Tellian Atlas.

In the western part of the **Sahara Atlas** the Lower Cretaceous is represented by sandstones and sandy claystone ("continental intercalaire"), whereas in the east in the same zone — by sandstones and evaporites (Sahara type).

In the **High Plateaux** the Lower Cretaceous is of terrigenous-carbonate type. All stages are developed (Fig. 17).

The Bulgarian geologists who investigated the High Plateaux (T c h o u n e v et al., 1969; K o l e v et al., 1970; Z i d a r o v et al., 1973 — oral communication of unpublished data) distinguished three main lithostratigraphic units connected with the Lower Cretaceous: the Oued Mina Carbonate Formation, the Berthelot Sandstone Formation and the Remailia Limestone Formation. The succession of these Formations can be seen very well along the Frenda — Tiaret road near the Oued Mina cascade.

The Remailia Limestone Formation lies transgressively and slightly discordantly over the Upper Jurassic dolomites of the Tlemsen Formation (T c h o u m a t c h e n c o — oral communication). It is represented by various limestones (biodetritic, intraclastic and organogenic), dolomites and marls. The limestones contain poorly preserved traces of bivalvs, gastropods and corals, while the marls are rather rich in foraminifera. Their thickness is 80-90 m.

Fauriella cf. *boissieri* (P i c t.) is found at the base of this Formation near Djebel Recheiga. This species marks the lower boundary of the Formation as Berriasian. *Exogyra mines* C o q., *Harpagodes jaccardi* (P i c t., C a m p.), *Nerinea* spp., *Trigonia* sp., as well as foraminifera: *Choffatella decipiens* S c h l., *C. zireggensis* S i g., *Ammobaculites subaequalis* M j a t l., *Dorothia* sp., etc. occur near the Oued Mina cascade.

These faunistic finds define the interval from the Berriasian to the Lower Hauterivian.

The Berthelot Formation lies with a clear lithological boundary higher up. It is represented predominantly by sandstones with intercalations of aleuritic claystones, reddish marls, sandy-clayey limestones and dolomites, whereas in some places in the upper part there also occur gritstone lenses. These are typical shallow-sea sediments formed in the peripheral deltaic environment. *Leopoldia biassalensis* (K a r.) and *Olcostephanus* (*R.*) *atherstoni densicostatus* (W e g n.), which charac-

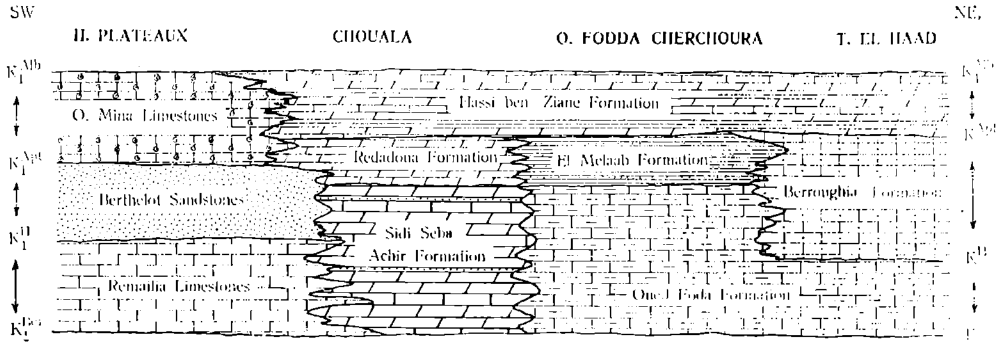


Fig. 17. Lithostratigraphic units in Northern Algeria between the High Plateaux and Tenict El Haad

terize the Lower Hauterivian, were found among the reddish marls near Bakhada. In addition to the ammonites, there are also bivalvs, gastropods and echinids: *Pterinella carteroni* (d'O r b.), *Echinospatagus ricordeanus* C o t t., *Nerinea atava* (R o e m.), *N. vogtina* M o r t., *Exogyra tuberculifera* K a c h., D u n k., *Pteritrigonia* cf. *caudata* (A g.)., *Tyllostoma allardi* C o s s., etc. In the upper part: *Exogyra tuberculifera* K u c h., D u n k., *Ostrea polyphaema* C o q. and *Plicatula carteroniana* d'O r b.

These fossil finds define the stratigraphic range of the investigated Formation from the upper part of the Lower Hauterivian to the Aptian included.

The Lower Cretaceous section in the High Plateaux ends with carbonate sediments of the Oued Mina Formation. Its characteristics are determined by biomorphic limestones built mainly of oyster shells, being of typically reef character in some places. In some beds the limestones are allochemical and coarse-biodetritic, built mainly of bivalvs detritus, with individual whole oyster shells. Oysters decrease gradually upwards and the section is built of limestones with interbeds of dolomites and marls. Coarse gastropods (*Natica*) are found in the upper part. *Ostrea praelonga* S c h a r p e, *O. falco* C o q. and the Albian ammonite "*Placenticeras*" *uhligi* C h o f f. are identified from the lower part of the Formation. Higher up the Oued Mina Formation continues in the Cenomanian.

Shallow-sea facies formed in littoral and sublittoral environment are characteristic of the Lower Cretaceous sediments in the High Plateaux. Terrigenous facies predominate in the western part of the Plateaux, whereas terrigenous-carbonate sediments are gradually imposed in the east-northeast.

In the northwestern part of the High Plateaux (Monts de Tlemsen, El Rhoraf and Ouled Mimoun) the Lower Cretaceous is represented by alternation of micrograined limestones, slightly aleuritic limestones (in some places with many oysters), sandstones and marls. In this region the lower part of the series is well characterized by B e n e s t at al. (1977).

At Ouled Mimoun (ex-Lamoricière) the base of the Berriasian is represented by the upper part of the so-called carbonate platform (Remailia Formation). Micritic and biomicritic limestones with *Salpingoporella annulata* C a r., *Clypeina jurassica* F a v r e, *Thaumatoporella parvovesiculifera* (R a i n.), *Triplorella neo-*

comiensis R a d., *Cayeuxia* sp., *Trocholina* ex gr. *alpinaelongata* (L e u p.), rare serpula, remains of echinids, bivalvs and gastropods, are developed at the base.

Fine biocalcarenites follow upwards, in some places with oölites containing *Ammobaculites* cf. *coprolithiformis* (S c h w.), *Trocholina* ex gr. *alpinaelongata* and *Lenticulina* sp., as well as remains of bryozoans, bivalvs, gastropods and echinids. Many ostracods are found among marl beds in the upper part of the described sediments, among which *Protocythere* aff. *revili* D o n z e characterizes the lower part of the Berriasian.

The greater part of the Berriasian and the base of the Valanginian are built of the Lamoricière Formation ("Argiles de Lamoricière"). It is represented at its base by clayey limestones and micrite limestones, among which there occur *Trocholina* ex gr. *alpinaelongata*, various benthonic foraminifera, bryozoans, bivalvs, gastropods and echinids. Thin intercalations of shell limestones with micrite, containing rare calpionellids, also occur. They are followed upwards by marls which are attributed to the top of the middle part of the Berriasian according to ostracods. These marls are covered by clayey limestones and clayey-sandy limestones, among which there is varied macrofauna. This level is known from the studies of P o m e l (1889). The following species have been found: *Jabronella paquieri* (S i m.), *J. zianidia* (P o m.), *Malbosiceras pouyannei* (P o m.), *Pomeliceras* (*P.*) *breveti* (P o m.), *Pomeliceras* (*P.*) sp., *P.* (*Mazenoticeras*) *broussei* (M a z.), *P.* (*M.*) *telloutense* (P o m.), *Pomeliceras* (*M.*) spp., *Neocosmoceras* aff. *rerolei* (P a q.), *N. sayni* (S i m.), *Spiticeras* sp., *Subalpinites mediterraneus* M a z., *Fauriella* sp., etc. This association defines the *Malbosiceras paramimounum* Subzone of the *Fauriella boissieri* Zone (base of the upper part of the Berriasian).

Brachiopods, bivalvs, echinids, serpula and many ammonites: *Fauriella boissieri* (P i c t.), *F.* aff. *rarefurcata* (P i c t.), *F.* aff. *latecostata* (K i l.), *Tirnovella alpillensis* (M a z.), *Berriasella* aff. *picteti* M a z., *Jabronella paquieri* (S i m.), *Malbosiceras* sp., *Spiticeras* sp., etc., are found higher up among marl beds (B e n e s t at al., 1977). The Berriasian is covered discordantly by Miocene sediments from the Sidi-bel-Abbes depression.

To the southeast of Ouled Mimoun, at El Rhoraf, the Lower Cretaceous is represented by the middle and upper part of the Berriasian and by the Lower Valanginian. Carbonate sediments (Remailia Formation) with typical shallow-sea fossils are at the base. Above them lies the "Argiles de Lamoricière" Formation which is lithologically similar to the outcrops at Ouled Mimoun, but it is characterized here by some intraformational hiatuses, cross-bedding and bioturbations. The faunistic remains are the same as at Ouled Mimoun. The Berthelot Formation follows on top, represented by sandstones, siltstones and aleuritic claystones. The Lamoricière "clays" should be considered as part of the Remailia Formation (Fig. 18).

The Lower Cretaceous sediments appear over vast areas in the Tellian Atlas, where they are represented by deep-sea facies which are in contrast to the neritic formations from the High Plateaux.

In the **Tellian Atlas** the Lower Cretaceous is connected with the following lithostratigraphic units: the Sidi Seba Achir Clayey-Calcareous Formation, the Oued Fodda Clayey-Carbonate Formation, the El Melaab Flyschoid Formation, the Redadoua Marl Formation and the Hassi ben Ziane Clayey-Carbonate Formation. The series is developed in its full volume from the Berriasian to the Albian included. In normal profiles the Lower Cretaceous is connected with gradual lithological transitions with the Upper Jurassic sediments below and with Cenomanian deposits above.

The Sidi Seba Achir Formation is represented by clayey-calcareous sediments. Alternation of marls and clayey limestones with intercalations of siltstones and sandstones predominate at the base. In the middle part mainly marls with rare intercalations of clayey limestones are developed. The upper part of the Formation is built of alternation of marls and clayey limestones. Limestones predominate at the base of this part, whereas marls passing into compact claystones become gradually imposed higher up.

The Formation is in a complex tectonic position — in the frontal part of the Chouala nappe, therefore it is difficult to characterize its boundaries. Many ammonites occur among the sediments of this Formation.

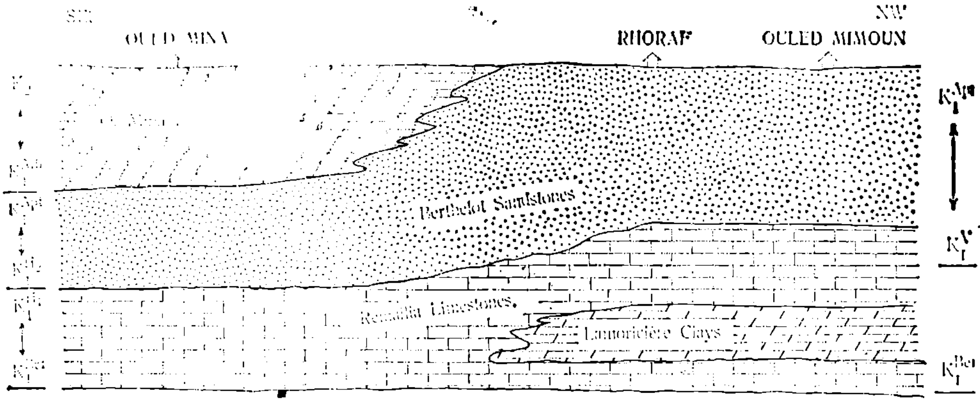


Fig. 18. Lithostratigraphic units in the northern part of the High Plateaux between the Oued Mina and Ouled Mimoun

The following Berriasian ammonites are found in the **Chouala** area in the lower part of the Formation: *Berriasella calisto* (d'O r b.), *Berriasella* cf. *privasensis* (P i c t.), *Fauriella boissieri* (P i c t.), *Spiticeras* sp. indet. and *Leptoceras studeri* (O o s t.).

Valanginian ammonites follow above the beds of this association: *Thurmanniceras* cf. *thurmanni* (P i c t.), *Kilianella* sp. indet., *Olcostephanus* (*O.*) *leptoplanus* (B a u m b.), and slightly higher up: *Saynoceras verrucosum* (d'O r b.), *Neocomites neocomiensis neocomiensis* (d'O r b.), *Olcostephanus* sp. indet., *Neolissoceras grasianum* (d'O r b.), etc.

A very rich Valanginian association was found at Ain en Nessissa: *Phylloceras* spp., *Neocomites neocomiensis neocomiensis* (d'O r b.), *N. neocomiensis premolicus* (S a y n), *N. neocomiensis subquadratus* (S a y n), *Olcostephanus* (*Olcostephanus*) *astierianus* (d'O r b.), *Olcostephanus* (*Rogersites*) *atherstoni* (S c h a r p e) and *O.* (*R.*) *psilostomus* (N e u m., U h l.).

The middle part of the investigated Formation is of Hauterivian age, which is proved by the find of *Crioceratites* sp. indet., *Olcostephanus* sp. indet. and *Phyllopachiceras* sp. at Sidi Seba Achir.

The upper part of the Formation is of Barremian age. The following species are found at Sidi Ounes: *Barremites nabdalsa* (C o q.), *B.* aff. *difficilis* (d'O r b.), *Subpulchellia sauvagensis* (H e r m.), *S. ochleafi* (N i c k.), *Spitidiscus pulvinatus* B u s n., *Holcodiscus* spp. and *Hamulina* sp. indet. A little higher: *B. nabdalsa* (C o q.), *Pulchellia compressissima* (d'O r b.), *Holcodiscus perezianus* (d'O r b.), *Spitidiscus querolensis* B u s n. and *Hypophylloceras barremense* B u s n., followed above by: *Pseudosaynella strettostoma* (U h l.), *Hypophylloceras barremense* B u s n., *Subpulchellia* sp. and *B. nabdalsa* (C o q.). At Ras el Masraf and at Sidi Aek: *Pulchellia ouachensis* (C o q.), *Subpulchellia sauvageani* (H e r m.), *Spitidiscus nemglonensis* (S a y n), *Spitidiscus* sp. indet., *Eotetragonites duvali* (d'O r b.), *Pseudosaynella strettostoma* (U h l.), etc.

On the territory of Douar Raouraoua (Oued Riou valley), in a rather tectonized section of the Sidi Seba Achir Formation, there are marls with intercalations of micrograined limestones and boudinated clayey limestones, among which the following Middle Aptian (Gargasian) ammonites were found: *Acanthohoplites stephanoides* (K a s.), *Colombiceras* cf. *crassicostatum* (d'O r b.), *Gargasiceras lautum* (A n t h.) and *Pseudohaploceras akuschense* (A n t h.).

The Formation is widespread in the Chouala area.

The Oued Fodda Clayey-Limestones Formation is revealed in scattered outcrops near Oued Fodda dam, around Grand Pic, east of Djebel Ouarsensis, between Koudiat Tifket and A. Hamichain, and around Kef Hala. Its sections are built of marls and limestones, in some places with intercalations of argillites, dolomites and sandstones. Stratigraphic volume: Tithonian-Aptian.

Berriasian fossils are found at Ain el Hadjella: *Berriasella* cf. *calisto* (d'O r b.). *Malbosiceras* cf. *malbosi* (P i c t.), *Pomeliceras* (*M.*) *paramimounum* (M a z.), etc. Among the limestones there occur many calpionellids as well.

At Oued Fodda dam: *Berriasella calisto* (d'O r b.) and *Berriasella* spp.

The Valanginian is proved by a number of ammonite finds (Ain el Hadjella) along the road to the mines Sidi Abd el Kader, near Koudiat Tifket and A. Hamichain: *Thurmanniceras* sp. indet., *Kilianella* sp. indet., *Olcostephanus* sp. indet., *Valanginites* sp., *Neocomites neocomiensis* (d'O r b.), etc.

The Hauterivian is not proved palaeontologically, but its development in the continuous succession between the Valanginian and the Barremian is indisputable.

The Barremian is proved by *Barremites* sp., *Silesites seranonis* (d'O r b.), *Eolytoceras subfimbriatum* (d'O r b.), *Heteroceras astieri* (d'O r b.), etc., found at Oued Fodda.

The Aptian comprises the upper part of the Oued Fodda Formation, built of grey-green marls with intercalations of sandstones, limestones and clayey limestones, while grey-black compact claystones appear in the upper part. The stage is proved palaeontologically by M a t t a u e r (1958).

The El Melaab Flyschoid Formation is widespread in the Tellian Atlas and reaches up to 1700 m. It is built of alternation of dark-grey to black argillites, siltstones and sandstones. Argillites predominate in the sections. Stratigraphic volume: Aptian-Lower Albian.

Aptian fossils are found in the El Melaab Formation. At Ami Moussa, on the eastern shore of Oued Riou: *Ancyloceras* ex gr. *urbani* (N e u m., U h l.); at Oued Lira: *Parahoplites* cf. *uhligi* A n t h.; west of Djebel Tafren: *P. melchioris* A n t h. and *Parahoplites* sp. indet.; at Oued Shifa: *Acanthohoplites* aff. *laticostatus* S i n z., etc. Rich foraminifera associations are established.

M a t t a u e r (1958) reports the Lower Albian *Desmoceras latidorsatum* (M i c h.) at Kef Assaker.

The Redadoua Formation ("Formation marneuse de Redadoua") is built of marls and calcareous argillites with limestone or dolomite concretions. Interbeds of limestones and sandstones are observed in some places. The Formation is very widespread in the Ouarsenis area, where it covers and / or replaces the El Melaab Formation and underlies the Hassi ben-Ziane Formation, with which it is connected through lithological transitions. On the basis of foraminifera it is assumed that this Formation comprises the Middle and Upper Albian Substages.

The Hassi ben-Ziane Formation ends the profile of the Lower Cretaceous in Ouarsenis. It is represented by marls, clayey limestones and micrograined limestones, and less frequently by dolomitized limestones. Intercalations of argillites, siltstones and sandstones occur in some places. Marls predominate in the upper part of the Formation, being with flint concretions in some places. Stratigraphic volume: Upper Albian-Lower Cenomanian.

Characteristic Upper Albian ammonites are found in the outcrops of the Hassi ben-Ziane Formation in the Western Ouarsenis area: *Mortoniceras nanum* S p a t h, *M. inflatum* (S o w.), *M. kiliani* (L a s s w.), *M. nanoides* W i e d m., D i e n i, *M.* cf. *pricei* S p a t h, *Hysteroceras orbigny* (S o w.), *H. carinatum* S p a t h, *H. binum* S p a t h, *Prohysteroceras* (*Goodhallites*) *candolianum* (P i c t.), *P.* (*G.*) *goodhalli* S o w., *P.* (*Neoharpoceras*) cf. *hugardianum* (P i c t., C a m p.), *Anisoceras armatum* (S o w.), *Elobiceras* cf. *elobense* (S z a j n.), etc.

Ammonites from the uppermost zone of the Albian are found at an upper level of the same Formation, but in strongly tectonized beds, east of Ain el Tarik and Koudiat Bameur: *Stoliczkaia dispar* (d'O r b.), *S. nota* S e e l e y, *Mortoniceras* (*Cantabrigites*) *cantabrigensis* S p a t h, *M.* (*C.*) aff. *minor* S p a t h, *Neophilceticeras sexangulatum* S e e l e y, *Mariella* sp., etc.

Lower Cenomanian foraminifera associations are discovered in the uppermost part of the Formation.

To the east of Djebel Ouarsenis, in the Teniet el Haad area, the base of the Lower Cretaceous is connected with the sediments of the Oued Fodda Formation, which is well exposed in the core of the Koudiat Larouah anticline. In the same facies are developed Berriasian, Valanginian, Hauterivian and Lower Barremian sediments in the Amrouna Massif to the north of Teniet el Haad.

The Upper Barremian and the Aptian in the Teniet el Haad are represented in terrigenous-carbonate (Urgonian) facies, fully characterized by M a t t a u e r (1958) on the western slope of Djebel Berrouaghia ("rochers étagés"). These are varied limestones: organogenous with rudists: biodetritic, sandy with Orbitolinidae and micritic; sandstones and sandy marls with Orbitolinidae. The facies is similar to the Aptian facies in the Fore-Balkan. These sediments are also well exposed along the road from Kemis Miliana (ex Affreville) to Letourneux.

Generally speaking, the Lower Cretaceous sediments in the Tellian Atlas contain many fossils, but the beds are strongly tectonized, often inverse, in many cases at the front of nappes, which complicates detailed correlation.

In the northern part of the Tellian Atlas (Dahra oriental), between Cape Tenes and Cherchelle, L e p v r i e r et al. (1970) have indicated by foraminifera the development of the Lower Cretaceous from the Neocomian to the Albian in clayey-carbonate sediments.

Flysch sediments are developed to the north of the Cheliff depression in the coastal area between Mostaganem and Biserta, part of which are dated to the Aptian and Albian.

Pelagic Lower Cretaceous sediments (micritic limestones with radiolaria and planktonic foraminifera, core- and breccia-type limestones, as well as marls) are developed in the Djurdjura area (Las Goulmine) (G é l a r d et al., 1981).

Of particular interest is the Lower Cretaceous in the Northeastern part of Algeria, between the town of Constantine and the Mediterranean Sea. Predominantly carbonate and terrigenous-carbonate sediments are developed within the southern confines of this area, in the High Plateaux around Constantine. They form a carbonate platform which divides the Aures Depression from the Tellian trough throughout the entire Early Cretaceous. The Berriasian and the Valanginian in this area are not well characterized palaeontologically.

The Hauterivian in the Constantine area is indicated by *Olcostephanus astierianus* (d'O r b.), *Olcostephanus* sp., *Oosterella* sp. and *Duvalia dilatata* (B l.). On the contrary, the Barremian is very rich in ammonites, which outline the same associations as in the Tellian Atlas. The Aptian and Albian are well characterized palaeontologically (M a s s e, T h i e u l o y, 1979).

Flysch sediments (Tithonian-Oligocene) are developed in the north, in the Kabyly zone. Among the Lower Cretaceous part of this thick flysch complex, D u r a n d

D e l g a (1969) distinguished three basic types: (1) fine sandy flysch ("flysch greseux fin de Guerrouch"); (2) sandy flysch ("flysch greseux-micacé"), and (3) flysch with calcareous microbrecchias ("flysch à microbrèches calcaires"). Similar flysch types may be observed in many Mediterranean zones.

The transition zone between the platform of the High Plateaux and the pelagic area to the north is outlined to the southwest of Constantine. In this zone (Monts de Batna — Aures) the Lower Cretaceous is markedly terrigenous or terrigenous-carbonate (B u r e a u, 1971).

The development of the Berriasian and Valanginian is interesting, because they are well substantiated palaeontologically only in the investigated zone in the Constantine region. At Ravin Bleu (M. de Batna) there are clayey-carbonate sediments with intercalations of sandstones and siltstones, from the transition between the neritic and the pelagic zones, in which D o n z e, G u i r a u d, L e H é g a r a t (1974) have found rich calpionellid and ammonite associations, known from the classical outcrops in the Mediterranean Region.

3.2. Tunisia

The Lower Cretaceous in Tunisia is connected with three main tectonic zones: the Tunisia Depression, the complex of intracratonnal basins and unstable neritic basins in Central Tunisia and Tunisian Sahara.

In the **southernmost (Sahara) part of Tunisia** the base of the Lower Cretaceous (Berriasian-Hauterivian) is built of continental terrigenous sediments and evaporites. Carbonates are developed further north in the southern periphery of the sea basin. The Barremian in this zone is represented by coarse terrigenous continental sediments: conglomerates and sandstones with intercalations of red sandy claystones. This is the classical "continental intercalaire" with thickness up to 1000 m. Remains of vertebrates and plants are found. There are no traces of sea organisms. A similar type of sedimentation continued during the Aptian as well, but with the appearance of dolomites and clayey dolomites during the Late Aptian. This marks the beginning of a lagoon environment in Sahara.

Purbeckian-Wealdian type of facies are developed to the north of the Sahara zone: sandstones, dolomites, claystones and gypsum (Merbah el Asfer Formation). They contain remains of vertebrates, silicified trees, bivalvs, gastropods, as well as some rare marine species.

The Barremian and the Lower Aptian are represented by terrigenous sediments: sandstones, conglomerates and red claystones (Bateun el Rhezae Formation). Higher up the Aptian and Albian sections are built of limestones, massive dolomites and gypsum-bearing marls. At Dj. Tebaga de Medine they lie transgressively on Permian or Jurassic rocks (B u r o l l e t, M a n d e r s c h e i d, 1965).

In the east and northeast the continental terrigenous facies are replaced by carbonates belonging to the typical Mediterranean Lower Cretaceous. Their southern boundary at the end of the Albian Age marks the starting point of the Trans-Sahara Late Cretaceous transgression.

B u r o l l e t (1956) outlined three main zones of Lower Cretaceous development in Central Tunisia: Dj. Nara zone, Kasserine zone and zone of the Periatlas basin.

The lower part of the series (Berriasian-Valanginian) is discovered in the Djebel Nara zone (North-South axis). The section starts with the marls of Sidi Kralif (earlier designated as "Argiles de Sidi Kralif"). These are grey marls with intercalations of limestones and clayey limestones. The marls are rich in fossils, among which many pyritized ammonites are known (B r e i t s t r o f f e r, 1937; A r n o u l d-S a g e t, 1951). The ammonite successions demonstrate the development of the three ammonite zones of the Berriasian and in some places of the Lower Valanginian as well. The Berriasian sediments are connected with the Tithonian deposits by means of a gradual lithological transition.

In the Gafsa area the described clayey-calcareous sediments are covered by the Maknassi Group which is divided into three formations: Meloussi Formation — built of dolomites, dolomite limestones, sandstones, sands and greenish claystones (Hauterivian?-Lower Barremian); sands of Boudinar — coarse-grained, lightly cemented, containing silicified plant remains (Upper Barremian), and Gafsa Formation — represented by alternation of sands, siltstones, claystones and carbonates, sometimes with evaporites (Aptian-Albian). The Gafsa Formation has its sea equivalent, i. e. limestones — massive, of the subreef to reef type, with rudists, corals and Orbitolinidae ("calcaires du Serdj") of Aptian age. They are covered by an alternation of claystones and sandstones (Albian-Lower Cenomanian).

The Lower Cretaceous is most extensively developed in **Northern Tunisia**, where it is connected with the **Tunisian Depression** ("Sillon Tunisien"). All stages from the Berriasian to the Albian included are represented (Burollet, Manderscheid, 1965; Stranik et al., 1974; Memmi, 1979; 1981). In this area Lower Cretaceous sediments are developed in two main facial environments: neritic and pelagic.

Neritic facies are well developed predominantly in the Zaghouan Massif. They are represented by organogenous and biodetritic limestones and sandy marls.

Pelagic facies are widespread in the middle part of the Depression and in the Eastern Tunisian Atlas — microgranular limestones and sublithographic limestones with intercalations of marls. They contain many calpionellids and ammonites.

The Lower Cretaceous in the Eastern Tunisian Atlas (Stranik et al., 1974) starts with sublithographic limestones, clayey limestones and marls of the **Berriasian:** *Tirnovella occitanica* (Pict.), *T. subalpina* (Maz.), *Berriasella* (*B.*) *oppeli* (Kil.), *B.* cf. *elegans* Arnould-Saget, *Fauriella boissieri* (Pict.), *Calpionella alpina cadischi* Dob., *C. undelloides* Col., *C. elliptica* Cad., *Tintinnopsella carpathica* (Murg., Fil.), *Calpionellopsis oblonga* (Cad.), *Calpionellites allemanni* Dob. (Stranik et al., 1974). These fossils date the interval from the *P. grandis* Zone to the *F. boissieri* Zone, as well as the calpionellid zones *Calpionella* and *Calpionellopsis.*

In the region of Temple des Eaux (Zaghouan) the Berriasian is represented by biodetritic limestones with intercalations of marls.

The Valanginian is represented by two types of sediments: marly and flyschoid. The marls near Oued Gelta contain many ammonites: *Neocomites neocomiensis premolica* Sayn, *N. neocomiensis subquadratus* Sayn, *Sarasinella* aff. *trezanensis* (Lory), *Kilianella roubaudiana* (d'Orb.), *K.* aff. *grossouvrei* (Sayn) and *Thurmanniceras pertransiens* (Sayn), as well as *Duvalia lata constricta* Uhl. and many foraminifera.

The flyschoid sediments are represented by alternation of marls, compact claystones and fine-grained sandstones.

The Hauterivian sediments follow with a lithological transition above the Valanginian flyschoid deposits. The following species are found at Kef el Blidah (Zaghouan): *Crioceratites* sp., *Oosterella gaudryi* (Nick.), *O. vidali* (Nick.), *O. stefanini* (Nick.), *Lyticoceras* cf. *longinodum* (Neum., Uhl.), *Olcostephanus* (*O.*) *astierianus* (d'Orb.), *O.* (*Rogersites*) *atherstoni* Scharpe, *Leopoldia* sp., *Hibolites subfusiformis* Rasp., etc.

They are followed upwards by marls, limestones and clayey limestones containing many foraminifera, as well as the following more characteristic cephalopods: *Olcostephanus* (*O.*) *hispanicus* (Moull.), *O.* (*O.*) aff. *sayni* Kil., *Plesiospitidiscus ligatus* (d'Orb.), *Spitidiscus* sp., *Subsaynella sayni* (Paq.), *Duvalia dilatata*

(B l.), etc. In the upper part of the Hauterivian section at Oued Gelta *Pseudothurmannia angulicostata* (d'O r b.) and *Pseudothurmannia* sp. are found among a packet of limestones, as well as foraminifera: *Hedbergella infracretacea* (G l a e s s n.), *Vaginulina recta* R e u s s, *Uvigerinamina moesina* N e a g u, *Milliammina sproulei* N a u s s, etc.

The Barremian in the area of the Eastern Tunisian Atlas is represented by pelagic and neritic biodetritic sediments (S t r a n i k et al., 1974).

The pelagic sediments are represented by packets of micrograined or sublithographic limestones with intercalations of marls.

The neritic (subreef) facies is represented by organogenous, biodetritic and core limestones with Stomatoporoidea, as well as by typical shell limestones. Intercalations of marls also occur. This facies is developed predominantly in the southeastern part of the investigated area.

There are characteristic marker beds ("barre calcaire") at the base of the Barremian, followed upwards by marls with *Barremites* gr. *difficilis* (d'O r b.), *Holcodiscus caillaudianus* (d'O r b.), *Nicklesia alicantensis* H y a t t, *Duvalia grasiana* D u v. - J o u v e, many brachiopods, echinids and foraminifera.

The upper part of the Barremian is proved at Koudiat Touila: *Hemihoplites feraudianus* (d'O r b.), *Pseudosaynella strettostoma pervinquieri* (B u s n.), *Barremites* sp., *Heteroceras astierianum* (d'O r b.), *Silesites seranonis* (d'O r b.), etc.

The section of the **Aptian** in ascending order is built of: flyschoid sediments, limestones, alternation of marls and clayey marls, and an upper flyschoid unit. The following ammonite succession is established: *Deshayesites consobrinus* (d'O r b.), *Aconeceras nisum* (d'O r b.), *Cheloniceras* (*C.*) *martini* (d'O r b.), *Gargasiceras gargasense* (d'O r b.), etc., which determine Bedoulian and Gargasian. The Clansayesian is dated by many foraminifera.

The Albian is represented by clayey-calcareous sediments (marls and limestones). It is dated by means of *Kosmatella sublaevis* W i e d m., *Valdedorsella getulina* (C o q.), *Beudanticeras revoili* P e r v., *Mortoniceras*, etc., as well as by many foraminifera. The stage is not differentiated in detail due to the lack of sufficient ammonites.

The section at **Djebel Oust** is most representative for the development of the Lower Cretaceous in the northeastern part of the Tunisian Depression (B u s n a r d o, M e m m i, 1972; M e m m i, 1981).

The Berriasian starts with alternation of marls and clayey limestones, and in some places intraclastic limestones with *Pseudosubplanites grandis* (M a z.). They are followed upwards by marls with several packets of sublithographic limestones and in some places resedimented breccias, which pass into biodetritic limestones with *Tirnovella occitanica* (P i c t.) and *Berriasella* (*B.*) *subcalisto* (T o u c.); above them there are marls and packets of clayey limestones with *Neocosmoceras sayni* S i m., *Neocosmoceras* spp., *Protancyloceras punicum* (A r n.-S a g.), etc., which are covered by marls with pyrite cores and clayey limestones with *Fauriella boissieri* (P i c t.), *Tirnovella romani* (M a z.), *Spiticeras* spp., etc.

The Valanginian starts with marls, slightly sandy in some places, with intercalations of biodetritic limestones containing *T. carpathica* (M u r g., F i l.), *Calpionellopsis oblonga* (C a d.) and *Remaniella cadischiana* (C o l.). This level is in fact transitional between the Berriasian and the Valanginian. Olive-green marls with rare intercalations of clayey limestones containing *T. pertransiens* (S a y n.), *Kilianella roubaudiana* (d'O r b.), *K. lucensis* (S a y n), *Chamalocia aenigmatica* (S a y n), *Pseudobelus bipartitus* (B l.), etc., follow higher up. Above them: flyschoid alternation of marls, quartzitized sandstones, limestones and clayey limestones with *Neocomites* (*Teschenites*) sp., *Duvalia lata lata* (B l.) and *D. lata constricta* U h l.; marls with *Saynoceras verrucosum* (d'O r b.), *Neocomites* (*N.*) *neocomiensis sub-*

quadratus S a y n, *N.* (*Teschenites*) *teschensis* (U h l.), *Olcostephanus* (*O.*) *astierianus* (d'O r b.), *Duvalia lata lata* (B l.) and *D. lata constricta* U h l. Above the beds with this association M e m m i (1981) describes an alternation of marls with packets of clayey limestones containing *Oosterella cultrata* (d'O r b.) and numerous olcostephanids. The presence of *O. cultrata* is not characteristic of the Valanginian, which ends with beds containing *Saynoceras verrucosum*.

The Hauterivian includes the following succession: clayey limestones with marl intercalations containing many *Oostrella*: *O. stevenini* (N i c k.), *O. gaudryi* (N i c k.), *O. vidali* (N i c k.), *O. vilanovae* (N i c k.), *Olcostephanus* (*O.*) *astierianus* (d'O r b.), *O.* (*O.*) *hispanicus* (M a l l.), *Breitstrofferella castellanensis* (d'O r b.) and *Duvalia dilatata* (B l.). The beds containing *O. cultrata* should also be included in the base of this level, incorrectly attributed to the Upper Valanginian by M e m m i (1981). Above them: marls with packets of limestones and clayey limestones containing *Crioceratites loryi* (S a r k.), *Crioceratites* spp., *Spitidiscus incertus* (d'O r b.), *Olcostephanus* spp., etc.; marls with intercalations of clayey limestones containing *N.* (*Teschenites*) *nodosoplicatus* (K i l., R e b.), *Abrytusites juliani* (H o n n.-B a s t), etc.; marls with rare intercalations of clayey limestones, in some places marls with sandy intercalations, containing *Subsaynella sayni* (d'O r b.), *Plesiospitidiscus ligatus* (d'O r b.), *Spitidiscus* spp., etc.; alternation of marls and limestones with *Pseudothurmannia angulicostata* (d'O r b.), *P. biassalensis* D i m ., *P. mortilleti* (P i c t., L o r.), *Balearites* aff. *balearis* (N o l.), *Crioceratites krenkeli* (S a r k.) and *C. stahleckeri* (S a r k.).

The Barremian is composed of the following succession: alternation of marls, limestones and clayey limestones containing *Holcodiscus caillaudianus* (d'O r b.), *Barremites difficilis* (d'O r b.), *B. vocontius* L o r y, S a y n and *Nicklesia* sp.; marls with rare intercalations of clayey limestones; alternation of thick packets of limestones, in some places with cores,containing *Heteroceras astieri* (d'O r b.), *Silesites seranonis* (d'O r b.), *Pseudosaynella strettostoma pervinquieri* (B u s n.), etc.; marls with sandy packets, containing *P. strettostoma pervinquieri* (B u s n.), "*Leptoceras*" *puzosianum* (d'O r b.), *Duvalia grasiana* (D u v.-J u v e), etc.; marls with thin intercalations of sandstones, containing *Barremites* and "*Leptoceras*".

The Aptian starts with marls containing *Deshayesites deshayesi* (L e y m.), above which there are: alternation of marls and clayey limestones with *Cheloniceras martini* (d'O r b.), *Aconeceras nisum* (d'O r b.), etc.; claystones with thin intercalations of sandstones and clayey limestones with *Valdedorsella getulina* (C o q.), *Melchiorites melchioris alpina* F a l., *C.* (*Epicheloniceras*) sp., etc. No Clansayesian or Albian sediments are developed in this part of Tunisia.

Generally speaking, the Lower Cretaceous in Tunisia manifests rather varied palaeodepositional environments, from continental to bathyal of a typically Mediterranean type. In the east and southeast, in Libya and Egypt, the Lower Cretaceous is represented by continental facies.

4. IBERIAN PENINSULA

The Lower Cretaceous sediments in the Iberian (Pyrenean) Peninsula are connected with several tectonic zones. Coastal facies with numerous intraformational hiatuses are developed around the Central Hercynian Massif of the Iberian Meseta. In the Cantabrian Range, in the Pyrenees, the Iberian Mountains and the Catalanes, the Lower Cretaceous is very varied, represented by a whole range of different facies: from Wealdian to flysch-type. Deep-sea facies are developed in the Subbetic Depression (between Meseta and the Betic Massif), including in the Balearic Islands. Generally speaking, the distribution of the Lower Cretaceous outlines a large triangle around Meseta, with Portugal in its western part, in the north-

northeast — the Cantabrian and Iberian mountain ranges, and to the southeast — the Subbetic zone with its continuation towards the Balearic Islands. In the north the Iberian Peninsula is limited by the Pyrenees. A number of consistent studies on the Lower Cretaceous were carried out in the past twenty years, among them notably the works of R a t (1963), R a n g h e a r d (1971), R e y (1972), V i a l l a r d (1973), C a n é r o t (1974), P e y b e r n e s (1976), etc.

4.1. Portugal

The Lower Cretaceous in Portugal is developed in the western periphery of the Iberian Meseta: in the area of Estramadoura, Beira, Arrabida and Algarv. Continental and epicontinental facies predominate.

Most representative are the sections in **Estramadoura**, which are studied in detail by J. R e y (1972). The lithological transition from the Jurassic to the Cretaceous is usually gradual.

In the area of Cascais, Sintra and Brouco the **Berriasian** is represented by the following succession: limestones and marls with *Mancellina purbeckiensis* (F o r b e s), covered by marls with *Anchispirocyclina lusitanica* (E g g e r), *Nerinea infravalanginiensis* (C h o f f.), limestones and marls with *Trocholina*. In the region of Ericeira and Cap Espichel the Berriasian is represented by alternation of variegated claystones, dolomites and sandy limestones. These are sediments of Purbeckian type.

The Valanginian is connected with two formations. The lower one is built of shallow-sea limestones and marls with *Natica leviathan* (P i c t., C a m p.), developed in the Sintra Massif and in the Caskais region. In the east these clayey-calcareous sediments are replaced by sandstones ("grès de Vale de Lobos"), formed under estuary conditions. The upper formation is developed in the Sintra area, near Brouco and to the north of Cap Espichel. It is represented by reddish sandy limestones, in some places ferruginized and oölitic ("calcaire roux") with *Neocomites* (*N.*) *neocomiensis* (d'O r b.) and echinids.

The Hauterivian is developed in the area of Sintra and Brouco. It is represented at its base by marls and clayey limestones with *Toxaster, Crioceratites* ex gr. *duvali* and *Neocomites* sp. In the east these sediments pass into subreef limestones, well developed near Brouco. The upper part of the stage is built of reef limestones with corals and echinids. At the same time marls and sandstones were formed in the north at Ericeira (Santa Suzana), followed above by limestones with Rudista (Praia des Coxos). The Hauterivian near Cap Espichel is also developed in a similar facies.

The Lower Barremian is developed at Sintra and Brouco: limestones with *Choffatella* and Dasycladacea.

The terrigenous-carbonate sediments of the Upper Barremian and Aptian (Almargen Beds) are particularly widespread. These are varied limestones (dolomitic, clayey, sandy-biodetritic, organogenous reef), marls and sandstones, testifying to shallow-sea conditions and marking a regressive cycle which ends at the end of the Gargasian Substage.

To the north of Torres Vedras the Lower Cretaceous passes into typical continental deposits of Wealdian type: river sandstones with plant remains. The classical outcrops of Serkal are found in this region, from where some of the oldest finds of fossil plants from Dicotyledonae — *Dicotylophyllum*, are known.

4.2. Subbetic Depression

This depression is developed in Southeastern Spain and the Balearic Islands. There are representative sections in the Andalusian area, in the regions of Grenada, Cordoba, Jaen, Alicante and on the Balearic Islands. Predominantly clayey-calcareous sediments of pelagic type are developed. Many ammonites, including pyritized forms, also occur.

The Berriasian is built predominantly of clayey limestones and it is characterized by the following ammonites and calpionellids: *Pseudosubplanites (P.) grandis* (M a z.), *Berriasella (Picteticeras) moesica* N i k., M a n d., *B. (P.) picteti* (K i l.), *B. (P.) elmii* Le H é g., *B. (B.) subcalisto* (d'O r b.), *Calpionella elliptica* C a d., *C. alpina* L o r., *Tirnovella occitanica* (P i c t.), *T. subalpina* (M a z.), *Malbosiceras paramimounum* (M a z.), *Fauriella rarefurcata* (P i c t.), *F. boissieri* (P i c t.) and many others (H o e d e m a e k e r, 1982; R a n g h e a r d, 1971).

The Valanginian is represented by marls with intercalations of clayey limestones. Marls with pyritized ammonites predominate: *Kilianella pexiptycha* (U h l.), *K. roubaudiana* (d'O r b.), *Sarasinella trezanensis* (L o r y), *Busnardoites campylotoxus* (U h l.), *Saynoceras verrucosum* (d'O r b.), *Bochianites neocomiensis* (d'O r b.), *Neocomites* spp., *Phylloceras* spp., etc.

The Hauterivian contains more clayey limestones. It is characterized by *Olcostephanus (O.) astieri* (d'O r b.), *O. (O.) jeannoti* (d'O r b.), *Lytoceras cryptoceras* (d'O r b.), *Phyllopachiceras infundibulum* (d'O r b.), *Crioceratites* spp., *Balearites* spp. and *Pseudothurmannia* sp. (W i e d m a n n, 1962).

The Barremian is represented by marls and clayey limestones, or by marls with pyritized ammonites: *Holcodiscus caillaudianus* (d'O r b.), *H. camelinus* (d'O r b.), *H. sophonisba* (C o q.), *H.* spp., *Barremites difficilis* (d'O r b.), *B.* spp., *Pulchellia compressissima* (d'O r b.), *P.* aff. *haugi* N i c k l., *P. maladae* Nickl., *Subpulchellia sauvageani* (H e r m.), *Pseudosaynella strettostoma* (U h l.), etc.

Bathyal **Aptian sediments** have a more limited distribution, mainly in Cadix Province and on the Balearic Islands (Ibiza and Formentera). It is characterized by *Cheloniceras (C.) martini* (d'O r b.), *Aconeceras nissum* (d'O r b.), etc. Paraurgonian facies with Orbitolinidae and Urgonian limestones with *Toucasia* appear at Hodar in Jaen Province and on Formentera Island.

Transitional types of sediments are developed in the northern zone of the Subbetic Depression: from the bathyal facies in the south-southeast to the neritic sediments in the northwest. The section of the series starts below with limestones containing *N. leviathan* (Valanginian) and ends with the orbitolinic beds and dolomites of the **Albian**.

This specific feature of the Lower Cretaceous is well manifested in the Alicante Province, where the following succession is found in ascending order: sandstones (Lower Valanginian), clayey limestones and marls with ammonites (Upper Valanginian-Barremian), marls with *Cheloniceras*, limestones with Rudista and Orbitolinidae (Aptian) and Albian limestones with Orbitolinidae. The section ends with dolomites (B u s n a r d o, D u r a n d D e l g a, 1960; B u s n a r d o et al., 1968).

Flysch sediments (Tithonian-Albian) which are a continuation of the flysch trough from Magreb are developed in the southwesternmost part of the Subbetic Depression.

4.3. Iberian Mountain Range

To the east of the Subbetic Depression there is extensive development of predominantly epicontinental Lower Cretaceous sediments in the Iberian Mountains. In their **Western Castilian area** and in **Teruel Province** the Lower Cretaceous is represented in continental terrigenous facies of Wealdian type. Particularly characteristic for this region is the so-called Utrilas facies which is represented by continental veriegated sandy claystones, feldspar and kaolin sandstones, often with cross-bedding.

Marine terrigenous-carbonate facies (sandstones, limestones and sandy marls with Orbitolinidae) of Barremian-Aptian age appear in the northeast. Urgonian sediments with *Toucasia* are developed in the Utrilas region and they are covered by marls with *Trigonia* and beds of lignite coal of Upper Aptian-Lower Aptian age. Further up the Albian section is built of shallow-sea limestones.

In the northern part of the Eastern Iberian mountains (Soria-Burgos region) the Lower Cretaceous is represented by thick (above 1000 m) Wealdian-type sediments (conglomerates, sandstones, marls and gypsum, as well as limestones with *Paludina, Unio* and *Cyrena*). In the southwestern part of this area the Lower Cretaceous sediments are in terrigenous-carbonate facies which are formed in different bays and / or channels (C a n e r o t, 1974).

Around the Catalonian Hercynian Massif, between Barcelona and Taragona, the Lower Cretaceous is represented at its base by brakish Wealdian limestones, followed above by paralic sediments of probable Hauterivian age, covered by Urgonian limestones (Barremian-Aptian) and Albian marls with Orbitolinidae and rare ammonites.

4.4. Pyrenean-Cantabrian Region

In the **Basco-Cantabrian area** which delimits the Bay of Biscay from the south, the Lower Cretaceous is represented at its base by terrigenous-carbonate Wealdian sediments which are covered by the Urgonian complex. The section of the Lower Cretaceous ends with Albian sandstones and limestones with Rudista and rare ammonites (R a t, 1959a).

In the **Pyrenees** the Lower Cretaceous is represented in extremely varied facies with rapidly varying thicknesses and complex spatial correlations between the lithostratigraphic units (R a t, 1969; P e y b e r n e s, 1976; J a f f r e z o, 1981). The Lower Cretaceous facies are predominantly neritic, mainly of carbonate type, in some areas also terrigenous. Urgonian facies are particularly widespread, forming thick sections from the Valanginian to the Albian inclusive. There exist many hiatuses and deep denudations of some horizons, which have resulted in the formation of considerable bauxite deposits. In the central part of the Northern Pyrenean area there was marked peridotite magmatism with which the formation of chrysotile-asbestos deposits is connected. The Lower Cretaceous is characterized palaeontologically predominantly with foraminifera, algae, nannoplankton, etc., as well as with bivalvs, gastropods, brachiopods and echinids. Ammonites occur rarely, mainly among Aptian clayey-calcareous rocks.

Berriasian-Hauterivian sediments are developed in the Central Pyrenees (Comminges oriental, Couserans and Pays de Foix), in the Eastern Pyrenees (Pays de Sanit, Corbières) and in the Southern Pyrenees (Aragon — Catalogne). The sections are most comprehensive in the Southern Pyrenees and in the Corbières.

Polygenous breccias are usually developed at the Jurassic-Cretaceous boundary, followed above by limestones with calpionellids or limestones with calpionellids and oncolites. They are covered by marls and clayey limestones with *Pseudosubplanites* (in the Southern Pyrenees) or dolomitic limestones with *Clypeina*. The middle part of the Berriasian is built of limestones with *Trocholina* and Dasycladacea. The Upper Berriasian and the Lower Valanginian are connected with reddish limestones with lignite intercalations of Purbeckian-Wealdian type, with the exception of the Francazal marls which are a marine formation under neritic conditions. They contain pyritized ammonites. Higher up the sections are built of sandy limestones, yellowish limestones with bryozoans or limestones with charophytes. Several rudists of the *Toucasia* group, as well as corals are found among these limestones (P e y b e r n e s, 1976).

Table 15

Major Lithostratigraphic Units Connected with the Barremian and the Aptian in French Pyrenees (simplified after Peybernes, 1976)

Stages and Substages		Depression (Bassin facies)	Urgonian platform		
Albian					
Clansayesian	Upper	Black marls with *Hypacanthoplites*	Limestones		
	Middle				
	Lower	Marls and clay limestones	Reef limestones		
Gargasian	Upper	Limy shales	Limestones with *Pseudochoffatella cuvillieri*		Lignites
	Lower		Limestones with *Mesorbitolina parva*		
Bedoulian	Upper	Marls with *Deshayesites*	Limestones with *Simplorbitolina praesimplex*		
	Lower		Limestones with *Preorbitolina*		
Barremian	Upper		Reef limestones	Limestones with annelids	Lignites
	Lower			Limestones	?

Barremian-Aptian sediments are of the following types: platform type — with predominance of neritic biomorphic limestones with rudists and Orbitolinidae (Urgonian facies), and bathyal (depression facies) — represented predominantly by marls with ammonites. This type was developed from the beginning of the Aptian Stage (the Barremian Stage in the Pyrenees is developed only in Urgonian, i. e. platform, facies). The bathyal type (basin facies) is developed in the Albian Stage as well (Table 15).

Bathyal sediments are developed in Comminges, Couserans, Corbières and in the Southern Pyrenees. Marls with *Deshayesites, Prodeshayesites* and echinids are developed at the bottom. In the Corbières the carbonate content increases and among the marls there are more calcareous intercalations with Orbitolinidae, oysters, large ammonites, echinids, brachiopods and corals. From these marls Peybernes (1976) reports: *Prodeshayesites fissicostatus* (Phill.), *P. bodei* (Koen.), *P. laevicostatus* (Koen.), *Deshayesites forbesi* Cas., *D. callidiscus* Cas., *D. euglyphus* Cas., *D. kiliani* Spath, *D. fittoni* Cas., *D. planus* Cas., *Roloboceras hambrowi subnodosum* Cas., *R. regale* Cas., *D. deshayesi* (Leym.), *Cheloniceras cornuelianum* (d'Orb.), *Tropaeum bowerbanki* Sow., *Dufrenoyia furcata* (Sow.), *D. lurensis* (Kil.), *D. discoidalis* Cas., *Gargasiceras garganense* (d'Orb.), etc. Above them there are calcareous shales (calschistes intermédiaires du Comminges), whose correlates are the Tarascon marls and the Val de Cabo marls in Spain. The following species are found among the marls at this level: *Aconeceras nissum* (d'Orb.), *Cheloniceras (E.) martinoides* Cas., *C. (E.) tschernyschewi* (Sinz.), *C. (C.) subnodosocostatum* (Sinz.), *Parahoplites nutfieldensis* (Sow.), *P.* cf. *melchioris* Anth., etc. These rocks are covered by marls and clayey limestones, as well as black marls among which there are: *Acanthohoplites bigoureti* (Seun.), *Hypacanthoplites nolani* (Seun.), *Diadochoceras nodosocostatum* (d'Orb.), *C. (E.) clansayense* (Jac.), *Hypacanthoplites rubricosus* Cas., *H. elegans* (Frit.), *H. anglicus* Cas., etc. The marls with *Hypacanthoplites* pass higher up into marls with *Trigonia*, above which black marls and clayey-carbonate sediments passing into the Cenomanian are developed.

The Albian is proved by *Leymeriella tardefurcata* (Leym.), *Douvilleiceras mammillatum* (Schl.), *D. inaquinodum* Quenst., *Dipoloceras cristatum* (Br.), *M. inflatum* (Sow.), *Stoliczkaia dispar* (d'Orb.), *Anisoceras perarmatum* (Pict., Camp.), *Ostlingoceras puzosianum* (d'Orb.), etc.

The platform type of Lower Cretaceous sediments in the Pyrenees are in Urgonian facies. These are varied limestones with Orbitolinidae, rudists and other neritic macrofossils, as well as many varied benthonic foraminifera, algae, corals, etc. (Peybernes, 1976; Jaffrezo, 1981).

A particularly characteristic feature of the Pyrenees is the extensive development of the complete volume of the Aptian and Albian Stages to the north of the Palaeozoic axis zone. The two stages are very thick and are exclusively of marine type. In the eastern part of the Comminges zone (Central Pyrenees) the Aptian sediments are locally metamorphosed.

4.5. Continental Margin of the Iberian Peninsula

The Lower Cretaceous in the continental margin of the Iberian Peninsula is characterized according to data from boreholes 120 and 398-D of the DSDP-IPOD (Taugourdeau-Lantz et al., 1982; Von Rad, Hinz, Sarnthein, Seibold (eds.), 1982).

Borehole 120 is situated in the area of the continental foothills in Gorringe Bank, to the west of Cape St. Vincent, approximately as a continuation of the northern strip of the Subbetic Depression. Berriasian basalts (age 131-135 m. y.) are discovered at the base of the Lower Cretaceous, followed above by claystones in which foraminifera zones are found: from the *Globigerina gulekhensis* Zone to the *Rotalipora apenninica* Zone (Valanginian-Albian), as well as nannoplankton zones: from the *Nannoconus colomi* Zone to the *Lithraphidites alatus* Zone (Berriasian-Albian) (P f l a u m a n n, Č e p e k, 1982).

Borehole 398-D is drilled in the outer part of the Iberian continental margin, on the southern slope of the submarine hill Vigo, to the west-southwest of Porto. The exposed Lower Cretaceous section from the Upper Hauterivian to the Albian inclusive is built of clayey sediments, including the so-called black shales and marls in the Middle and Upper Albian. The dating is performed on the basis of foraminifera, spores, pollen and dinoflagellates (T a u g o u r d e a u - L a n t z et al., 1982).

In the shelf (continental plateau) of Northern Portugal the Lower Cretaceous is represented by Wealdian-type sediments (B o i l l o t et al., 1975). In the north, in the shelf zone of Southwest Spain, it is represented by neritic limestones and marls with *Choffatella, Orbitolina,* Dasycladacea and gastropods (Barremian-Albian) (L a m b o y, D u p e u b l e, 1975).

5. FRANCE

Historically the foundations of the Lower Cretaceous stratigraphy were laid in France during the second half of the 19th century. The stratotypes of the Berriasian, Barremian, Aptian and Albian are found in this country. Reference sections of the Valanginian and Hauterivian were described recently in pelagic facies, complementing the Swiss stratotypes of these two stages, developed in neritic facies.

There exists vast literature on the Lower Cretaceous in France, notably the publications of Kilian, Lory, Sayn, Haug and Gignoux, and more recently the works of Mazenot, Breistroffer, Busnardo, Destombes, Donze, Le Hégarat, Magniez-Jannin, Moullade, Rat, Remane, Sigal, F.-Taxy, Thieuloy, Thomel, etc. Some fundamental data about the Lower Cretaceous in the stratotype area of the Lower Cretaceous Stages were presented in Chapter Two. This is why, only the main areas of development of the series in France will be outlined here, without enumerating fossils whose list is long and familiar.

The Lower Cretaceous in France is connected with the following areas: the Alps (including the Subalpine Mountains with the Vocontian trough), Provence, Jura Mountain, Paris and Aquitanian Basins. Here it is also necessary to mention the Lower Cretaceous in the French Pyrenees, which was considered in the previous pages.

5.1. The Alps

The French Alps demonstrate varied Lower Cretaceous which is developed in deep-sea facies. Several zones in which the Lower Cretaceous manifests specific features are outlined in this area.

5.1.1. Savoy Area

The area comprises a considerable part of the Western Alps with the massifs of Pelvoux, Belledonne and Mont Blanc. In the northwestern part of this area, to the west of Mont Blanc (chaines des Aravis), the Berriasian-Hauterivian are represented by micritic limestones and clayey limestones; the Barremian and Aptian — by limestones and sandy limestones in Urgonian facies, covered transgressively by Albian glauconitic sandstones. Only Barremian clayey limestones — part of the Rosselette nappe, are developed to the southwest of the Mont Blanc Massif in the Ultrahelvetian area (E l t c h a n i n o f f-L a n c e l o t et al., 1982).

In the same area, in the Nantebelte Group (Sulens klippe), C h a r o l l a i s et al. (1981) have found the following succession in the Lower Cretaceous: alternation of micritic spotty limestones with radiolaria and calpionellids, and shaly clayey limestones with calpionellids and nannoplankton (Berriasian-Barremian), followed above by sandy-glauconitic sediments (Aptian-Lower Cenomanian).

5.1.2 Dophinoise Area

This area represents an Early Cretaceous depression between the Central Massif and the massifs of Mont Blanc, Belledonne and Mercantour. In southern direction the depression widens and passes into the Vocontian trough. The depression is narrower in the northern part and the sediments are thicker, e. g. at Cévennes the Berriassian-Hauterivian sediments (subflysch) (1500-2000 m) are 5-6 times thicker than in the Vocontian trough. Moreover, in the northern part the sediments are aleuritic and / or slightly sandy, often with turbidites, whereas exclusively clayey-calcareous sediments are developed in the south. A strip of neritic sediments encircles the depression: in the northwest these are the high calcareous mountains of Savoy, the massifs of Grande-Chartreuse and Vercors, and the environs of Valence; in the south— the Languedoc and Provence.

The Lower Cretaceous in the **Southern Subalpine Range (Vocontian trough)** is represented by pelagic sediments of Alpine type, unlike the neritic type in the Jura Mountains. This is the only area in France, where deep-sea sedimentation existed from the Berriasian to the Albian and passed into the Cenomanian as well. In fact, the Vocontian trough represents an enormous bay of the Subalpine Early Cretaceous depression. Fine micritic limestones, clayey limestones and marls, rich in ammonites and planktonic microfossils (calpionellids, radiolaria, foraminifera and nannoflora) are developed there. This is the same facies in which the Lower Cretaceous of the Salaš syncline in Northwestern Bulgaria is developed.

The Northern Subalpine Range in which the Lower Cretaceous is developed in mixed facies, starts to the north of Diois. To the north of the region around the town of Die is the prominent high wall of the Urgonian limestones building the southern end of Vercors and representing a characteristic element of this zone. The Lower Cretaceous is represented by mixed facies — multiple repetition of biomorphic limestones with marls. These sediments form the transition from the Vocontian to the Jura-type facies of the Lower Cretaceous. All stages of the series are developed and they are very well characterized palaeontologically. Particularly representative is the section between Grenoble and Chambery.

5.1.3. Piemont Area

The Lower Cretaceous in this area is represented by a thick monotonous series of "calcschistes" which were transformed into "schistes lustrés" during the Upper Eocene-Oligocene under the effect of dynamometamorphosis. These "calcschistes" are identified as Lower Cretaceous through comparison with a similar unmetamorphosed formation in the Northern Apennines, which is dated to the Tithonian-Neocomian by calpionellids. The schists overlie green rocks — ophiolites (diabases and spilites) and gabbro, being covered by radiolarites which are metamorphosed into quartzites with sericite and chlorite, well revealed today at Mont Viso. The calcschistes are covered by Upper Cretaceous flysch with helminthoids.

5.2. Provence

The Lower Cretaceous in Provence is represented by shallow-sea sediments: zoogenic limestones, glauconitic sandstones with phosphorites and marls. The ammonites decrease, while bivalvs and echinids increase. In many respects the Provence facies resemble the Lower Cretaceous in the Northern Subalpine Range, but the limestones are more widespread. A characteristic feature is that the maximum thicknesses of the series are measured in the transitional strip between the deep-sea Vocontian and neritic Provence facies. For example, while the thickness of the Berriasian-Barremian sediments in the Vocontian trough is 150-200 m, in the Ventoux region it reaches up to 1000 m.

The Berriasian-Hauterivian sections are formed of clayey-calcareous sediments (marls with *Spatangus*), which are deeper-sea in the south and more neritic close to the coastal area of the Maures-Esterel Massif. They are covered by the thick complex of the Urgonian limestones whose type is found at Orgon village, in the valley of Durance river. The Urgonian limestones near Orgon are very varied: light, massive and rich in rudists. There also occur corals, gastropods, echinids, brachiopods, Orbitolinidae and very rarely ammonites. The limestones of the Ruse Formation, south of the town of Ruse, are a striking analogue of the type section of the Urgonian.

Urgonian limestones determine specific landscapes observed from Ardèche, along the Rhône valley, south of Ventoux, in the Aix-en-Provence area, in Marseilles and north of Toulon.

In its stratotype at Bedoule — Cassis the Lower Aptian (Bedoulian) is represented by limestones with flint, among which there are rare intercalations of marls. The sediments are similar to the transitional facies of the Bedoulian in Northeast Bulgaria.

The Gargasian near Gargas and Apt is represented by marls, ammonites, belemnites and *Orbitolina*. The Clansayesian is characterized by glauconitic marly-sandy sediments with intraformational hiatuses.

The Albian is represented predominantly by glauconitic sandstones, in some places with phosphorites, which are traced in the northern strip of Provence: from Nice and Gras towards Escragnole to the region south of Drôme. Around Apt the Albian-Cenomanian glauconitic sediments are strongly oxidized. This is the zone of the Durance vault which has divided Provence from the Alpian Basin since the Albian Age and opens it towards the Pyrenees.

5.3. Aquitanian Basin

Located between the Pyrenees and the Central Massif, the Aquitanian Basin was represented during the Early Cretaceous by two bays inherited from the Jurassic period and considered to be in fact two basins: Adour Basin and Parentis Basin.

The Adour Basin is located between the Pyrenees and the Landes threshold which separates it from Parentis. The Berriasian is represented by limestones. They are covered transgressively by Neocomian sandy-clayey and dolomitic sediments. Neritic limestones with anellids and *Spatangus* occupy the central part of the depression. The Lower Aptian starts with a thick unit of marls (the Sainte-Suzanne marls) which are distributed in the southern part of the basin. The marls are followed upwards by thick Urgonian limestones (1000 m thick at Lacq), which comprise the Upper and Lower Albian, and are developed in the southern strip of the basin, whereas in its middle part there are marls reaching the Cenomanian. Flysch sediments (flysch noir ardoisier) are developed in the axis zone, their formation being related to pre-Cenomanian tectonic activation. An olistostrome formation is developed in the west, in the Basque area, which passes into the flysch in the north. Parallel with the axis zone, part of the Mesozoic sediments (Lias-Upper Albian) were metamorphosed during the Late Cretaceous or Eocene. Basic volcanites are also found in the Albian and Cenomanian.

In the **Parentis Basin** the Lower Cretaceous starts with lacustrine-lagoonal Purbeckian sediments. The Neocomian is represented by sandy claystones of estuary type. Marine conditions are established during the Barremian, when sandy and oölitic limestones were deposited. The Aptian starts with marls covered with limestones and sandstones, whereas Urgonian limestones develop in the periphery, comprising, similar to Adour, the Lower Aptian as well. Deltaic sandstones are developed in the peripheral parts of the basin, whereas 1500 m flysch is deposited in the axis zone.

5.4. Jura Mountains

Lower Cretaceous sediments in Jura Mountains are represented by platform-type, predominantly carbonate facies. The series starts with Purbeckian lagoon sediments, above which there are marls and clayey limestones with intercalations of lignites and brackish ostracod fauna from the middle part of the Berriasian (D o n z e, 1958). Above them there are reddish limestones and marls, known from the Neuchâtel — Valangin — Hauterive region in the Swiss Jura Mountains. Hauterivian marls with echinids are relatively the deepest-sea deposits among the Lower Cretaceous sediments in Jura Mountains. Their formation coincides with the time when the sea was opened widest to the northwest towards the Paris Basin.

The Barremian and the Aptian are developed only in the high parts of Jura Mountains, being represented mainly by Urgonian limestones. Albian glauconitic sandstones are deposited transgressively over them.

5.5. Paris Basin

Lower Cretaceous sediments are discovered as a continuous strip in the southeastern part of the Paris Basin, starting at Hirson (the Ardennes) in the north, passing through the region of Revigny, Brienne and St. Florentin, crossing the Loire valley and ending in the northern slope of the Central Massif, north of Bourges. In the remaining part of the Basin the Lower Cretaceous is identified everywhere by drilling.

During the Early Cretaceous the Paris Basin represented a strait connecting the Mediterranean Basin with the North Sea and this determined the distribution and the specificities of the different stages. Over lagoonal or lacustrine clayey Purbeckian limestones there are Wealdian clayey-sandy deposits, among which iguanodons (at Bernissart), crocodiles, turtles and fishes have been found.

In the central part of the strait (Aube) marine sedimentation started with Upper Valanginian zoogenic limestones with echinids and oysters. The facies and the distribution of these limestones indicate the beginning of the transgression. During the Hauterivian it expanded to the northwest, whereby clayey limestones with *Spatangus* were deposited in the Basin, similar to those from Jura Mountains. They contain also Exogyra and rare ammonites (*Acanthodiscus radiatus*). They are followed by Barremian claystones with oysters, which are outlined by variegated fresh-water sandy-clayey sediments with *Unio*, above which there are red claystones (Wassy Red Beds) with *Heteraster oblongus* and many bivalvs, indicating the return of the marine conditions. The Aptian is represented by marls with *Plicatula*. The Albian starts everywhere with glauconitic sandstones which are covered by claystones with many ammonites. To the north of Revigny Albian sediments overlie Jurassic rocks and they become markedly shallow-water upon approaching the Ardennes Massif.

In the central part of the Basin and in the Bray region, the lower part of the Lower Cretaceous is in continental (Purbeckian-Wealdian) facies. Marine sedimentation started during the Aptian when marls with *Plicatula* and *Ostrea* were deposited. The Albian sediments are typically deep-sea claystones.

In addition to Jura Mountains, where it is developed in neritic facies, the Lower Cretaceous is widespread in the Swiss Alps as well. This is one of the most complex, if not the most complex, mountain structures on Earth, characterized by the predominance of nappe structure. The palinspatic reconstruction makes it possible to "unfold" the nappes and to indicate the synsedimentational position of the different lithostratigraphic units. This reconstruction which was carried out for the first time by H e i m (1919-1921) for the Eastern Alps and by G i g n o u x (1950) for the Western Swiss Alps, indicates clear facial zonality, whereby lateral transitions are observed for the facies of Jura type to the north, the Vocontian type to the south, through the mixed facies of the Northern Subalpine ranges to the facies of the Swiss Alps. The Lower Cretaceous is connected with the outer zone of the Alps, with the Fore-Alps and with the Helvetian nappes (H e i m, 1921; H e i m, B a u m b e r g e r, 1933; G i g n o u x, 1950; F u n k, 1969-1975; F u n k, B r i e g e l, 1979).

Lower Cretaceous sediments are traced from the Savoy Alps in the northwest beyond the Rhône valley to the Morcles Massif. Clayey limestones and marls with sandstones are developed. The Lower Cretaceous is partially presented in the autochthonous cover of the Aar Massif. At Doldenhorn and Blumlisalp the Berriasian and the Valanginian are represented by marls and clayey limestones with characteristic ammonites, followed above by Hauterivian cherty limestones with *Toxaster retusus*, covered by the Palaeogene. To the east of Aar the series is greatly reduced: the Hauterivian (limestones with *T. retusus*) is 4-6 m thick, whereas the Barremian (Urgonian limestones with *R. ammonia*) is 6-10 m thick. The Aptian comprises marls with *Orbitolina lenticularis* and *Heteraster oblongus*, covered by a second formation of Urgonian limestones. These sections indicate that even in the autochthonous Alps the Lower Cretaceous is strongly folded and most often with reduced thicknesses.

Lower Cretaceous facies become deeper-sea upon the transition from the autochthone to the lower nappes, as well as from the lower to the upper and more southern nappes (G i g n o u x, 1950). Thus, the Berriasian is represented by marls (marnes d'Oerhli), the Valanginian—by zoogenic limestones (calcaires d'Oerhli), marls and core limestones with neritic fauna and rare ammonites (*Neocomites*). They are followed upwards by breccia-like limestones(Calcaires spathiques)formed of echinid detritus. They correspond to the Fontanil Limestones (Upper Valanginian) near Grenoble. The Hauterivian starts most frequently in the lower nappes with limestones containing echinids which are covered by glauconite sandstones with ammonites: *Neolissoceras grasi* (d'O r b.) and *Olcostephanus astierianus* (d'O r b.), followed above by Barremian clayey limestones with glauconite and many ammonites: *Barremites difficilis* (d'O r b.), *Barremites* spp., *Holcodiscus falax* (M a t h.) and *Nicklesia pulchella* (d'O r b.). The section ends with Urgonian limestones (Lower Aptian) with thickness 300 m. In fact, the Urgonian is very shortened in the autochthone, but its thicknesses are considerable in the Morcles and Diablerets nappes. In the Wildhorn nappe Urgonian limestones become gradually wedged and are replaced by Drusberg Beds which are developed between Schwyz and Glaris.

The upper part of the Aptian, as well as the Albian are represented by glauconite facies and correspond to a regressive cycle which lasted into the Cenomanian.

Of particular interest is the development of siliceous limestones (Helvetischer Kiesekalk) in the lower nappes. These limestones contain up to 40 per cent fine (1-10 mm) evenly distributed authigenic quartz crystals resulting from early diagenetic dissolution of the opaline sponge spicules (F u n k, 1975). These Helvetic siliceous limestones pass to the south into Wildhorn nappes in a thick formation of deep-sea clayey limestones.

The Lower Cretaceous has an interesting section to the southwest of Lucern in the Pilatus-Kulm region, where the following succession is established: (1) Valanginian marls and limestones, in some places with glauconite; (2) siliceous limestones (Kiesekalk) (Hauterivian); (3) Altmann Beds (marls, sandy marls, limestones and sandy limestones with glauconite) (Lower Barremian); (4) Drusberg Beds (Middle Barremian); (5) Lower Urgonian limestones (Upper Barremian); (6) *Orbitolina* Beds; (7) Upper Urgonian limestones (Lower Aptian); (8) glauconite sandstones (Albian).

In the **Upper Helvetic nappes** the Berriasian-Valanginian comprises black marls discovered at Justisthal, north of Thun Lake, where the following species are found: *Leptoceras studeri* Oost., *Phylloceras calypso* (d'Orb.), *Neolissoceras grasi* (d'Orb.), *Kilianella pexiptycha* (Uhl.) and *Duvalia lata* (Bl.). Urgonian limestones are found in a deviation of the nappe at Lutere Zug close to Wolfenschiessen, followed above by black phosphatized marls with condensed fauna: *Aconeceras nissum* (d'Orb.), *Colombiceras tobleri* (Jac.) and *Cheloniceras buxtorfi* (Jac.) (Jacob, Tobler, 1906).

In the **Lower Fore-Alps (Ultrahelvetic nappes)** the Lower Cretaceous is represented by deep-sea Berriasian-Hauterivian marls and clayey limestones with many ammonites, which are covered by Upper Cretaceous limestones.

There is a continuation of the Lower Cretaceous from the Ultrahelvetic nappes to the Middle Fore-Alps, where there are clayey shales or marls and limestones with rare belemnites and aptychi.

The classical deposits Voirons, Châtel-Saint-Denis are in the external Fore-Alps, east of Lausanne and Mont-Salève, where the latest outcrops of Urgonian limestones are discovered. From this region Sarasin and Schöndelmayer (1901-1902) described Berriasian, Valanginian, Hauterivian and Barremian fossils.

An enormous flake built of deep-sea marls with cephalopods, among which Urgonian limestones are also included, is discovered in the internal zone of the Fore-Alps, between the Morcles and Diablerets nappes.

In the **Fore-Alpine nappes** the Lower Cretaceous is known in the **Nisen flysch nappe**. It is represented by clayey shales and calcareous shales with aptychi. Intercalations of orbitolinic limestones occur in some places — peripheral Urgonian facies.

In Central Switzerland, in the **klippe zone**, which is remnants of the Fore-Alpine nappes, there are limestones with *Pygope*, aptychi and calpionellids, which touch upon marls with *Orbitolina* along the fault.

7. EASTERN ALPS

The Lower Cretaceous has limited distribution in the Eastern Alps. Two Lower Cretaceous strips are discovered in the **flysch zone.** In the northern strip there are: (1) marls with *Duvalia lata* and Valanginian ammonites; (2) breccia-like limestones (Valanginian); (3) siliceous Hauterivian limestones; (4) Urgonian limestones with orbitolinic marls in the upper part (Barremian-Aptian). In the southern strip the Valanginian limestones and the Urgonian are replaced by marls. A similar transition from neritic to bathyal facies is observed in the Western Alps as well.

The Lower Cretaceous is also well preserved in some synclines in the **Bavarian nappe.** It lies concordantly and with transition over Jurassic rocks and is covered transgressively by Upper Cretaceous sediments. Two Formations are distinguished: lower — Strambach Limestones, and upper — Rossfeld Beds (mainly marls).

The Strambach Limestones are Berriasian-Valanginian in age, whereas the Rossfeld Beds belong to the Hauterivian and Barremian. The basic sections have been studied by S a y n, U h l i g and H a u g (Kufstein, Ruhpolding, Rossfeld, Salzburg and Ischel). Exclusively bathyal clayey limestones, marls and clayey shales (Berriasian-Barremian) are developed, containing: *Fauriella boissieri* (P i c t.), *Tirnovella occitanica* (P i c t.), *Berriasella privasensis* (P i c t.) (Berriasian), *Kilianella pexiptycha* (U h l.), *Neocomites neocomiensis* (d'O r b.) (Valanginian), *Lyticoceras cryptoceras* (d'O r b.), *Crioceratites duvali* L é v., *Olcostephanus astierianus* (d'O r b.) *O. jeannoti* (d'O r b.) (Hauterivian), *Barremites difficilis* (d'O r b.), *Silesites seranonis* (d'O r b.) (Barremian). The Aptian is developed in the same facies, whereas the Albian is represented by glauconitic sandstones (U h l i g, 1882; 1887; S a y n, 1893).

8. HUNGARY

The Lower Cretaceous in the Pannonian Massif is known from its southern part — Vilany and Meczek, as well as from the Hungarian Central Mountains — Bakony and Gerecse. Of particular importance for the stratigraphy of the series are the works of J. ir. N o s z k y and especially the more recent research of F ü l ö p (1958-1976). Varied facies with numerous intraformational hiatuses are developed. In most places the Lower Cretaceous sediments overlie the strongly denuded surface of the Tithonian limestones.

8.1. Vilany and Meczek

These are low-mountainous elevations in the peripheral part of the Pannonian Massif. The section of the series usually starts over the strongly denuded and partially karstified surface of the Upper Jurassic limestones. Generally speaking, it is characterized by complex block and / or flake structure, which is also reflected in the fullness of the sections.

In Meczek there are sections in which the Berriasian deposits are connected by a gradual transition with the Tithonian rocks. The Berriasian is represented by dense micritic limestones and clayey limestones (30 m) with *Tintinnopsella carpathica, Calpionellopsis oblonga, Remaniella cadischiana,* radiolaria and ammonites. The Lower Valanginian is connected with volcanogenic-sedimentary formations (the trachydolerite tufogenic formation with thickness up to 10 - 100 m), among which *Kilianella roubaudiana* (d'O r b.) has been found. The Upper Valanginian is represented by marls and sandstones (5-30 m) with *Thurmanniceras thurmanni* (P i c t., C a m p.), *Olcostephanus astierianus* (d'O r b.) and *Neocomites neocomiensis* (d'O r b.).

Urgonian limestones with many rudists overlie the denuded surface.

In the **Vilany Mountains** above the deeply denuded Kimmeridgian-Tithonian limestones there are diabase volcanic rocks (trachydolerites) which are assumed to have the same age as the Valanginian trachydolerite tufogenic formation in Meczek. In the Beremend horst and in Harsany bauxites were formed during the Hauterivian. Marine sedimentation started during the Barremian with the formation of Urgonian limestones with Orbitolinidae and rudists which reach until the base of the Albian.

In the Tenkes flake there is a big hiatus and over the strongly denuded surface of the Kimmeridgian limestones there are Urgonian limestones deposited transgressively but concordantly, followed upwards by clayey-calcareous siltstones (Albian) (F ü l ö p, 1966).

The section of the series is most complete at **Bakony. The Berriasian sediments** are connected by lithological transition with the Tithonian deposits (Sumeg, Lokut and Somhet). They are represented by light micritic limestones, clayey limestones ("Biancone" facies) containing *Berriasella privasensis* (P i c t.), *B. picteti* (J a c.), *Malbosiceras malbosi* (P i c t.), *Fauriella boissieri* (P i c t.), *Spiticeras* spp., many calpionellids and radiolaria. In the Alsomajor-Zirc valley and in the eastern part of Somhet the Berriasian is represented by reddish limestones with ammonites or by limestones with rare crinoids (Istenesmal-Zirc), while to the north of Zirc and at Bakonycsernye it is represented by light limestones with calpionellids.

The Valanginian and the Hauterivian are not clearly differentiated. They are represented by marls. In the Közöskut graben there are: *Kilianella roubaudiana* (d'O r b.), *Thurmanniceras thurmanni* (P i c t., C a m p.), *T. pertransiens* (S a y n) and *Neocomites neocomiensis* (d'O r b.), at Sumeg, Harskut and Lokut — *Olcostephanus astierianus* (d'O r b.), above which at Lokut there are beds with *Crioceratites*. Nannoconuses are also discovered.

The Barremian in the Marvanybanya region is represented by yellow-reddish limestones among which there are *Barremites, Hamulina* and *Valdedorsella*. F ü-l ö p (1964) unjustifiably refers to this stage the glauconitic sandstones, marls and sandy limestones with *Deshayesites, Silesites* and *Mesohibolites*, discovered in the Közöskut graben. These are beds formed under condensation conditions and the existence of *Deshayesites* indicates that they include the Lower Aptian as well. At Sumeg the Barremian comprises a packet of marls with radiolaria and ammonites, *Hamulina paxilosa* (U h l.), *Macroscaphites yvani* (P u z.), *Barremites* spp., "*Leptoceras*" *parvulum* (U h l.), *Nicklesia* sp., etc.

The Aptian is represented by grey crinoid limestones which are traced from Sumeg to the south through Varoslog, Harskut, Lokut, Zirc, Bakonycsernye to Tata. There also occur limestones with gastropods, brachiopods and ammonites: *Cheloniceras martini occidentale* (J a c.), *C.* cf. *cornuelianum* (d'O r b.), *C.* cf. *seminodosum* (S i n z.), *Parahoplites* cf. *melchioris* A n t h., *Diadochoceras nodosocostatum* (d'O r b.), etc.

The Aptian usually starts with algal limestones, above which there are claystones and marls with Orbitolinidae, covered by Urgonian limestones with rudists.

The Albian is represented by marls which are glauconitic in their upper part and contain typically Upper Albian ammonites (N a g y, 1971).

In the Tata horst (northwest of Tatabanya) near Kalvaria hill, the Berriasian s represented by limestones with calpionellids, ammonites, belemnites, etc. F ü-ö p (1976) reports a long list of characteristic Berriasian ammonites, which date n a condensed section the entire volume of the stage from the *P. grandis* Zone to the *F. boissieri* Zone. The descovery of *Kilianella* spp. and *Neocomites* is also evidence about the existence of the Valanginian in the northern part of the horst.

Glauconitic sandy limestones, sandstones, marls and crinoid limestones, containing rich Clansayesian fauna, overlie the deeply denuded surface of the Tithonian-Berriasian (and in some places of Valanginian) limestones. Most of the fossils are concentrated in the basal glauconitic layer, where they are also phosphatized. F ü l ö p (1976) has carried out a perfect investigation of this unique section which is recognized as geological reserve.

To the northeast of Tata the Lower Cretaceous section ends with Albian marls with glauconites, discovered at Vertes.

The Lower Cretaceous is also developed in the northern part of Gerecse (F ü-l ö p, 1958), where it is connected with an uninterrupted complex from the upper parts of the Berriasian to the Barremian included. Below there is a basal packet of clayey-calcareous sandstones and sandy limestones with *F. boissieri* and calcareous breccias, which lie transgressively over denuded Tithonian limestones. Above them follow a marl formation (Valanginian-Lower Hauterivian), sandstone formation (Upper Hauterivian-Upper Barremian p. parte) and a coarse-terrigenous formation built of conglomerates, gritstones, sandy limestones with Orbitolinidae, and limestones with rudists and corals (Upper Barremian p. parte-?Lower Aptian). A clear ammonite succession is established from the Upper Berriasian to the base of the Upper Barremian, with typical Mediterranean species.

9. CZECHOSLOVAKIA

The Lower Cretaceous manifests considerable variety in the Western Carpathians.

In the **klippes zone** the Lower Cretaceous is connected with the "Czorsztyn-Serie", "Pruské-Serie", "Podbiel-Serie", "Kysuca-Serie" and "Manin-Serie" (B o r z a, 1969). **The Berriasian** is represented by limestones (Lysa Skala) (crinoidal, crinoidal-brachiopod and biodetritic), dated by means of aptychi and by *Calpionella alpina* L o m b., *Tintinnopsella carpathica* (M., F.), *Calpionellopsis simplex* (C o l.) and *C. oblonga* (C a d.).

The Valanginian comprises crinoid limestones among which aptychi also occur. In the Podbiel Group it is represented by micrograined limestones with many calpionellids. **The Valanginian-Aptian** comprises marls and clayey limestones. "Neocomian" and Urgonian limestones are developed in the Manin Group.

The Albian is represented by dark-green, dark-grey to black marls with intercalations of limestones with radiolaria. This facies comprises part of the Aptian as well.

The Western Carpathian Group is distributed in the **High Tatras**. The Neocomian is represented by limestones covered by basaltic lavas and tuffs which are assumed to be Valanginian-Hauterivian in age. The Barremian is probably not represented or only its upper part is developed, connected with 100 m Urgonian limestones which are entirely referred to the Aptian. Middle and Upper Albian sediments are found above the Urgonian, namely: (1) glauconitic limestones with *Hoplites dentatus* (S o w.); (2) sandy marls passing into glauconitic limestones with *Hysteroceras varicosum* (S o w.); (3) green marls with *Mortoniceras inflatum* (S o w.); (4) marls and sandstones with *Stoliczkaia dispar* (d'O r b.).

The Lower Cretaceous is particularly widespread in the **Silesian zone (Beskydy)** where it has been known since the 19th century owing to Uhlig's classical investigations. Of great significance for the Lower Cretaceous stratigraphy are the works of R o t h and M a t e j k a (1953) and V a š i č e k (1972, 1979). Two main facial types are developed: predominantly neritic and deep-sea facies (Table 16).

Clear ammonite successions are established from the Valanginian upwards. The **Berriasian** is dated with calpionellids.

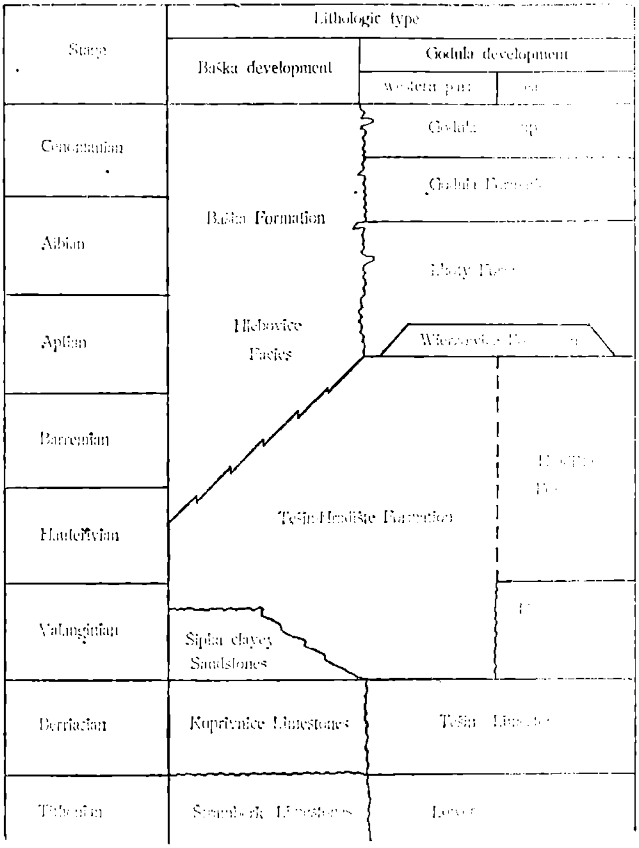
Valanginian: *Thurmanniceras pertransiens* (S a y n), *T. thurmanni* (P i c t., C a m p.,) *Kilianella pexiptycha* (U h l.), *K. clavicostata* N i k., *Busnardoites campylotoxus* (U h l.), *Neocomites (Teschenites) callidiscus* T h., *N. (T.) teschenensis* (U h l.), etc.

Hauterivian: *Acanthodiscus radiatus* (B r.), *Endemoceras amblygonium* (N e u m., U h l.), *Crioceratites duvali* L é v., *C. majoricensis* (N o l.), etc.

Barremian: *Nicklesia pulchella* (d'O r b.), *Karsteniceras pumilum* (U h l.), *Hamulinites parvulus* (U h l.), *Acrioceras tabareli* (A s t.), *Hamulina astieriana* (d'O r b.), *Anahamulina* sp., *Barremites psilotatus* (U h l.), *Pseudosaynella strettostoma* (U h l.), *Silesites vulpes* (C o q.), *S. seranonis* (d'O r b.), as well as a rich association of belemnites among which *Mesohibolites* predominate.

T a b l e 16

Lithostratigraphic Units Related with the Lower Cretaceous in the Beskydy (modified after R o t h, M a t e j k a, 1953 and V a š i č e k, 1972)



Aptian: *Procheloniceras pachystephanum* (U h l.), *P. albrechtiaustriae* (H o h.), *Deshayesites borowae* (K o e n.), *D. beskidensis* (U h l.), *Prodeshayesites* sp., *Acanthohoplites* cf. *bigoureti* (S e u n.), etc.

Albian sediments are dated by microfauna.

10. POLAND

The Lower Cretaceous in the Polish Depression is of northern type and therefore it will not be discussed here. In the area of the **Polish Carpathians** the series is developed in three zones: flysch zone, zone of the Pieniny klippes belt and in the Tatra Mountains (K s i a z k i e w i c z, 1956; K o s z a r s k i, S l a c z k a et al. in S o k o l o w s k i, 1976).

The flysch zone comprises a considerable part of the Carpathians. The Lower Cretaceous there is in full volume, developed predominantly in flysch facies. The summated thickness in the western part of the zone is 4000 m. Detailed lithostratigraphy is elaborated, whereby some of the lithostratigraphic units are known in Czechoslovakia as well (Tables 16, 17).

The Berriasian is connected with the **Těšin (Teschen) Limestones** (about 200 m thick) — they are clayey in their base, and pelitomorphic and biodetritic in their upper part, where they alternate with marls and shales. *Calpionella alpina* is found

Table 17

Lithostratigraphic Units Related with the Lower Cretaceous of the Polish Carpathians Flysch Zone (after Koszarski, Šlaczka in S o k o l o w s k i, 1976)

Stage	Lithostratigraphic units	
Cenomanian	green shales and radiolarites	
Albian	Lgota Beds	
Aptian	Sandstones locally to the west	Veřovice (Wierzowice) black Shales with lydites
Barremian		
Hauterivian	Grodziszcze Sandstones and Shales	
Valanginian	Upper Cieszyn (Tešin) Beds	
Berriasian	Cieszyn (Tešin) Limestones	
Tithonian	Lower Cieszyn (Tešin) Shales	

among them, as well as *Euthymiceras euthymi* (P i c t.), different algae, bryozoans echinoderms and foraminifera. These limestones overlie the Lower Tešin Beds (Tithonian).

The Upper Tešin (Teschen) Beds (300 m thick) are represented by calcareous sandstones and black marly shales with many concretions and lenses of clayey siderites (pelosiderites). Frequent intercalations of breccias and conglomerates are also observed. The following species are found among them: *Kilianella pexiptycha* (U h l.), *Thurmanniceras thurmanni* (P i c t., C a m p,.), *Neocomites neocomiensis* (d'O r b.), *Olcostephanus astierianus* (d'O r b.), *Duvalia conica* (B l.), *D. lata* (B l.), *D. emerici* (R a s p.), etc.

Hradiště (Grodziszcze, Grodischt) Sandstones (about 200 m thick). These are coarse-grained sandstones and siltstones, in some places to unsaturated conglomerates, with calcareous cement and few intercalations of shales. In some places the coarse-grained sandstones are replaced by fine-grained varieties with intercalations of dark-grey shales and marls. The following faunistic associations are found among these sediments: *Acanthodiscus* aff. *radiatus* (B r.), *Duvalia dilatata* (B l.), *D. poligonalis* (B l.), *Pseudobelus bipartitus* (C a t.), etc. (Hauterivian); *D. grasi* (D u v.), *Nicklesia pulchella* (d'O r b.), *Costidiscus recticostatus* (d'O r b.) (Barremian); *Procheloniceras albrechtiaustriae* (H o h.), *Ancyloceras* cf. *urbani* (N., U.), *Orbitolina* sp., etc. (Aptian).

Veřovice (Wierzowice, Wernsdorf) Shales (200-300 m thick). These are clayey-calcareous or siliceous shales with lydites and siderites in the lower part. They contain rich fauna characteristic of the Barremian and Aptian: *Hamulina astieri* (d'O r b.), *H. meyrati* (d'O r b.), *H. lorioli* (U h l.), *Hamulina* spp., *Barremites difficilis* (d'O r b.), *B. charrierianus* (d'O r b.), *Barremites* spp., *Holcodiscus caillaudianus* (d'O r b.), *Karsteniceras karsteni* (U h l.), *Crioceratites emerici* L é v., *Silesites vulpes* (C o q.), "*Leptoceras*" spp., etc. (Barremian); *Procheloniceras albrechti-austriae* (H o h.), *Deshayesites berovae* (U h l.), etc. (Aptian).

The Lgota (Ellgoth) Beds (about 300 m thick). They are formed of three parts: thin sandstone beds lie at the base, followed above by silicified sandstones and shales, covered by siliceous rocks (spongiolites) with intercalations of sandstones and shales. Rare fossils are found: *Inoceramus laubei* L i e b., *Neohibolites* cf. *minimus* L i s t. and *Acanthohoplites bigoureti* (S e u n.). which characterize the Upper Aptian and the Albian.

The Lower Cretaceous in the **Pieniny zone** is developed in two types: southern — Pieniny facies, and northern — Czorsztyn facies, which pass into one another.

The Pieniny facies is represented by white limestones with thin beds or lenses of black flint, and intercalation of shales. These beds are known by the name of hornstein limestones or limestones with *Aptychus* (Tithonian-Barremian).

The Czorsztyn facies is represented by crinoid limestones (Tithonian-Berriasian) which are covered by clayey limestones with flint and intercalations of black and green marls.

The Aptian has not been proved in this zone, whereas the Albian is represented by marls and marly shales with intercalations rich in radiolaria and globigerines.

In the **Tatra zone** the Lower Cretaceous is exposed in the so-called High-Tatran and Sub-Tatran nappes. In both tectonic units the rocks of the series are connected by lithological transition with Upper Jurassic sediments.

In the High-Tatran nappes the lower part of the section is built of dark, partially oölitic limestones which do not contain fossils. According to their stratigraphic position (between the Kimmeridgian and the Urgonian limestones), these sediments are assumed to be Tithonian-Neocomian. They are covered by limestones with Orbitolinidae, algae, bivalvs and brachiopods: *Orbitulina* aff. *bulgarica* D e s h., *Janira* sp., *Lima, Requienia*, etc.

The upper part of the Urgonian limestones is denuded and karstified, being covered by Albian glauconite limestones with phosphorite concretions and rich fauna: *Douvilleiceras mammillatum* (S c h l.), *Hoplites dentatus* (S o w.), *Dippoloceras cristatum* (D e l u c.), *Turrilites mayorianus* (d'O r b.), *Beudanticeras beudanti* (B r o n g.), *Inoceramus concentricus* P a r k., *I. sulcatus* P a r k, etc.

These sediments are followed upwards by glauconitic marls with *Mortoniceras inflatum* (S o w.), *Anisoceras* cf. *armatum* (S o w.), etc., which are covered by dark-coloured marls with *Stoliczkaia dispar* (d'O r b.), *Turrilites* cf. *bergeri* B r o n g., etc.

In the Sub-Tatran nappes the Lower Cretaceous is represented by marls with intercalations of clayey limestones (Valanginian-Barremian), which are covered by limestones and marls probably belonging to the Albian.

11. ROMANIA

The Lower Cretaceous is widespread in the Carpathians, the Apuseni, the Wallachian Depression and in Northern Dobrogea (О н ч е с к у, 1960; К о д а р ч а, Р э й л я н у, 1961; М у р д ж я н у et al., 1961; M u t i h a c, 1959; P a t r u l i u s, 1960-1976; A v r a m, 1970-1976; B l e a h u et al., 1981).

Lower Cretaceous sediments are part of the Mesozoic cover of the crystalline foundation. They are represented in two main types: flysch and marls, which are very rich in ammonites.

The following succession is established in the **Perşani zone:**

1. Marls and clayey limestones with ammonites (Berriasian-Hauterivian). In some places breccias and conglomerates are developed, as well as partially sorted calcarenites, sandstones and silicites with radiolaria, in some places in association with diabases. In the Carhaga valley **Berriasian marls** are extremely rich in cephalopods (P a t r u l i u s, A v r a m, 1976): *Spiticeras* spp., *Pseudosubplanites* (*P.*) *ponticus* (R e t.), *P.* (*Hegaratella*) *paramacilentus* (M a z.), *Malbosiceras paramimounum alutenze* (P., A.), *Fauriella* cf. *rarefurcata* (P i c t.), *Dalmasiceras* sp., *Berriasella* spp., and many others. The existence of blocks of Tithonian limestones among the Berriasian marls is assumed by the Romanian geologists as indication of Berriasian transgression.

The Valanginian is proved by: *Bochianites oosteri* (S a r., S c h.), *Bochianites* sp., *Kilianella* sp., *Neocomites* sp., etc.

The Hauterivian is characterized by: *Partschiceras winkleri* (U h l.), *Spitidiscus* sp., *Plesiospitidiscus* sp., *Lyticoceras transsylvanicum* (J e k.), *Pseudobelus bipartitus* (d'O r b.), etc.

In the external part of the Perşani zone the pelagic facies is replaced by flysch (Sinaia Beds).

2. Coarse flysch with olistolites (Barremian-Lower Aptian). It is represented by sorted sandstones and claystones with olistolites of Triassic and Lower Jurassic limestones and Middle Jurassic sandstones, diabases and porphyrites. Similar sediments of coarse (wild-flysch) facies, in association with Urgonian limestones and sandstones with rich neritic faunas, are developed in the Hăghimaş and Rareu synclines (М у р д ж я н у et al., 1961).

3. Polygenous conglomerates and sandstone-marl flysch with Orbitolinidae (Aptian-Albian). Among this flysch there is a packet of conglomerates.

4. Calcareous sandstones and quartzitized small-fragment conglomerates (Upper Albian-Cenomanian).

Two strips differing in the facies of the sediments are outlined in the **Dîmbovicioara-Baraolt zone.**

In the southern strip (Dîmbovicioara) the following succession is observed:

1. Glauconitic limestones, sublithographic limestones and clayey limestones with flint concretions (Upper Valanginian-Hauterivian). These sediments overlie transgressively the Upper Jurassic. Many fossils occur among them in the environs of Braşov, namely: *Duvalia dilatata* (B l.), *Olcostephanus psilostomus* (N., U.) and *O. klaatschi* (B a u m b.). *Lyticoceras* sp. and *Crioceratites* spp. are found among the limestones near Dîmbovicioara.

2. Marls with cephalopods and reef limestones with rudists (Barremian-Lower Aptian).

3. Sandstones, conglomerates and sandy marls (Upper Albian-Cenomanian).

The following lithostratigraphic units are observed in the **Baraolt Mountains**:

1. Sinaia Beds (Berriasian-Hauterivian). The base of the Sinaia Beds is revealed out of Baraolt in the area of the town of Miercurea Ciuc. They start with fine-grained sandstones, shales, calcareous breccias and calcarenites which overlie Triassic dolomites. They are followed upwards by: clayey and calcareous shales, limestones and marls: clayey shales with rare sandstone intercalations, reddish and greenish shales of the "Azuga" type, in association with diabases; clayey limestones and calcareous sandstones which include in their upper part intercalations

of microbreccias formed of crystalline shales. Packets of breccias and calcarenites are found on top.

2. Marly-sandy or sandy flysch (Barremian). There also occur intercalations of breccias, clayey limestones, coarse-grained sandstones and gritstones with fragments of sericite shales and Triassic dolomites.

3. Sandstones (Aptian). At their base there are conglomerates with blocks of Urgonian limestones with rudists and corals. To the south the sandstones pass into conglomerates.

4. Marly-sandy flysch (Upper Aptian-Albian). Among this flysch there are intercalations of coarse-grained sandstones and conglomerates with fragments of reef limestones with rudists.

5. Polygenous conglomerates (Albian). These conglomerates are of the type of Bucegi conglomerates, with many fragments of dark-grey Middle Triassic limestones.

In the **Bucegi — Piatra Mare zone** the Lower Cretaceous is represented by terrigenous sediments (2000-2500 m) (Barremian-Albian). They are developed of flysch facies, comprising in some places thick sandstone packets (Sinaia and the eastern slope of Piatra Mare), conglomerates and calcareous breccias with inclusions of Jurassic limestones (Moroieni — Sinaia). Thick wedges of Urgonian limestones with rudists and Orbitolinidae (Furnica, St. Anna and Piatra Arse) are connected with the conglomerates at Sinaia. Rare ammonites have been found in the Cerpenişului valley — *Deshayesites borovae*; in Seacă a Carai manului — *Dufrenoya furcata* and *Colombiceras subpeltoceratoides*; in the Buşteni — *Leymeriella* sp. (aff. *revili*).

In the upper reaches of Prahova river the marl-sandstone complex includes in its upper part a thick packet of calcareous breccias and calcarenites. These sediments are more extensively developed in the southern part of the Bucegi Massif, whereas in the west they pass into marl-sandy flysch which directly overlies the crystalline shales of the Leaota Massif.

Above the flysch sediments there is a sandstone-conglomerate unit of molasse type (Middle Aptian-Upper Aptian), which is covered by Upper Albian marls and sandstones.

A thick Lower Cretaceous complex (4000 m) is developed in the **Zamura anticlinorium**, manifesting considerable variations in the thicknesses and in the facies. The following succession is observed:

1. Sinaia Beds (Berriasian-Hauterivian). They are represented at their base by schists and marls with rare intercalations of breccias and coloured shales ("Azuga" type) with diabases. In the middle part — calcareous sandstones with rare "Azuga"-type intercalations and diabases, whereas in the upper part there are marls with rare ammonites, sandstones, breccias and calcarenites.

2. Comarnic Beds (Barremian-Lower Aptian). They are developed in the southern part of the anticlinorium. Marls with ammonites are found in their lower part. From these marls in the Doftana valley A v r a m (1976) has described an extremely rich cephalopod association. The upper part is built predominantly of sandy marls with intercalations of sandy limestones with Orbitolinidae.

3. Sandy flysch (Middle Aptian-Lower Aptian). In some places this flysch directly overlies the Sinaia Beds. In some places massive sandstone packets, conglomerates, calcareous breccias and lenses of reef limestones with rudists and Orbitolinidae are developed.

4. Polygenous conglomerates (Middle Albian).

5. Clayey-sandy flysch with pelosiderites (Upper Albian).

In the zone of the upper internal nappe (Bratocea — Ciucaş — Zăganu — Teliu — Bodoc) the Lower Cretaceous is represented by the Sinaia Beds (Valanginian-Hauterivian), flysch (Barremian-Aptian), sandy flysch (Upper Aptian- Middle Aptian) and coarse flysch (Upper Albian-Cenomanian).

In the zone of the lower internal nappe the Early Cretaceous sedimentation started during the Barremian with the formation of sandy flysch, followed above by the so-called curbicortical flysch (regular alternation of calcareous sandstones, marls and claystones) of Upper Aptian-Lower Albian. Above them lie sandstones (Middle Albian-Upper Albian).

The development of the series is interesting in the **flake zone** where the black shales formation is represented (Valanginian-Lower Touronian). It is formed by several members:

1. Sphaerosiderites (Valanginian-Barremian). Their lower part contains clayey-sandy shales and sandstones with thin intercalations of lydites. These beds contain *Neocomites neocomiensis* (d'O r b.). The middle part is built of clayey-siliceous shales with intercalations of marls and sandstones, among which *Leopoldia castellanensis* (d'O r b.) and *Pseudothurmannia angulicostata* (d'O r b.) are found. The upper part includes green clayey shales with sphaerosiderite intercalations, spongiolites and calcareous sandstones. *Costidiscus recticostatus* (d'O r b.) and *Parahoplites borowae* (U h l.) are found.
2. Shales — clayey or siliceous, associated with bituminous shales, clayey sandstones, marls with radiolaria and foraminifera. Intercalations of tuffites and lydites are found, as well as coarse-grained sandstones. *Procheloniceras* and *Ancyloceras* occur, in the upper part — *Neohibolites* spp.
3. Quartzitized and glauconitic sandstones (Albian-Cenomanian) with *Neohibolites* and *Rotalipora apenninica* (R e n z).

11.2. South Carpathians

The rapid change of facies is particularly characteristic for the development of the series in this territory (К о д а р ч а et al., 1961).

In the Getic area there are most representative sections in the **Reşiţa-Moldova Noua zone**, where the Lower Cretaceous has been investigated in detail and characterized with many fossils by M u t i h a c (1959). In this zone the series is predominantly of calcareous and clayey-calcareous type. **Berriasian sediments** overlie in normal sequence the Tithonian ones. They are represented by marls with intercalations of clayey limestones which build the upper part of the Marila Beds. The following species are found: *Pseudosubplanites grandis* (M a r.), *Fauriella latecostata* (M a z.) and *F. boissieri* (P i c t.).

The Valanginian and Hauterivian are represented predominantly by marls (Crivina Beds) among which *Kilianella* cf. *lucensis* S a y n, *Neocomites neocomiensis* (d'O r b.), *Bochianites neocomiensis* (d'O r b.), *Crioceratites* spp., etc., have been found.

The Barremian and the Lower Aptian are connected with reef facies of Urgonian type (the Plopa Beds). A gradual transition from the Crivina Marl Formation to the reef limestones of the Plopa Formation is observed in the middle part of the Reşiţa zone. In the peripheral parts of the zone the Urgonian limestones directly overlie the crystalline (metamorphic) foundation. This indicates development of a transgression which comprises the entire territory of the South Carpathians.

The upper part of the Aptian is represented by massive limestones intercalated by marls with Orbitolinidae.

Similar sediments are revealed in the Hatzeg Basin (around the villages Stinka Lobkova and Ohaba Ponor), where quartzite conglomerates with ostreids are found above the Urgonian limestones. Albian or Cenomanian sediments follow transgressively above them.

The Albian sediments in the Reşiţa zone lie transgressively above older Lower Cretaceous rocks. They are represented by conglomerates with small fragments, coarse-grained sandstones, glauconitic sandstones and sandy claystones, which are of molasse type. *Douvilleiceras mammillatum* (S c h l.), *Hamites compressus* S o w., *Scaphites circularis* S o w., etc. occur among them.

In the Danubian area of the South Carpathians the Lower Cretaceous rocks are well exposed in **the Sviniţa zone**, where they demonstrate successions and facies known from the Salaš syncline (Western Fore-Balkan). They start with Berriasian pelitomorphic limestones with characteristic ammonites.

The Valanginian and the Hauterivian are built of clayey limestones with cherty concretions.

The Barremian comprises predominantly marls (Sviniţa Beds), similar to the Mramoren Formation in the Western Fore-Balkan, with many ammonites. Urgonian limestones with rudists and corals follow above them. In the valley of Cerna river they directly overlie massive Tithonian limestones (a situation similar to some sections in the Western Fore-Balkan) and they are often described by one name — "Cerna Limestones".

In the Coşuştea zone there are Nadanova Beds above the Urgonian limestones. These are sandy clayey-calcareous shales with *Neohibolites* and *Ticinella roberti*, (G a n d.), followed above by calcareous shales, sandy marls and clayey limestones wit ı characteristic Albian foraminifera.

Also interesting are the flysch sediments of the Arjana type. Their age has not been precisely determined, but according to their stratigraphic position they are younger than the Nadanova Beds and are an analogue of the Mehedinian flysch (**К о д а р ч а et al.**, 1961).

11.3. Apuseni

The Lower Cretaceous sediments in the Apuseni are very varied, but they are mainly of terrigenous type. Owing to the complex structure of this area the section of the series is difficult to reproduce, though nevertheless some regularities connected with the Northern and Southern Apuseni become apparent (B l e a h u et al., 1981).

In the **Southern Apuseni** the Lower Cretaceous in the **Higiş-Drocea zone** is represented by Berriasian-Hauterivian conglomerates and limestones, developed in the eastern part of this zone, as well as by marls developed to the west of the Baia—Slatina de Mureş line. The sections from the eastern part of the zone are characterized by the existence of silicified packets developed in the contact with diabases. As indicated by O n c e s c u (О н ч е с к у, 1960), the submarine diabase volcanism provided the necessary material for the abundant development of the radiolaria, as well as colloid material for the claystones and silicified limestones. *Punctaptychus* cf. *punctatus* (V o l t z.), *Lamellaptychus beyrichi* (O p p.) and *Olcostephanus astierianus* (d'O r b.) have been found among these sediments.

The Barremian is represented by flysch (500 m thick).

The Aptian is built of conglomerates, sandstones, claystones and intercalations of limestones. Intercalations of zoogenic limestones with Orbitolinidae and algae occur.

In the **Traskeu-Metalici zone** the lower part of the series (Berriasian-Barremian) is built of marls with intercalations of clayey shales and sandstones. Characteristic fossils (ammonites, belemnites and aptychi) are found.

The sections in the **Băcium Group** start with black shales with sandy lenses (Tithonian?-Neocomian), followed above by the flysch-like Povernei Formation (Upper Hauterivian-Lower Albian), built of quartzitized sandstones with calcareous cement and intercalations of grey-black clayey shales. Graded and in some places cross-bedding is observed among the sandstones. Intercalations of polygenous conglomerates among which fragments of Upper Jurassic limestones prodominate are also discovered.

The Ponor Formation covers transgressively the crystalline foundation in the northeastern part of the Băcium Group, as well as the Upper Jurassic limestones developed longitudinally along the Feneş Group. This unit starts with conglomerates built predominantly of crystalline rocks followed above by clayey limestones with intercalations of marls among which there are olistostromes in some places. In the southwest these sediments pass into clayey flysch with olistostromes (Sohar Formation), being replaced in the south by coarse flysch with olistolites from Upper Jurassic limestones. The following species define the Albian age of the sediments described: *Plectorecurvoides alternans* (N o t h.), *Psammosphaera laevigata* W h i t e, *Hedbergella planispira* T a p p., *Trochammina abrupta* G e r., etc.

Transgressively above these sediments there is an aleuritic flysch (alternation of siltstones and aleuritic claystones) of Upper Albian, proved by *Hysteroceras orbigny* S p a t h and characteristic sporo-pollen spectrum.

In the Southern Apuseni the Lower Cretaceous is also known in the Feneş nappe, where the Feneş Formation is developed at its base, consisting of volcanogenic-sedimentary deposits of flysch type. This Formation starts with sandstones and claystones, followed higher up by intercalations of tuffs and spilitic lavas, as well as by bioconstructed, sometimes thin-bedded micritic limestones with rudists, algae, etc. (Barremian-Aptian). The Valea Dosului Formation follows above them, represented by calcareous limestones with intercalations of marls. These sediments are covered by the coarse flysch of the Meteş Formation which is dated by characteristic foraminifera as Upper Aptian-Middle Albian.

The Lower Cretaceous sediments in the Fracin, Kebeştin and a number of other nappes in the Southern Apuseni are of flysch or flyschoid type.

In the Northern Apuseni most representative is the Lower Cretaceous section in the Bihor Mountains. Bauxites were formed in this zone at the beginning of the Early Cretaceous, above which the following succession is observed: (1) lacustrine limestones with Haracea; (2) brackish limestones with gastropods; (3) Barremian micritic, pelletic and lithoclastic limestones with rudists and foraminifera; (4) breccia (Lower Aptian?); (5) Ekley Formation (Lower Aptian-Middle Aptian), represented by limestones at the base and by marls in the upper part; (6) "Middle pachyodontic limestones"; (7) clayey siltstones with intercalations of glauconitic sandstones, conglomerates, limestones with corals, rudists and Orbitolinidae, followed above by red clayey shales (Upper Aptian-Upper Albian, partly); (8) clayey-aleuritic shales and sandstones (Upper Albian (Vraconian)-Turonian). The discordant position of the Ekley Formation over older rocks is indication about the beginning of the Austrian activation in the Apuseni.

A strong Austrian phase was manifested in the Apuseni after the Aptian. Upper Albian terrigenous sediments covered transgressively and discordantly the older rocks.

11.4. Wallachian Lowland

In the greater part of the Wallachian Lowland (the northern part of the Moesian Platform) the Lower Cretaceous is represented by the same facies as in Central North Bulgaria (P a t r u l i u s et al., 1976). Limestones of Kaspičan type are developed in the Berriasian-Valanginian part of the section.

A bay intrudes from the north into the central part of the lowland, in which deeper-sea limestones with calpionellids are developed.

Clayey-calcareous sediments of Razgrad type (Hauterivian-Lower Aptian) follow everywhere above the Kaspičan limestones.

The Albian sediments transgressively overlie the older Lower Cretaceous stages (Barremian-Aptian), similar to the northern strip of Central North Bulgaria (Brest—Gigen). The following species have been found among the Albian sediments near Giurgiu: *Douvilleiceras* sp., *Neohibolites minimus* L i s t., *Anahoplites planus ittoni* (L e y m.), *A. planus discoideus* S p a t h, *A. intermedius* S p a t h, etc. (P a t r u l i u s, 1960).

11.5. Northern Dobrogea

In Northern Dobrogea C h i r i a c (1956) found the following succession on the basis of echinoderms: marls (Berriasian), clayey limestones with *Monopleura valangiensis* (Valanginian), claystones and marls (Hauterivian), limestones with rudists (Barremian) and a hiatus at the base of the Aptian. The Aptian sedimentation started at the end of the Bedoulian with gravel, followed above by limestones with Orbitolinidae and rudists, and again a hiatus at the end of the Clansayesian. The Albian starts with conglomerates, covered by glauconitic limestones with *Leymeriella*, glauconitic sandstones and sands. During the Late Albian there is a new hiatus in the sedimentation.

12. SOVIET CARPATHIANS

The Lower Cretaceous is exposed in two basic zones: Staro-Sambor and Marmoroš zones (Ч е р н о в, 1972; Ч е р н о в et al., 1980).

In the **Staro-Sambor Carpathians** the Lower Cretaceous is contected with the Spasca Group which is represented by three formations developed in the external flysch zone. The lower part of the series is not exposed. Its section can be observed starting from the Jablonovo Formation (Barremian) — lower black shales with scanty occurrence of molluscs: *Crioceratites* aff. *emerici* L é v., *Barremites difficilis* (d'O r b.), *Hamulina lorioli* (U h l.) and *Pseudosaynella strettostoma* (U h l.).

Above these sediments follow the Teršovskaja Formation (massive sandstones with intercalations of shales) and the Jankovaja Formation (upper black shales which are strongly silicified). Both formations belong to the Aptian.

The section ends with the siliceous marls of the Golovina Group, among which *Neohibolites minimus* L i s t. (Albian) has been found.

In the **Marmoroš zone** the Lower Cretaceous is connected with three formations. The Kamennopotok Formation (Tithonian-Hauterivian), represented by sandy-clayey flysch, is at the base. Its lower part is dated as Upper Jurassic, whereas *Oosterella cultrata* (d'O r b.) and *Crioceratites* ex gr. *balearis* (N o l.) have been found in its upper part.

The Kamenelina Formation (Upper Barremian-Aptian) lies transgressively and sharply discordantly over the Priluk Formation (Upper Triassic-Lower Jurassic) and on the Kamennopotok Formation (Tithonian-Hauterivian). It is represented by many varied facies: conglomerates, sandstones, siltstones, argillites, organogenous-detritic limestones, biomorphic limestones, calcareous breccias and argillites with siderite concretions. These sediments form the two extreme facies of the Formation: Urgonian and terrigenous. The Urgonian limestones which are very varied are the most characteristic element of the Kamenelina Formation. The following species are identified among them: Orbitolinidae — *Orbitolina lenticularis* (B l u m.), *O. discoidea* G r a s. and *O. conoidea* G r a s.; corals — *Felixigyra picteti* (K o b y), *F. duncani* P r e v., *Polytremacis urgonensis* K o b y and *Actinastraea pseudominima* K o b y; rudists — *Requienia scalaris* M a t h., *Requienia* sp. and *Monopleura* sp.; brachiopods — *Belbekella irregularis* (P i c t.), *Tamarella tamarindus* (S o w.), etc.

Among the siltstones and sandstones there are Orbitolinidae, corals, belemnites — *Neohibolites* cf. *beskidensis* (U h l.), ammonites — *Pseudosaynella strettostoma* (U h l.), *Parahoplites* cf. *melchioris* A n t h. and *Colombiceras* ex gr. *tobleri*. These taxa determine the stratigraphic volume of the Kamenelina Formation: Upper Barremian-Aptian.

The section of the Lower Cretaceous ends with the Soimula Formation which passes into the Cenomanian as well. It is represented by siltstones and calcareous sandstones. Lenses of polygenous conglomerates and gritstones are developed at the base and in the uppermost part of the Formation (Ч е р н о в, 1972; Ч е р н о в et al., 1980).

13. CRIMEA AND THE CAUCASUS

There exists an enormous number of publications about the Lower Cretaceous in the Crimea and the Caucasus, among which it is necessary to note the monographic studies of R e t o w s k i (1893), R e n g a r t e n (Р е н г а р т е н, 1951), L u p p o v (Л у п п о в, 1952), E r i s t a v i and E g o j a n (Э р и с т а в и, Е г о я н, 1959), D r u š č i c and K u d r j a v c e v (Д р у щ и ц, К у д р я в ц е в, 1960), E r i s t a v i (Э р и с т а в и, 1960), M o r d v i l k o (М о р д в и л к о, 1960-1962), D r u š č i c and M i h a j l o v a (Д р у щ и ц, М и х а й л о в а, 1966), K o t e t i š v i l i (К о т е т и ш в и л и, 1970), K a k a b a d z e (К а к а б а д з е, 1971) and H a l i l o v et al. (Х а л и л о в et al., 1974). Therefore, only the most general law-governed regularities in the development of the series over this vast territory will be outlined here.

13.1. Crimea

The Lower Cretaceous is revealed as a strip starting from the second range of the Crimean Mountains in the valley of Černa river and continuing to the north-northeast towards Bahčisaraj — Simferopol, and from there in the east towards Theodosia. In Steppe Crimea the series is discovered by deep drilling. In the Jaila and Eastern Crimean synclinorium the Lower Cretaceous is developed predominantly in deep-sea facies, whereas neritic sediments are represented in the rest of the Crimea (Fig. 19).

Lower Cretaceous sediments manifest considerable changes in the facies and thicknesses, as well as a number of intraformational hiatuses. The series has greatest thickness in Eastern Crimea (1500 m), whereas in Southwestern Crimea it hardly reaches 5 m in some places.

The Lower Cretaceous sediments are connected by means of a gradual transition with the Upper Jurassic deposits, or they overlie a varied basement — transgressively and discordantly over the "Tavric series" (Triassic-Middle Jurassic), or they fill ingressively different depressions in the pre-Early Cretaceous relief. In some places Lower Cretaceous deposits are absent.

The Berriasian is represented predominantly by claystones, siltstones ana alternation of claystones, marls and limestones. Berriasian sediments are best studied at Theodosia from where R e t o w s k i (1893) has described many Berriasian ammonites. On the basis of the ammonite successions from the Theodosia region, K v a n t a l i a n i and L y s e n k o (К в а н т а л и а н и, Л ы с е н к о, 1979) distinguished six ammonite zones in the Berriasian in the Crimea (Table 18). However, the scheme proposed by these authors does not contribute to the stabilization of the zonal nomenclature of the stage.

In the Old Crimean (Starij Krim) region the Berriasian is represented by dark-grey clays with rare intercalations of limestones with insignificant thickness. An alternation of claystones, marls and limestones is developed in the west towards Kučuk Karas and Tonas.

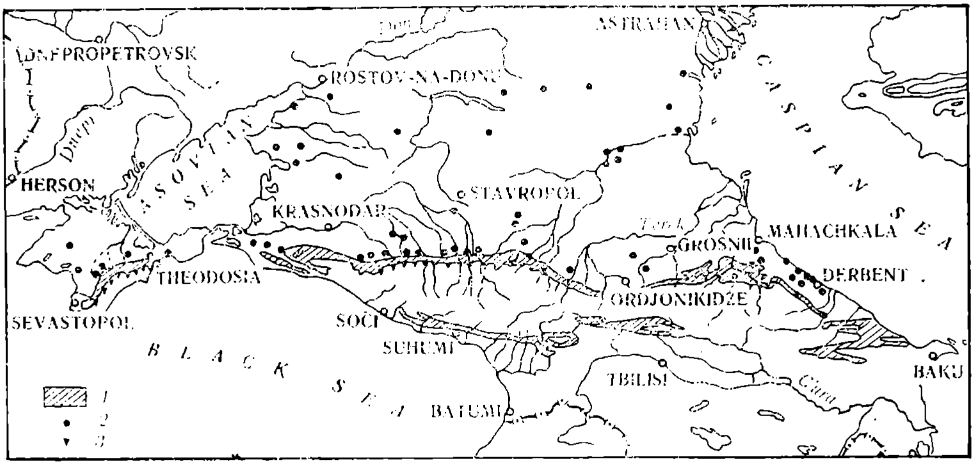


Fig. 19. Map of distribution of the Lower Cretaceous in Crimea and Caucasus (after Д р у щ и ц, К у д р я в ц е в, 1960)

In Southwestern Crimea, in the valley of Belbek river, between Kuibyshevo and Golubinka (Fotisala), there are terrigenous sediments: siltstones, sandstones and calcareous sandstones with detritus, as well as marls with rich neritic fauna of bivalvs and gastropods. Rare ammonites also occur.

The Valanginian is represented by marls, claystones and limestones, containing siderite concretions in some places. Together with the typical Mediterranean faunistic elements, there also occur some belemnite species which are more frequently found in the Volga Province of the Boreal Realm (*Pseudobelus bipartitus* (B l.), *Conobelus conicus* (B l.) and *Duvalia constricta* (U h l.).

Oölitic, oncolitic, detritic and organogenous limestones with bivalvs, gastropods, corals and rare cephalopods are developed in the valley of Belbek river, near Kuibyshevo village.

The Hauterivian is represented by various sediments. Claystones are developed in the Theodosia region — Tonas river, in the central part of Crimea (Burulča and Bešterek rivers) there are sandstones, sands, conglomerates with rare intercalations of claystones, in Southwestern Crimea (Bolšoj Salgir and Belbek rivers)— sandstones, conglomerates and claystones. The Hauterivian sediments are characterized by rich faunas. Mediterranean species predominate, although northern species also occur (*Speetoniceras* and *Simbirskites*).

In Steppe Crimea the Hauterivian sediments (siltstones and sandstones with glauconite) are discovered by drilling on the Tarhankut Peninsula, where they cover the Tithonian rocks with denudation.

Barremian sediments have a more limited distribution. They are represented by limestones and conglomerates, in some places with intercalations of claystones. The sediments are characterized by typical Mediterranean species with which taxa from the Volga Province are also associated (*Speetoniceras* and *Craspedodiscus*).

Table 18

Zonal Schemes of the Berriasian in Crimea and Northeastern Caucasus

<table>
<tr><th>Stage</th><th colspan="2">Standard Zones and Subzones</th><th colspan="2">Crimea (after Кванталиани, Лысенко, 1979)</th><th colspan="2">N.-E. Caucasus (after Сахаров, 1976)</th></tr>
<tr><td>Valanginian</td><td colspan="2">K. roubaudiana</td><td colspan="2">K. roubaudiana</td><td colspan="2">T. thurmanni</td></tr>
<tr><td rowspan="9">Berriasian</td><td rowspan="4">F. boissieri</td><td>B. calisto</td><td colspan="2">F. boissieri</td><td rowspan="2">R. rjasanensis</td><td>F. boissieri</td></tr>
<tr><td>B. picteti</td><td colspan="2">T. crassicostatum</td><td>R. rjasanensis s. s.</td></tr>
<tr><td rowspan="2">M. paramimounum</td><td colspan="2" rowspan="2">E. euthymi</td><td rowspan="2">E. euthymi</td><td>E. euthymi s. s.</td></tr>
<tr><td>T. berriasensis</td></tr>
<tr><td rowspan="3">T. occitanica</td><td>M. dalmasi</td><td colspan="2">D. dalmasi</td><td colspan="2">D. dalmasi</td></tr>
<tr><td>B. privasensis</td><td colspan="2">S. spitiense</td><td colspan="2" rowspan="2">T. occitanica s. s.</td></tr>
<tr><td>T. subalpina</td><td rowspan="3">P. grandis-B. jacobi</td><td>M. malbosi</td></tr>
<tr><td colspan="2" rowspan="2">P. grandis</td><td>P. euxinus</td><td colspan="2">M. malbosi</td></tr>
<tr><td>P. grandis</td><td colspan="2">P. ponticus</td></tr>
<tr><td rowspan="2">Tithonian</td><td rowspan="2">P. transitorius</td><td>M. chaperi</td><td colspan="2">?</td><td colspan="2">?</td></tr>
<tr><td>M. microcanthum</td><td colspan="2">T. transitorius</td><td colspan="2">P. transitorius</td></tr>
</table>

The Aptian is represented predominantly by calcareous claystones with siderite concretions. These sediments are discovered in Eastern and Central Crimea, between Theodosia and Burulča river. There are no Aptian deposits between the rivers Burulča and Bolšoj Salgir. To the south of Simferopol they are discovered by drilling in the Salgir valley, as well as in outcrops near Perevalnoe village. In Southwestern Crimea Aptian claystones are found in isolated outcrops, most frequently preserved in ingression valleys. Intercalations of siltstones and sandstones occur in some places.

The Aptian is characterized by varied faunas, most prominent among which is the wide distribution of belemnites. Among the ammonite faunas there are some species (*Deshayesites dechyi* (P a p p.), many *Dufrenoya* and *Pseudosaynella*) which are more frequent in the Volga Province or only in the northern strip of the Mediterranean Region.

Albian sediments are developed in Eastern Crimea, between Theodosia and Burulča river, where they are represented by claystones and thin sandstone intercalations. In the central part of Crimea Albian sediments are absent.

The Albian is best developed in Southwestern Crimea, in the valleys of the rivers Alma, Kača and Černa, where it is represented by aleuritic claystones, sandstones, calcareous sandstones and sandy limestones. Most widely represented among Albian faunas are the belemnites (*Neohibolites*) and bivalvs (*Aucellina*). Ammonites, among which are the most widespread Albian species, have a relatively more limited distribution.

13.2. The Caucasus

The Lower Cretaceous in the Caucasus is connected with several tectonic zones, each of which is characterized by different facies and thicknesses (Fig. 20).

13.2.1. Northwestern Caucasus

The Lower Cretaceous sediments in Northwestern Caucasus are tied to the northern slope of the Main Caucasian Ridge to the west of Belaja river. They are characterized by great thicknesses (4-5 km) and predomination of pellitic sediments, the so-called siderite claystones (Fig. 21).

The Berriasian sediments are developed to the west of Belaja river. They are represented by limestones with insignificant thickness (20-25 m). In most places the limestones are sandy, passing at the base into calcareous sandstones below which there are conglomerates. They overlie transgressively variegated lagoon sediments of the Tithonian and contain rich faunas of cephalopods, bivalvs, gastropods, brachiopods, echinids, corals and spongia, part of which have been described by P č e l i n c e v (П ч е л и н ц е в, 1927) and G r i g o r y e v a (Г р и г о р ь е в а, 1938): *Pseudosubplanites ponticus* (R e t.), *"Berriasella" subchaperi* (R e t.), *Rjasanites rjasanensis* (W e n.), *Blanfordiceras caucasicum* G r., *Pomeliceras* (*P.*) *breveti* (P o m.), *Pomeliceras* (*P.*) spp., *Protacanthodiscus (Rengarteniceras) rengarteni* G r., *Euthymiceras transfigurabilis* (B o g o s l.), *E. salenskii* G r., *Malbosiceras malbosi* (P i c t.), *M. korjeli* G r., *Aucella volgensis* L a h., *Septifer lineatus* (S o w.), *Pleurotomaria blancheti* (P i c t., C a m p.,), *Nerinea* spp., etc.

This association is of particular interest from biostratigraphic and palaeontological points of view, because it offers opportunities for correlation between the Mediterranean and the Boreal Realms, as well as for outlining the palaeobiogeographic provinces.

To the west of Hokodz river, after a hiatus, Berriasian sediments are developed in the valley of Pšeha river, where they are represented by calcareous claystones and marls (200 m) with ammonites.

In the basin of Pšiš river the Berriasian is connected with conglomerates in the base, followed higher up by claystones with intercalations of fine-grained sandstones covered with marls (80 m). They contain characteristic ammonites (Л у п п о в, 1952).

Berriasian sediments are developed in similar facies along the rivers Psekups, Beseps, Ubin and Nabl.

Valanginian sediments are seen everywhere above the Berriasian ones. They are represented by similar facies and are characterized by *Kilianella pexiptycha* (U h l.), *Olcostephanus astierianus* (d'O r b.), *Neocomites neocomiensis* (d'O r b.), *Conobelus conicus* (B l.), *Aucella weerthei* P a v l., *A. jasikovi* P a v l., *A. niciformis* P a v l., etc.

Hauterivian sediments are represented by various rocks: sideritic claystones — to the west of Pšiš river, sandy-clayey deposits — in the upper course of Pšeha river and in the middle course of Pšiš river, and sandstone-conglomerate — in the region south of Majkop. They are characterized by *C. duvali* L é v., *Acanthodis-*

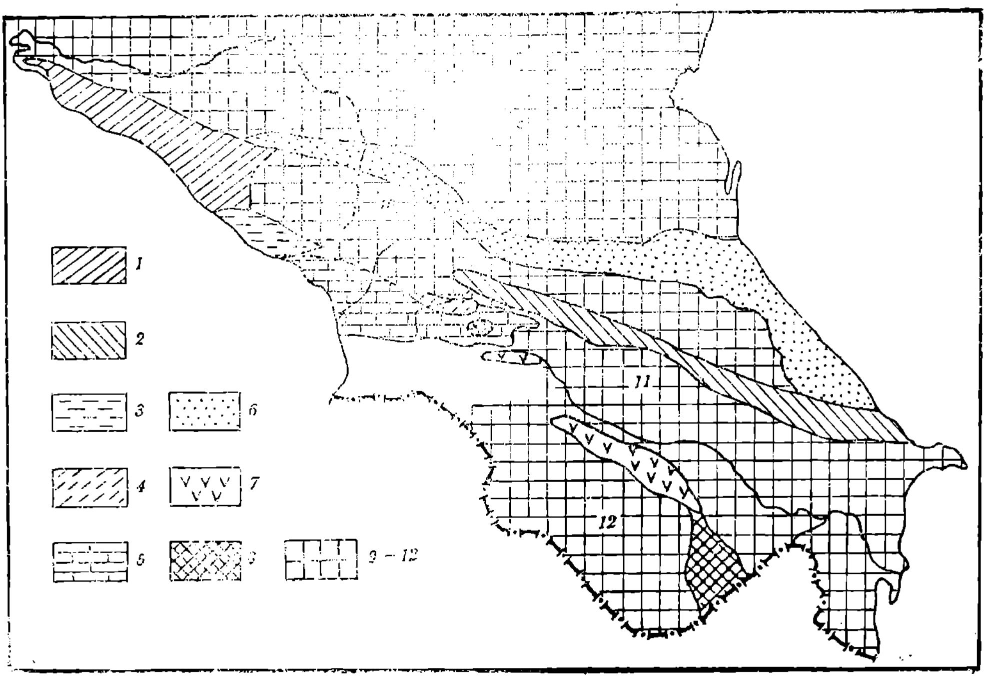


Fig. 20. Sketch of the distribution of the main types of facies of the Lower Cretaceous in Caucasus (after Э р и с т а в и, 1962)

1 — Novorosijsk geosyncline: *2* — geosyncline of the southern slope: *3* — Abhazia trough: *4* — Rača trough: *5* — Georgia block: *6* — neritic sediments of Northern Caucasus; *7* — volcanogenic sedimentary complexes in Caucasus Minor: I— mixed facies (Kafan region): *9* — Stavropol platform; *10* — anticlinorium of Bolšoj Caucasus: *11* — Azerbaidjanian Block; *12* — Armenian block

cus cf. *stenotonus* B a u m b., *Distoloceras* sp.. *Spectoniceras* (*S.*) spp., *S.* (*Craspedodiscus*) sp., *Pseudothurmannia* sp., many brachiopods, bivalvs and gastropods.

Barremian sediments are discovered to the west of Belaja river. They are represented by alternation of sandy claystones, clayey sands passing into slightly cemented sandstones, and many intercalations of calcareous sandstones, sandy limestones and conglomerates (60 m). Among the claystones there occur bivalvs — *Ostrea*, *Trigonia*. *Astarte*. *Panopaea* and *Perna*: gastropods — *Nerinea*. *Pleurotomaria* and *Natica*: brachiopods — rhynochonellids and telebratullids.

A gradual increase of claystones is observed in the Hokodz river basin, especially in the upper part, as well as disappearance of the coarse-fragment conglomerates. Their thickness reaches 120 m.

To the west of Hokodz river the Barremian is represented by sandy claystones with thin intercalations of sandstones (500 m). A thick bed of poorly cemented sandstones with oblique stratification is developed in the upper part.

Barremites cf. *subdifficilis* K a r., *B.* cf. *hemiptychus* K i l., *Saynella suessi* (S i m.), *S.* cf. *davydovi* T r., *Hamulina* sp. indet., many bivalvs, gastropods and brachiopods are found among the claystones

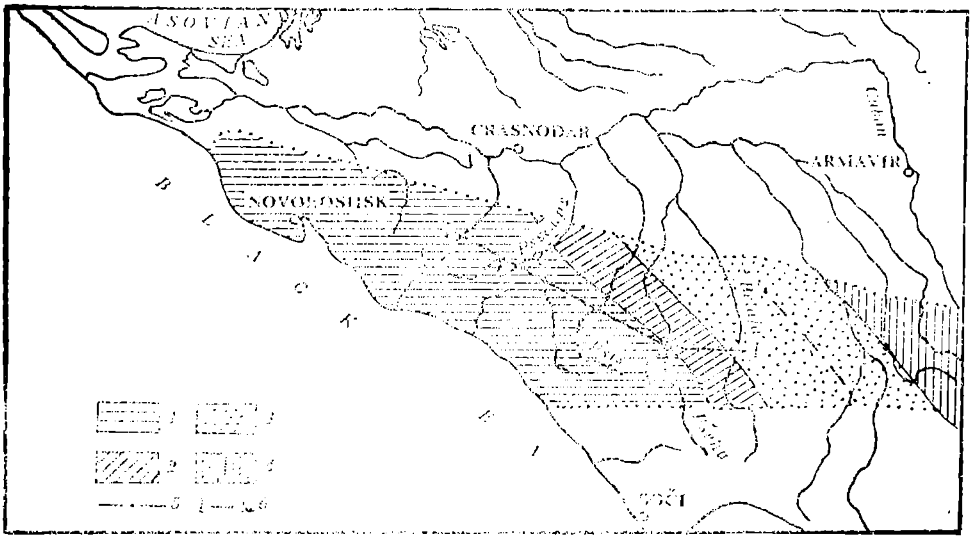


Fig. 21 . Sketch of the distribution of the main types of facies of the Lower Cretaceous in North-western Caucasus (after Л у п п о в, 1952)

1 — facies of the depressional region; *2* — transitional facies; *3* — facies of the elevation regions; *4* — Northern Caucasian facies; *5* — axis of the barrier; *6* — section line

To the west of Kurdžips river the Barremian clayey sediments reach a thickness of 1200 m, in the valley of Pšiš river — 1300-1400 m. Dark-grey claystones, similar to the upper sideritic claystones from Pšeha river, are developed.

In the basin of Psekups river the Barremian is connected with the Fonar Formation: thick-bedded sandstones and conglomerates, divided by a clayey packet. These deposits are synchronous with the upper sideritic claystones from Pšeha river. Claystones with sphaerosiderites lie above the Fonar Formation, among which characteristic Barremian ammonites, as well as bivalvs and gastropods, are found (Fig. 22).

The most characteristic **Bedoulian** feature in the Northwest Caucasus is the facies of the so-called "brachiopod horizon", which, in addition to the abundance of brachiopods, also contains large ammonites (15-20 cm) and sometimes very large forms as well. Sideritic claystones are also developed, being with sandstone lenses in some zones. The following species are found among these sediments: *Procheloniceras albrechtiaustriae* (H o h.), *Matheronites* cf. *ridzewskyi* K a r., *Cheloniceras seminodosum* S i n z., *Ancyloceras matheroni* (d'O r b.), *Deshayesites deshayesi* (L e y m.), *Deshayesites* spp., *Aconeceras trautscholdi* S i n z., *Pseudosaynella bicurvata* (M i c h.), etc.

The Gargasian is represented by glauconitic clayey sands with concretions (Belaja Reka Formation), sideritic claystones, sandy-clayey sediments and sandstones. They are characterized by many ammonites: *Cheloniceras buxtorfi* (J a c.), *Cheloniceras* spp., *Colombiceras crassicostatum* (d'O r b.), *Colombiceras* spp., *Acanthohoplites* spp., *Ammonitoceras pavlowi* W a s., *Tropaeum* sp., *Parahoplites uhligi* A n t h., etc.

Clansayesian sediments are absent along Belaja river. In the valley of Hokodz river they are with similar facies to that of the Gargasian deposits. They are characterized by: *Acanthohoplites trautscholdi* S i m., B a c., S o r., *A. nolani* (S e u n.), *A. aschiltensis abichi* A n t h., *A.* cf. *bigoureti* (S e u n.), *Hypacantho-*

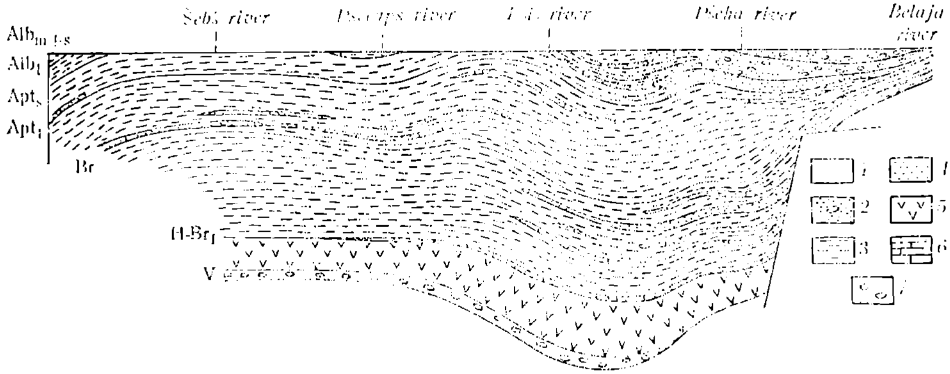


Fig. 22. Section of the Lower Cretaceous in the northern slope of the Northwestern Caucasus (after Л у п п о в, 1952)

1 — Middle and Upper Albian; *2* — clayey sands with concretions (Upper Aptian-Lower Albian); *3* — sideritic claystones; *4* — sands, sandstones and conglomerates; *5* — sandy-clayey and marly sediments (Valanginian); *6* — limestones; *7* — conglomerates; Vln — Valanginian; Ht-Brm_1 — Hauterivian and Lower Barremian; Brm — Barremian (without the lower part); Ap_1 — Lower Aptian; Apt_s — Upper Aptian; Alb_1 — Lower Albian; Alb_{m+s} — Middle and Upper Albian

plites cf. *sarasini* (C o l l .), *Diadochoceras nodosocostatum* (d'O r b.), *Diadochoceras* spp., etc.

The Albian is represented by its three substages, but its sections are not complete in the different regions. Albian sediments are absent along the valleys of the rivers Belaja, Psekups, Kaverze, Šebš and Beseps.

The Lower Aptian is differentiated on the southern slope of the main Caucasian Ridge, where it is represented by claystones with concretions, containing *Leymeriella* cf. *tardefurcata* (L e y m.).

The Middle and Upper Albian are reliably identified only in several sections. They are represented by dark-grey claystones with belemnites, *Inoceramus, Aucellina* and rare ammonites. A certain deviation from this type is demonstrated by the sandstones with intercalations of sandy claystones in the basin of Hokodz river, where *Hoplites* ex gr. *dentatus* has been found.

13.2.2. Northern Caucasus and the Fore-Caucasus

This is the area to the east of Belaja river to the Caspian Sea. The Lower Cretaceous section is formed by two large complexes.

The lower complex is represented by terrigenous-carbonate sediments of Berriasian-Lower Barremian. Pure marls and dolomitized limestones are found in the Valanginian, whereas the Hauterivian and the Lower Barremian are connected with sandy marls and sandy oölitic limestones, often with cross-bedding. Thickness up to 850 m.

The upper complex is terrigenous (Upper Barremian-Lower Albian). Sandy-clayey glauconitic sediments predominate, often with calcareous concretions. There exist separate packets of black pyritized claystones with obliquely stratified sandstones. Thickness up to 700 m.

The Middle and Upper Albian are usually represented by black argillites in the upper part of which there appear marly intercalations. Their thickness is between 40-80 and 150 m in the north in the Fore-Caucasus.

The Lower Cretaceous in Northern Caucasus and the Fore-Caucasus is characterized in great detail by M o r d v i l k o (М о р д в и л к о, 1960-1962). It is interesting to note the extensive development of predominantly neritic faunas of bivalvs, gastropods, brachiopods, echinids and relatively fewer ammonites. Many Boreal forms occur among the ammonite communities.

12.2.3. Georgian Zone

In the **Abhasian-Račin region** the Lower Cretaceous sediments differ from the flysch deposits along the southern slope of Bolšoj Kavkaz (Major Caucasus) and from the neritic formations in the Northern Caucasus (Р е н г а р т е н, 1951). Limestones are widespread in the region, being often pelitomorphic. The marls forming the sections of the Berriasian, Valanginian, Hauterivian and Barremian are also developed. They are characterized by rich cephalopod faunas, known from the numerous publications. Mediterranean species predominate, although Boreal forms occur as well. The Aptian is represented by marls, the Albian — by terrigenous sediments.

In the **Dzirulian-Kutaisi region** the Lower Cretaceous sections are built of limestones, often with rudists in the Barremian. The Aptian is represented by marls, whereas siltstones, sandstones and tuffites are developed in the Albian (Э р и с т а в и, 1960).

13.2.4. Caucasus Minor

The Lower Cretaceous is developed in three zones of Caucasus Minor: Mishano-Kafan, Sevano-Karabah and Somhito-Agdam (Х а л и л о в et al., 1974).

The Berriasian-Valanginian Stages are represented predominantly by carbonate sediments.

The Berriasian in the **Kafan zone** is built of silicified limestones or less frequently by sandy limestones with flint and intercalations of calcareous tuffs and tuff-sandstones. *Berriasella* sp. indet., *Lamellaptychus beyrichi* (O p p.), *Punctaptychus* spp., *Duvalia lata* (B l.), etc., are found among them. Conglomerates occur in some places in the base of the Berriasian. Similar sediments are distributed in the **Valanginian** as well. *Neocomites* and many aptychi occur among them.

The Hauterivian sediments are connected with the Valanginian ones by a gradual transition. They are represented predominantly by pelitomorphic and in some places by siliceous limestones with rare tuffite intercalations. The following species occur: *Lamellaptychus angulicostatus* (P., L.), *Spitidiscus rotula* (S o w.), *Subsaynella sayni* (P a q.), *Duvalia binervia* (R a s q.), etc.

The Barremian is represented by strongly calcareous tuff-sandstones and sandy limestones. Organogenous-detritic limestones with intercalations of tuff-sandstones and gritstones are developed in some places. Many ammonites are found: *Barremites difficilis* (d'O r b.), *B. charrierianus* (d'O r b.), *Silesites seranonis* (d'O r b.), *Hamulina crassicostata* (K a r.), *Pseudosaynella strettostoma* (U h l.), etc.

Organogenous builtups of Urgonian type with rudists, Orbitolinidae, corals, etc. appear in the Barremian section west of Tejmur-Mjuskanli village.

Aptian sediments are similar to the Barremian ones. They are characterized by *Deshayesites weissi* (N e u m., U h l.), *Pseudohaploceras matheroni* (d'O r b.), *Acanthohoplites aschiltensis subangulatus* L u p p., *Aucellina caucasica* (B u c h.), etc.

The Urgonian facies of the Aptian is associated with tuffs and tuffites. It is characterized by typical neritic fauna (Х а л и л о в et al., 1977).

The Albian is represented by clayey sandstones, sandy argillites and tuff-sandstones. It is characterized by *Hoplites* cf. *hexagonalis* L u p p., *Kosmatella agassiziana* (P i c t.), *Hysteroceras orbignyi* S p a t h, *Mortoniceras inflatum* (S o w.), *Mariella bergeri* (B r o n g.), etc.

To the north of the Kafan zone is the **Sevano-Karabah zone**, where the Lower Cretaceous is facially very varied, being with numerous intraformational denudations and considerable hiatuses. Predominantly terrigenous sediments with tuffs and tuffites in the upper part of the series are developed. Tuff-sandstones are widely represented. The faunistic characteristics are the same as for the stages in the Kafan zone.

In the northernmost **Somhito-Agdam zone** the Lower Cretaceous sedimentation usually starts during the Hauterivian and only in the region of Abdal village there are Barremian sediments overlying Upper Jurassic volcanites. Hauterivian and Barremian terrigenous-carbonate sediments are developed: conglomerates, tuff-gritstones and tuff-sandstones, limestones, detritic and zoogenic limestones. The fossil associations, though poorer, are similar to those in the Kafan zone.

14. SOUTHERN ALPS, APENNINES AND SARDINIA

This is the central part of the Mediterranean Region in which the Lower Cretaceous is developed predominantly in the deep-marine facies.

14.1. Southern Alps

Lower Cretaceous sediments are developed in the Puez and Venetian Alps, as well as in Lombardy, from where H a u g (1888) and R o d i g h i e r o (1919) have described various cephalopods.

Particularly representative is the section in the **Puez Alps** on Gardenaza Plateau, close to Corvara. Over the Dachstein limestones of the Upper Triassic there are breccias with dolomitic cement, lying usually transgressively in Southern Tyrol. The following succession is usually discovered above the dolomitic breccias:

1. Siliceous limestones with cherty concretions.

2. Marls with nodular limestones with *Terebratula neocomiana* d'O r b., *Pygope janitor* (P i c t.), *Ptychophylloceras semisulcatum* (d'O r b.), *Lytoceras liebigi* (O p p.), *Olcostephanus jeannoti* (d'O r b.), etc. (Berriasian-Valanginian).

3. Limestones with cherty concretions: *Pygope janitor* (P i c t.), *Phyllopachiceras infundibulum* (d'O r b.), *Neolissoceras grassianum* (d'O r b.), *Olcostephanus astierianus* (d'O r b.), *Pseudothurmannia angulicostata* (d'O r b.) (Hauterivian).

4. Alternation of limestones, in some places nodular, with marls: *Pholadomya barremense* P i c t., *Phylloceras tethys* (d'O r b.), *Lytoceras* spp., *Hamulina* spp., *Barremites difficilis* (d'O r b.), *B. psilotatus* (U h l.), *B. cassidoides* (U h l.), *Silesites vulpes* (C o q.), *Acrioceras dissimile* (U h l.), *Heteroceras* sp., etc. (Barremian). Many radiolaria are found among the cherty concretions.

Ancyloceras matheroni (d'O r b.) and *Melchiorites melchioris* (T i e t z e), which are indicative of Bedoulian age, are found in the upper part of this packet.

5. Nodular limestones and shaly marls without fossils (?Aptian).

Albian sediments are absent in Southern Tyrol.

In the Venetian Alps the Tithonian limestones at **Biancone** are followed above by white limestones with light cherty concretions with a transition. Ammonite successions characterizing each of the Lower Cretaceous Stages are found among them (P a r o n a, 1890, 1897; R o d i g h i e r o, 1910).

Berriasian: *Berriasella privanensis* (P i c t.), *Fauriella rarefurcata* (P i c t.), *Lamellaptychus didayi* (C o q.), etc.

Valanginian: *Kilianella* sp., *Neocomites neocomiensis* (d'O r b.), *Neolissoceras grasianum* (d'O r b.), etc.

Hauterivian: *Leopoldia cryptoceras* (d'O r b.), *Crioceratites duvali* L é v., *Olcostephanus astierianus* (d'O r b.), *Pseudothurmannia longispina* (U h l.), *Spitidiscus incertus* (d'O r b.), etc.

Barremian: *Barremites cassida* (R a s p.), *Crioceratites emerici* L é v., *Macroscaphites yvani* (P u z.), *Costidiscus recticostatus* (d'O r b.).

Aptian: *Salfeldiella guettardi* (R a s p.), *Melchiorites melchioris* (T i e z e), *Aconeceras nisum* (d'O r b.) and *Ancyloceras matheroni* (d'O r b.).

Albian: *Inoceramus concentricus* P a r k., *Hamites alternans* (S o w.) and *Pxytropidoceras roissyanum* (d'O r b.).

Lower Cretaceous organogenous limestones with rudists and *Nerinea* are developed only in the southern part of the Venetian Alps, in the area of Tarcent (Frioule region). These sediments pass from the zoogenic facies of the Tithonian and demonstrate the existence of an elevation in this region which has inherited the anticline structure of the Jurassic period.

In **Lombardy** the upper part of the Maiolica Formation is attributed to the Lower Cretaceous (Berriasian-Barremian), its lower part being considered to be Tithonian. The Maiolica Formation is represented by clayey limestones with aptychi and rare ammonites, which indicate the Berriasian, Valanginian, Hauterivian and Barremian Stages. Aptian and Albian sediments are developed in Scaglia facies.

14.2. The Apennines

14.2.1. The Apennine Peninsula

Light limestones of the Biancone and Maiolica types are developed in the northern and middle parts of the Peninsula. The following species are found among them: *Calpionella alpina* L o r., *C. elliptica* C a d., *Calpionellopsis oblonga* (C a d.), *Calpionellites darderi* (C o l.), aptychi, radiolaria, etc., which date the top of the Tithonian to the Lower Valanginian. The so-called Scaglia Clays whose lower part is attributed to the Lower Cretaceous are also widespread in this part of the Peninsula.

These sediments indicate the existence of a deep trough as early as the beginning of the Jurassic Period, which had reached the middle part of the Peninsula.

In the southeastern part of the Peninsula the Lower Cretaceous sediments are in neritic facies. At Monte Gargano, near Capri, in Pulia and Calabria they build a carbonate platform of zoogenic limestones with *Toucasia carinata* and dolomites, lying discordantly over the Middle Jurassic or over the Tithonian (Di-S t e f a n o, 1893).

14.2.2. Sicily

The Berriasian and the Valanginian are not developed in the southwestern part of the Peninsula, where the Tithonian is represented by coral limestones. The sedimentation of the series starts with Hauterivian clayey limestones with cephalopods: *Phyllopachiceras infundibulum* (d'O r b.), *Neolissoceras grasianum* (d'O r b.), *Duvalia dilatata* (B l.), aptychi, etc.

Limestones with rudists and gastropods (Barremian-Aptian), lying transgressively over the Tithonian, are developed in the environs of Palermo.

Table 19

Simplified Stratigraphic Scheme of Some Jurassic-Cretaceous Sequences in the Central Mediterranean Area and Their Facies Equivalents in the Western North Atlantic Basin (after Bernoulli, 1972)

System	Stage	Southern Alps Lombardian Zone	Central Apennines Umbria — Marche	Western Greece Ionian Zone	Atlantic: Western # 99A+100	Atlantic: Northern # 101+105
Cretaceous	Cenomanian	Scaglia rossa ... bianca	Scaglia	Vigla Limestone (Maiolica)	gap	black clay
Cretaceous	Albian to Aptian	Scaglia variegata	Marne à fucoidi			
Cretaceous	Barremian to Hauterivian	Maiolica	Maiolica		Maiolica facies	Marne à fucoidi facies
Cretaceous / Jurassic	Valanginian to Upper Tithonian					
Jurassic		Rosso ad Aptici	pel. lim. / gap; Scisti + Radiolariti		Am. Rosso & Rosso ad Aptici facies	

14.3. Sardinia

The Lower Cretaceous is developed in three regions of the island: Nurra — in the northwestern part, San-Antioco — in the southwestern part, and Dorgali—Orosei—Siniscola — in the northeastern part. The section at Orosei is most representative (D i e n i, M a s s a r i, 1965a, b; W i e d m a n n, D i e n i, 1968).

The series is also well exposed in the Tuttavista Mountain, west of Orosei. Its base is connected with carbonate sediments which pass from the Tithonian. Lagoon environments are discovered episodically in the uppermost part of the carbonate complex.

At the top of the reef complex there are calcarenites of littoral type with oölites, remnants of corals, algae (*Lithocodium* sp.), *Trocholina alpina* (L e u p.), *T. elongata* (L e u p.), which belong to the Berriasian.

Upper Valanginian calcarenites and siliceous marls with *Neocomites neocomiensis* (d'O r b.) and *Teschenites teschenensis* (U h l.) overlie the denuded surface of the Tithonian-Berriasian limestones. These marls also contain clastic material with *Exogyra couloni* (D e f r.), serpulae, ostracods, which are of shallow-sea character with estuary influences.

The Hauterivian is represented by a monotonous formation of limestones, in some places with flint. Among them the following species have been found: *Acanthodiscus radiatus* (B r.), *A. pseudoradiatus* (B a u m b.), *A.* cf. *bernensis* (B a u m b.), *Leopoldia cryptoceras* (d'O r b.), *L. leopoldi* (d'O r b.), *Leopoldia* sp., *Oostrella cultrata* (d'O r b.), *Oosterella* spp., *Crioceratites sablieri* (A s t.), *C. sornayi* (S a r k.), *Spitidiscus rotula* (S o w.), etc.

The Barremian comprises oölitic limestones and calcarenites which pass upwards into subreef bioclastic limestones of Urgonian type. They contain different foraminifera, most frequent among them being the Orbitolinidae: *Orbitolinopsis flandrini* M o u l g., *O. cuvillieri* M o u l l., *O. elongatus* D i e n i, M a s s a r i, *Orbitolina conoidea-discoidea* G r a s. There are also remains of Dasycladacea: *Lithophyllum shebae* E l l., *Gayeuxia* sp., *Munieria baconita* D e e c., *Actinoporella podolica* A l t h., *Salpingoporella dinarica* R a d., *Clypeina* sp., *Bacinella irregularis* R a d., etc.

The Aptian starts with limestones, silicified in some places. Intraformational breccias with glauconite and phosphorite concretions are developed locally. Brachiopods, bivalvs and rare ammonites occur most frequently among them. Above them follow clayey limestones which pass into marls with cherty concretions. They contain *Deshayesites deshayesi* (L e y m.), *Praeglobotruncana* (*Hedbergella*) sp. and *Conorotalites* cf. *bartensteini aptiensis* (B e t t.), which characterize the Bedoulian Substage. The Gargasian is represented by glauconitic marls at the base and by clayey limestones with flint in the upper part. It is characterized by: *Acanthohoplites* cf. *bigoti* (S e u n.), *Colombiceras tobleri* (J a c.), *C. caucasicum tyrrhenicum* W i e d., D i e n i, *Neohibolites semicanaliculatus* (B l.), *N. ewaldi* (S t r.), *N. spicatus* S w i n n., *Orbitolina* sp., etc. The Clansayesian comprises clayey limestones with cherty concretions. It is characterized by: *Acanthohoplites abichi* (A n t h.), *A. nolani* (S e u n.), *A. quadratus* (C o l l.), *A. subangulicostatus* S i n z., *Neohibolites strombecki* (M ü l l.), *N. aptiensis* K i l., etc.

The Albian is represented by clayey limestones. Calcareous conglomerates are developed locally in the upper part. It is characterized by extremely rich ammonite association: *Phylloceras* spp., *Protetragonites* spp., *Eogaudryceras* spp., *Kossmatella* spp., *Tetragonites* spp., *Hamites* spp., *Lechites* spp., *Anisoceras* spp., *Ostlingoceras* spp., *Puzosia* spp., *Hysteroceras* spp., *Dipoloceras* cf. *rectangulare* S p a t h, *Mortoniceras nanum* S p a t h, *Mortoniceras* spp., *Stoliczkaia notha* (S e e l.), *S. dorsetensis* S p a t h, *Neohibolites* spp., etc. (W i e d m a n n, D i e n i, 1968).

The Lower Cretaceous has wide distribution in Yugoslavia and it is represented in all its stages. It is widespread in the following palaeogeographic zones: Slovenian Depression, Dinarides, Kosovo, Šumadia and Eastern Serbia.

15.1. Slovenian Depression

This depression is developed south of the Julian Alps, in the boundary zone between the Southern Alps and the Dinarides. Particularly characteristic is the extensive development (from the Late Triassic to the Berriasian) of pelagic carbonate sediments, shaly or silicified radiolarities,which are in contrast to the neritic formations in the adjacent regions (C a r o n, C o u s i n, 1973).

In the middle part of the valley of Kneža river the Lower Cretaceous is connected with the Kobilia unit. The Berriasian rocks show a transition from Tithonian ones. They are represented by limestones with flint, developed in the Biancone facies; the limestones are slightly clayey and micritic. They contain *Calpionella alpina* L o r., *C. elliptica* C a d., *Crassicollaria parvula* R e m., *Remaniella cadischiana* (C o l.), *Tintinnopsella carpathica* (M., F.), *Globochaete alpina* (L o m b.) and radiolaria, which characterize the Lower Berriasian.

Calcareous breccias with remnants of rudists, Orbitolinidae, algae (*Lithocodium aggregatum* E l l., *Gayeuxia* sp. and *Bacinella irregularis* R a d.), *Hydrozoa,* rare *Hedbergella* and primitive *Talmaniella,* which define the Aptian-Albian age, overlie transgressively but concordantly the Berriasian limestones.

Above the breccias there are breccia-like limestones; limestones with flint containing *Ticinella* and *Hedbergella*; mottled marls, silicified in some places; lenses of red or black flint and marls with intercalations of intraclastic limestones with flint among which *Hedbergella planispira* (T a p p) (Albian) has been discovered.

The described succession, with the great hiatus (Upper Berriasian-Barremian) is observed in other sections of the Slovenian Depression as well (C a r o n, C o u s i n, 1973).

15.2. Dinaric Mountains

In the Dalmatian zone, in the High Karst zone and in the Prekarst zubzone the Lower Cretaceous is developed exclusively in carbonate facies, in the Bosnia zone — in flysch facies (B l a n c h e t, 1972).

In the **Dalmatian zone** there are powerful sandy and bioclastic limestones, rich in algae and foraminifera (Codiaceae, Dasycladacea, *Gayeuxia* sp., *Salpingoporella annulata* C a r., *S. dinarica* R a d., Litholidae, Textularidae and Miliolidae), as well as remnants of gastropods, echinoderms and corals.

In the **High Karst** the series is built of limestones and dolomitized limestones (800 m), rich in algae, foraminifera, ostracods and coprolites.

Similar carbonates are developed in the **Prekarst subzone** as well, where sandy limestones with Orbitolinidae also occur.

In the **Bosnia zone** the Lower Cretaceous is represented by flysch (Tithonian-Lower Cretaceous). Flysch sediments are traced from the localities southeast of Banja Luka in Dinarides direction towards Sarajevo and from there to the southeast to Albania (B l a n c h e t et al., 1970).

The flysch is formed by rhythmic alternation of sandstones and sandy limestones with intercalations of clayey limestones, limestones and breccias. The existence of successions of calpionellids and foraminifera (including Orbitolinidae) defines the stratigraphic volume of the flysch from the Upper Tithonian to the Lower

Albian included. The section of the series ends with calcareous breccias dated to the Middle and Upper Albian, which pass into the Cenomanian.

The flysch sediments overlie a volcanogenic-sedimentary formation of the ophiolite group with Upper Jurassic radiolarites in the uppermost part (B l a n-c h e t et al., 1972).

15.3. Kosovo

Only Barremian, Aptian and Albian sediments are known in Kosovo, developed in the Kukes zone, in Metohia, Crnolevskodrenička zone, west of Kosovska Mitrovica and in the plane of Kosovo (Kosovo Pole). Terrigenous-carbonate sediments are represented, predominantly in neritic and more rarely in bathyal facies (Р а д о и-ч и ћ, 1975).

15.4. Šumadia Zone

This zone comprises the southern periphery of Banat, the area around Belgrade, Šumadia, Eastern and Southeastern Kopaonik.

In Southern Banat (Vojvodina) the Lower Cretaceous is represented by Neocomian limestones, clayey limestones and calcareous breccias; siltstones and radiolarites are developed in some places. The Barremian and Aptian comprise sandstones, sandy and organogenous limestones with Orbitolinidae and other foraminifera, bryozoans, rudists, *Nerinea* and echinoderms. The Albian is not developed (А н ђ е л к о в и ћ, 1975).

In the **Belgrade region** the series is developed in its full volume from the Berriasian to the Albian included (А н ђ е л к о в и ћ, 1975).

The Berriasian is represented by calcarenites, breccia-like limestones and calcareous sandstones with *T. carpathica* (M u r g., F i l l.), *Stenosemellopsis hispanica* (C o l.), rare belemnites and ammonites, many bivalvs, brachiopods and echinids.

The Valanginian is represented by claystones and marls which are poor in fauna.

The Hauterivian and the Lower Barremian are built of marls, sandy-clayey marls, clayey-calcareous sandstones with intercalations of clayey limestones containing characteristic cephalopods (А н ђ е л к о в и ћ, 1975).

Neocomian flysch is also widespread in the Belgrade region.

A considerable part of the Barremian and Aptian are connected with two types of sediments: Urgonian (reef and subreef) and terrigenous. A substantial part of Belgrade is built over these sediments.

Urgonian limestones are usually massive, with rudists and Orbitolinidae. They contain intercalations of claystones, marls and rarely of sandstones.

In the southeast the Urgonian limestones pass into sandy-conglomerate sediments: conglomerates, sandstones and calcarenites, among which there are Orbitolinidae, gastropods and ammonites: *Holcodiscus caillaudianus* (d'O r b.), *H. perezianus* (d'O r b.), *Barremites ponticus* (K a r.), etc. These sediments are similar to the Paraurgonian facies in the Pyrenees and in the Fore-Balkan.

The terrigenous type of Barremian-Aptian sediments replace the Paraurgonian deposits in the southeast. They are designated by Serbian geologists as flysch sediments, but in fact they are molasse-like in character, similar to the sediments in the Roman Formation in the Fore-Balkan. They are represented by cross-bedded aleuritic marls, siltstones and sandstones. They contain Orbitolinidae, ridists, brachiopods, corals, etc. The peripheral fans of these sediments are the so-called clastic Aptian sediments (sandstones, calcarenites and a few conglomerates) which contain the same types of faunas. Similar law-governed regularities in the horizontal facial zonality of Lower Cretaceous rocks are found in the Fore-Balkan as well.

The Albian is represented by conglomerates, sandstones, glauconitic sandstones and sandy marls, containing many bivalvs, echinids, as well as cephalopods: *Leymeriella tardefurcata* (L e y m.), *Douvilleiceras mammillatum* (S c h l.), *Lyelliceras lyelli* (L e y m.), *Mortoniceras inflatum* (S o w.), *Neohibolites minimus* (R a s p.), etc.

At the base of the sediments described by Serbian geologists as Albian there are Clansayesian ammonites: *Parahoplites milletianus* (d'O r b.), *Acanthohoplites uhligi* (A n t h.), etc.

In the **Šumadia region** the Lower Cretaceous is represented by three basic facial types: neritic (predominantly terrigenous and terrigenous-carbonate sediments), pelagic (clayey-calcareous sediments) and flysch. The different stages are well characterized palaeontologically (А н ђ е л к о в и ћ, 1975).

In **Kopaonik** the series is exposed in the eastern peripheries of the mountain, where Valanginian-Hauterivian flysch is developed at its base, followed above by Barremian-Aptian terrigenous sediments of molasse-like type. The Albian is represented by massive and/or thin-bedded limestones which pass into the Cenomanian.

15.5. Eastern Serbia

The Lower Cretaceous is widespread in Eastern Serbia, where it is represented by various rocks with considerable thicknesses. It is well exposed from the region between the rivers Morava and Timok in the north to Suva and Stara Planina in the southeast (G r u b i ć, 1974; А н ђ е л к о в и ћ, 1975).

Serbian geologists distinguish four basic types in the Lower Cretaceous sediments: (1) shallow-sea; (2) flysch; (3) transitional; (4) deep-sea. However, their spatial differentiation is not very well clarified. An example in this respect is the generalizing work of M. A n ž e l k o v i ć (А н ђ е л к о в и ћ, 1975) in "Geology of Serbia", in which he describes typical pelagic limestones as the shallow-sea type.

In the **Golubač hills — Kučai — Tupijnica — Svarlik mountain and Suva Planina mountain** Lower Cretaceous sediments are predominantly of the shallow-sea type, with the exception of Berriasian deposits.

The Berriasian is built of clayey limestones and micritic limestones with many calpionellids: *Calpionella elliptica* C a d., *Tintinnopsella carpathica* (M u r g., F i l.), *Stenosemellopsis hispanica* C o l., as well as aptychi and rare brachiopods.

Clayey limestones and marls, in some places with intercalations of micritic limestones containing many calpionellids, overlie with a transition the Upper Jurassic lithographic limestones in the Golubač hills.

Berriasian deposits of the same time are discovered in Belanica, Kučai and Suva Planina mountain.

The Valanginian is revealed in the Golubač where it is represented by sandy marls and clayey limestones with *Natica pidancepi* (C o o p.), *N. bulimoides* d'O r b., *N. hugardiana* (d'O r b.), *N. javaschovi* T o u l a, *Pterocera desori* P i c t., C a m p. Massive subreef limestones come to the east.

In the Miroč zone (Miroč, Veliki Greben and Vrška Čuka) there are clayey limestones and marls, in the south in the Timok region — limestones with *Salpingoporella annulata* C a r. and *Pseudocylamina* sp.

In the southern part of Kučai the Valanginian is connected with micrograined limestones, rarely oölitic limestones and algal limestones, whereas in the northern part of Kučai and in Belanica this stage comprises a part of a thick limestone complex among which there are rich neritic faunas and algae.

The Hauterivian is discovered over considerable areas in the investigated strip, where it is of typically neritic type: sandy limestones, marls, clayey limestones, sandstones, organogenic limestones, among which there are: *Rhynchonella irregularis* Pict., *R. lata* d'Orb., *R. multiformis* (Roem.), *Terebratula sella* Sow., *T. rusillensis* Lor., *T. acuta* Quenst., *Neithea atava* (Roem.), *Spondylus roemeri* Deach., *Pholadomya gillieroni* Pict., Camp., *Ostrea tuberculifera* (Koch.-Dunk.), *Natica bulimoides* d'Orb., etc.

The Barremian and Aptian are represented by subreef and reef limestones with rudists and Orbitolinidae. They are well exposed in the Gornač area — Suva Planina mountain zone, Kučai-Svarlik zone, Tupijnica zone and in the Dobrodol-Grlica zone. The following species have been found among them: *Requienia ammonia* (Goldf.), *R. lonsdalei* (Sow.), *R. pellati* Paq., *R. gryphioides* Math., *Toucasia, Monopleura*, as well as various other bivalvs, gastropods, brachiopods and echinids.

These sediments are traced to the southeast near Pirot and Dimitrovgrad, from where they pass into Bulgarian territory. Paraurgonian terrigenous-carbonate sediments are developed to the side of the Urgonian limestones.

The Albian is connected with two lithostratigraphic units: Lenovač Beds and Jabukovač Beds.

The Lenovač Beds are found in the zone Tupijnica — Gamsigrad — Golubač hills. They are represented by sandstones and sandy marls among which there are fossils characterizing the three substages of the Albian.

The Jabukovač Beds occur in Northeastern Serbia between Dolni Milanovac and Negotin, reaching the Bulgarian frontier in the Kula region. Their lower part is built of glauconitic limestones, breccia-like limestones, marls and sandy claystones with *Inoceramus* and ammonites, whereas the upper part consists of marls, claystones and sandstones of Cenomanian.

The faunistic composition of these sediments is analogous to that of the Albian associations in Northwestern Bulgaria.

Two considerable depressions were formed in Eastern Serbia during the Early Cretaceous, in one of which flysch was formed (Lujnica zone) and in the other one—volcanogenic-sedimentary formations (Kraina area of the Danubian trough).

The Lujnica zone is a continuation of the flysch trough of the Kraište, which is traced to the northwest of the western slopes of Suva Planina mountain. The flysch sediments of the Berriasian and Valanginian are formed in this zone. In fact, there exists exact proof only for the Berriasian, namely: *Pseudosubplanites* sp., *Berriasella (P.) picteti* (Zitt.), *Fauriella gallica* (Maz.), *Calpionella elliptica* Cad., *C. alpina* Lor., *Tintinnopsella carpathica* (Murg., Fil.), etc.

In the Kraina area which comprises the western and central parts of the Danubian trough according to Grubić (1975), there are volcanogenic-sedimentary rocks which are described as "Vratarnica Series" comprising the base of the Lower Cretaceous as well. Above them lie the Timok (or Sinaia) Beds. These are aleuritic limestones, calcarenites, clayey limestones and marls (silicified in some places). Diabases and diabase tuffs occur among these sediments, their partial analogue being the Azuga Beds from the South Carpathians. The sediments contain only radiolaria.

In their upper part the Timok Beds are built of breccia-conglomerates with calcareous cement, sandy limestones, calcarenites, siltstones, micrograined limestones and marls.

The Timok Beds (Berriasian-Hauterivian) are exposed in the Miroč antiform, in the Eastern Miroč syncline in the Kosovica zone, in the Negotian region and on the Veliki Izvor Plateau.

Above the Timok Beds lie the so-called Miroč Beds (Barremian-Aptian), represented by clayey marls, sandstones and sandy limestones, among which there are corals, echinids, bryozoans, rudists, gastropods, brachiopods and Orbitolinidae. From Miroč and Veliki Greben these beds are traced to the south until the valley of Timok river. Together with the Timok Beds they are in allochthonous position.

In the **Rsovci zone** (Rsovci, Visočica, Velika Rjana, Kolčasti Gabar — Gradište), in the **Dobrodol zone** (between the Upper Jurassic ridge of Gradište — Kitka — Vidlič) and in the **Novo Korito — Kadibogaz zone** the Lower Cretaceous sediments are of transitional type between neritic and deep-water deposits. All stages of the series are represented. This development of the Lower Cretaceous in these zones is similar to the facies of the series in the boundary strip between the Fore-Balkan and the Moesian Platform.

In the Kraina Depression and in the Wallachian Basin in Eastern Serbia the Lower Cretaceous is developed in deep-sea facies (pelagic clayey-calcareous sediments). This is the Danubian area, i. e. the eastern part of the Danubian trough after Grubić (1974).

The Berriasian in the region of **Dolni Milanovac** is represented by clayey limestones, partly dolomitized, containing: *Fauriella boissieri* (Pict.) and *Tintinnopsella carpathica* (Murg., Fie.). The Valanginian comprises the clayey limestones with *Busnardoites campylotoxus* (Uhl.), which are incorrectly included in the volume of the Berriasian.

The Hauterivian and Barremian are built of clayey limestones and marls with characteristic ammonites.

The Aptian is connected with marls which are replaced by clayey-sandy marls with belemnites, bivalvs, brachiopods and rare ammonites. They are covered by marls with Orbitolinidae.

The Albian is represented by sandy limestones and clayey sandstones, characterized by *Aucellina grypheoides* Sow., *A. aptiensis* d'Orb., *Beudanticeras beudanti* (Brong.), *Ticinella* aff. *roberti* (Grand.), etc.

In the **Kamenica zone** of Stara Planina the Lower Cretaceous sediments are exposed near Kamenica village, Visočka Rjana, in the Visočica valley and in the north-west in the region of Rsovci village. Deep-sea clayey-calcareous deposits are developed, a continuation of the sediments of the Gubeš syncline. The Berriasian, Valanginian and Hauterivian are represented, being characterized by calpionellids and cephalopods.

16. ALBANIA

The Lower Cretaceous sediments in Albania are a continuation of the Dinaric sediments. Neritic carbonate facies predominate. Pelagic limestones with flint, as well as flysch sediments, are also developed (Papa, 1972; Dodona et al., 1975).

In the zone of the **Albanian Alps and Sajan** the Lower Cretaceous is connected with a thick limestone complex containing Orbitolinidae. The lower part of the series is missing.

Flysch sediments (Neocomian), analogue to the Bosnia flysch, are represented in the Mirditza zone. They overlie transgressively the volcanogenic-sedimentary formation of the Upper Jurassic. The carbonate complex of the Lower Cretaceous (Barremian-Albian) is found transgressively above them. The flysch zone is wedged between the carbonate platforms, evidently formed in the place of a deep channel.

Pelagic limestones with flint and radiolarites of Tithonian-Valanginian age are developed in the **Krast-Sukal zone** and in the **Ionian zone** (Papa, 1972).

17. GREECE

The stratigraphic differentiation of the Lower Cretaceous in Greece is hampered by the strongly manifested tectonic processing and the absence of sufficient fossils (A u b o u i n et al., 1963).

In the Western part of Greece, in the **Preapulian zone**, the Lower Cretaceous comprises part of the Vigla Limestones (Tithonian-Lower Senonian). The limestones are developed in the **Ionian zone** as well, where they are of deeper-sea type, with radiolaria and jaspes lenses. They contain calpionellids, aptychi, *Mesohibolites* and *Orbitolina*, which permit the determination of the interval from the Berriasian to the Albian inclusive.

In the continental part of the **Gavrovo zone** the Lower Cretaceous is connected with algal limestones which pass into the Upper Jurassic. More varied neritic limestones are developed in the Peloponnesus, with remains of foraminifera and corals, which characterize the interval between the Upper Jurassic and the base of the Lower Cretaceous.

In the **Pind zone** the base of the series is connected with radiolarites, often impregnated with manganese oxides, which alternate with pelagic limestones containing radiolaria. In the peripheral parts there are intercalations of breccia-like limestones, sometimes sandy and oölitic with *Trocholina alpina* L e u p . and *T. elongata* L e u p. A sandy-marly flysch associated with red marls with radiolaria follows above these sediments. Different *Orbitolina* and *Dictyoconus* define Barremian-Aptian age.

In the **Parnas zone** the Lower Cretaceous comprises part of the breccia-like limestones with *Ellipsactinia ellipsoidea* S t e i n (Tithonian-Valanginian), oölitic and dense limestones, above which the second bauxite level of Parnas is developed.

The Lower Cretaceous is absent in the Subpelagonian and Pelagonian zones, to appear again in the **Vardar zone**, where Aptian-Albian sediments with Orbitolinidae and *Nerinea* are developed. These are conglomerates with limestone and sometimes with ophiolite fragments; sandy-detritic limestones are also represented. They overlie transgressively and discordantly Upper Jurassic ophiolites.

In **Crete** the Lower Cretaceous is represented exclusively by limestones, in some places with radiolarites.

In the **Southeastern Rhodopes** the Lower Cretaceous is connected with the phyllite complex of Makri village, discovered to the northwest of Alexandroupolis. This complex is built of phyllites, shales, greywackes and slightly metamorphosed ophiolites. They contain intercalations of limestones among which Upper Jurassic and Lower Cretaceous corals have been found (B r a u n, 1968).

At Makri village (west of Alexandroupolis) in Northeastern Greece the Greek geologist L. Dimadis found among phyllitized rocks an ammonite which was identified by the author as *Pseudosubplanites* sp. (Upper Tithonian-Lower Berriasian).

In **Samothrace** the Lower Cretaceous comprises part of the ophiolite complex. It is represented by gabbro, diabases, coral limestones, shales and polygenous breccias. The interactions of the gabbro and diabases with the sediments indicate that the basic volcanism was manifested at the boundary between the Lower and Upper Cretaceous (B r a u n, 1968).

In **Trodos** the Lower Cretaceous is represented by dolerites (130-120 m. y.) (D e l a l o y e et al., 1980).

18. TURKEY

The Lower Cretaceous has limited distribution in Turkey. It often transgressively overlies Jurassic or Palaeozoic terrains.

Lower Cretaceous rocks are known from the southern coast of the Sea of Marmara, from Anatolia, in the northern part of the Beipazar-Nalihan region, to the south of Bolu, to the north of Goinuk and Abant lake, in the Zonguldak region, to the north of Ilgaz-Kurshunlu, around Baiburt, to the north of Tartuma and in Taurus (Эрентоз, 1967; Durand Delga, Gutnic, 1966; Логинова, 1970).

Along the Black Sea Coast the Lower Cretaceous sediments transgressively overlie Devonian and Carbonian rocks. The series starts with conglomerates, followed above by limestones (Valanginian-Lower Aptian), calcareous sandstones and limestones with *Nerinea* and *Requienia*. Higher up there are sandstones of Velebek (Upper Aptian) and Albian sandstones and marls covered by marls and coarse flysch (Upper Albian-Cenomanian).

White massive limestones with ammonites (Berriasian-Lower Barremian) are developed between the Black Sea and the Ilgaz-Kurshunlu region.

Lower Cretaceous sediments in deep-sea facies are developed between the Anatolian Mountains and the Northern mountain ranges. Many calpionellid finds are known from this zone.

Sandy and silicified shales with deep-sea fauna are developed in the south, in the Baiburt region, as well as clayey limestones with thickness up to 2800 m (Эрентоз, 1967; Durand Delga, Gutnic, 1966).

Dolomitic limestones with Orbitolinidae are discovered in deep drillings in Southeastern Anatolia.

19. THE MIDDLE EAST

The Lower Cretaceous is known in all countries in the Middle East. It is developed in shallow-sea, predominantly carbonate and / or terrigenous facies. Aptian and Albian sediments have the widest distribution, being almost everywhere of marine type. Continental formations are widespread over some territories.

The basalt volcanism of the Late Jurassic age continued during the Early Cretaceous as well, with a clearly manifested paroxysm during the Aptian (Dubertret (ed.), 1959-1964).

Faunistic finds are rare, being usually of Mediterranean type for the ammonite, rudists and Orbitolinidae faunas. A number of species, especially among bivalvs, gastropods and echinids, as well as some ammonites, are endemic for the Middle East.

Of considerable interest are the Berriasian-Valanginian ammonite faunas from Israel and Iran, among which the most widespread Mediterranean taxa are present (Raab, 1962; Seyed-Emami et al., 1972; Seyed-Emami, 1975). In Iran the characteristic calpionellid taxa are established as well.

To the east of Iran, in Afghanistan and Pakistan, the Lower Cretaceous already contains typical Himalayan faunistic elements (Fatmi, 1977).

Part Three

GENERALIZATIONS AND CONCLUSIONS

IV. SRATIGRAPHIC OUTLINE

1. BERRIASIAN

The Berriasian is widespread in the Mediterranean Region. It is represented by varied marine facies, in some places by continental formations of Purbeckian or Sahara type as well.

A gradual lithological transition from Tithonian to Berriasian sediments is observed in most regions. This continuity is disrupted in some places by local tectonic and / or palaeogeographic phenomena. The absence of Berriasian sediments in some regions is the result of stable uplift with considerable duration.

In the southwesternmost part of the area (the Cape Verde Islands) the Berriasian is represented by pelagic limestones with flint, formed in the continental base of Southwestern Africa. It also comprises part of the slightly metamorphosed limestones.

Further north, in the continental foothills of the **Moroccan Meseta**, the Berriasian comprises part of the thick complex of Lower Cretaceous flysch, in the marl associations of which characteristic *Nannoconus* and foraminifera associations have been found.

These sediments from the southern part of the North Atlantic Ocean are in contrast to the shallow-sea sediments of the stage in the **Agadir Basin** in Morocco. Carbonates with typical neritic fauna are developed there at the base of the Berriasian, followed above by clayey limestones and marls with ammonites.

The Agadir section demonstrates a gradual deepening and entrainment of new areas from the continental margin below the ocean waters during the Berriasian.

Deep-sea clayey limestones, rich in radiolaria, nannoplankton, calpionellids and aptychi are developed in the north, in the coastal strip of the Moroccan Reef.

The spatial distribution of the facies of the Berriasian sediments in Southwestern Africa and in its continental margin is determined by a number of local factors, though a regular shallowing of the basin from west to east and from north to south is observed, whereby continental facies are reached ("continental intercalaire" after Kilian).

Berriasian sediments are widespread in **Algeria** and **Tunisia.**

In the High Plateaux the Berriasian is connected with neritic facies. Terrigenous sediments predominate in the western part of the Plateaux, whereas terrigenous-carbonate deposits begin gradually to be imposed in the east-northeast. In the southern part the flysch is predominantly carbonate, whereas terrigenous components prevail to the north of Chelif river. The transition between the neritic facies of the High Plateaux and the deep-sea deposits of the Tellian Atlas is observed well in the profile El Rhoraf — Ouled Mimoun, where there is a complex intertwining of neritic with bathyal facies, formed in an active continental margin.

In Southern Tunisia the Berriasian comprises part of the continental terrigenous sediments with evaporites. Purbeckian facies are developed to the north of the Sahara Zone, followed by the zone of the carbonate platform.

Pelagic facies with many ammonites, most of which are pyritized, are predominantly represented in the Tunisian Depression. Neritic sediments are also developed in the peripheral parts.

The Berriasian is extensively developed in the Iberian Peninsula. Almost exclusively Purbeckian facies are developed in Portugal.

Pelagic clayey-calcareous sediments with many ammonites, calpionellids and radiolaria are widespread in the Subbetic Depression which comprises the southeastern part of the Iberian Peninsula and the Balearic Islands. Of the same time are the Berriasian sediments in Sardinia, which was located considerably further west during the Early Cretaceous than it is today.

Flysch sediments which are a continuation of the Magreb flysch are developed in the southwestern part of the Subbetian Depression.

The Berriasian is not represented in the **Iberian Mountain Range.**

In the Basco-Cantabrian zone the Berriasian comprises part of the thick continental complex. Marine Berriasian sediments are developed in the Central Pyrenees. In this zone, usually at the Jurassic-Cretaceous boundary, there are polygenous breccias, followed above by clayey-carbonate sediments with calpionellids and ammonites, covered by limestones with Dasycladacea and *Trocholina.* They demonstrate a gradual shallowing of the trough during the Berriasian, which led to the imposition of continental Purbeckian sediments at the end of the Berriasian.

In the **Corbières** the Berriasian sediments are entirely in neritic carbonate facies.

Berriasian basalt volcanism is established in the continental base of the Iberian Peninsula.

The most widespread sediments in **France** are of Vocontian type: pelagic clayey-calcareous sediments with many ammonites and calpionellids. In Provence the Berriasian is connected with neritic carbonate sediments, in Jura Mountains and in the Paris Basin — with the Purbeckian facies. Transitional facies are observed in the localities to the northwest of Grenoble towards Jura Mountains.

In the **Alps** the Berriasian comprises deep-sea clayey-carbonate and flysch facies. Very characteristic are the shiny shales and silicified limestones with biomorphic silicites (radiolarites). In the Southern Alps the stage comprises part of the pelagic white limestones with radiolarites (Biancone facies). These sediments are also widespread in the disrupted body of the **Pannonian Massif** (Vilany, Meczek and the Hungarian Central Mountains).

In the **Western Carpathians** (the Moravian-Silesian Beskydy) the Berriasian comprises the Lower Tešin Beds (clayey-calcareous sediments with calpionellids and aptychi) and the Tešin Limestones, whereas in the klippe zone there are pelagic limestones with many calpionellids and radiolaria. Thus, a neritic zone is outlined in the Beskydy Mountains, to the south of which is the zone of typical deep-sea sedimentation. This zonality is traced in the Polish Carpathians as well.

The Berriasian sediments in the **Romanian Carpathians** are very varied. In the Eastern Carpathians the Berriasian is connected predominantly with flysch sediments. In the Perşani zone the Berriasian comprises part of the formation of marls with cephalopods, among which in some places there are breccias, conglomerates, calcarenites, sandstones and radiolarites in association with diabases. Particularly widespread is the facies of the Sinaia Beds, among which diabase lenses are developed in some places, as well as shales with diabase intercalations (Azuga Beds).

In the Southern Carpathians the Berriasian comprises limestones with cherty concretions, containing many ammonites and calpionellids.

In the middle part of the **Wallachian Depression** the Berriasian is connected with the facies of the Kaspičan Formation.

The Berriasian in the **Crimea** is represented by two types: deep-sea — developed in the Theodosia region, and neritic — to the west of Burulča-Bešterek. A characteristic feature of the development of the Berriasian is the appearance of northern (Volgian) elements among the ammonite faunas.

Berriasian sediments in the **Caucasus** are very varied. In the Northwestern Caucasus (Belaja river) the Berriasian comprises neritic limestones with rich faunas, including ammonites. In addition, clayey-calcareous sediments and conglomerates are distributed. Among the ammonite faunas there are northern taxa as well.

In Central Caucasus and in the Fore-Caucasus the stage is connected with marls and claystones, intercalated by limestones with bivalvs and ammonites. In the east, in Dagestan, the Berriasian is built predominantly of dolomites formed under lagoonal conditions.

The Berriasian is not developed on the southern slope of the Main Caucasian Ridge. Lower Cretaceous sedimentation started here during the Hauterivian.

Pelitomorphic limestones, in some places clayey and bituminous, are discovered in Western Abhasia. Similar sediments are also developed in the Rača Depression, where intercalations of dolomites also occur. Ammonites are very well represented.

The Berriasian is also known in the Kafan region of Caucasus Minor, where it comprises part of the tufogenic formation with intercalations of limestones.

In **Bulgaria** the Berriasian is represented by three main facial types: neritic carbonates in the Moesian Platform, flysch sediments in a considerable part of the Fore-Balkan and the Kraište, and pelagic clayey-carbonate sediments in Northwestern Bulgaria. In the eastern part of the Western Fore-Balkan the Berriasian comprises part of the carbonate builtup of the Brestnica Formation. Flysch sediments of the Carpathian (Sinaia) type are developed in the Kula region.

In the **Dinarides** and **Hellenides** the Berriasian is connected with carbonate and flysch sediments.

The Berriasian is represented by pelagic, predominantly clayey-carbonate sediments with calpionellids in the east, in **Anatolia**, whereas in the remaining regions (Turkey and the Middle East countries) it is developed in shallow-sea terrigenous and / or terrigenous-carbonate facies with insignificant thicknesses, or it is completely absent.

2. VALANGINIAN

The distribution of the Valanginian and the type of its sediments are similar to those of the Berriasian. In some places, however, Early Cretaceous sedimentation started during the Valanginian. Moreover, in all zones with clayey-calcareous sedimentation there is a gradual increase of the clayey content in the Valanginian sections and increase of the marls at the expense of limestones.

The Valanginian comprises part of the formation of slightly metamorphosed limestones developed in the **Cape Verde Islands.** In the north it is connected with limestones and clayey-calcareous sandstones discovered by Borehole 367 in the Atlantic Ocean. In the continental base of the **Moroccan Meseta** the stage is represended by turbidites with intercalations of marls. Between the Canary Islands and Cap Bojador it comprises part of the formation of aleuritic argillites with siderite concretions.

In the **Agadir Basin** of Morocco the Valanginian sections are built of varied, predominantly aleuritic marls with ammonites, bivalvs, brachipods, corals, echinoderms and benthos foraminifera, which characterize the neritic conditions in moderately deep shelf.

The Valanginian sediments are of a deeper-sea type in the north, at Safi.

In the **Moroccan Meseta** the Valanginian is represented by marine dolomitic limestones with ammonites, which are included in the continental Wealdian complex of the Lower Cretaceous. This is the result of clearly expressed marine ingression among the continental Wealdian basin, manifested during the Valanginian.

In the **Moroccan Reef** there are predominantly clayey-calcareous sediments (calcareous claystones, marls and clayey limestones) with ammonites, radiolaria and calpionellids.

In the **Sahara Atlas** the Valanginian comprises part of the thick continental complex ("continental intercalaire" after Kilian).

In the **High Plateaux of Algeria** the Valanginian sediments are terrigenous-carbonate of neritic type.

The Valanginian in the Tellian Depression is connected with terrigenous-carbonate flysch and subflysch sediments with deep-sea fauna. Pyritized ammonites occur in many places in this zone.

A transition of the neritic facies in the High Plateaux to the pelagic sediments in the north is observed to the southwest of Constantine. This transition is well manifested in a number of Valanginian sections.

The Valanginian is well manifested in **Tunisia** as well. Continental sediments of Wealdian type are developed in the southernmost part, which are substituted in the north by shallow-sea carbonates. In the Tunisian Depression the stage is connected everywhere with clayey-calcareous and flyschoid sediments containing many cephalopods.

In **Portugal** the Valanginian is represented by facies which are similar in many respects to those from Jura Mountains. In the Sintra Massif and at Cascais (Estramadoura) the base of the stage is represented by sublittoral limestones and marls, which are replaced in the east by sandstones formed under estuary conditions. Sandy limestones, oölitic in some places, were formed during the Late Valanginian. To the north of Torres Vedras the Valanginian is developed in Wealdian facies.

In the continental margin of the Iberian Peninsula the Valanginian is represented by claystones with planktonic foraminifera.

The Valanginian in the **Subbetic Depression** is represented by flysch in the southwestern part by clayey-calcareous sediments in the northeast towards the Balearic Islands. It is characterized by many ammonites.

The Iberian Mountain Ranges, as well as the Basco-Cantabrian zone, present the Valanginian in Wealdian facies.

The Pyrenean facies of the Valanginian are predominantly neritic, mainly carbonate or clayey-carbonate, in some places also terrigenous. It is interesting that the Urgonian type of sedimentation in the **Pyrenees** started from the Valanginian.

The development of the Valanginian in **France** is subordinated to the same basic laws as that of the Berriasian. An increase of the marls compared with the Berriasian is observed in the Vocontian sections.

The Valanginian in the **Alps** is represented prodominantly by deep-sea clayey-calcareous and flysch sediments, widespread in the east and in the Carpathian trough, where they are associated in many places with basic volcanites.

In the southern part of **Hungary**, in Meczek and Vilany, the Valanginian comprises volcanogenic-sedimentary formations with well-expressed trachydolerite formation with sedimentary intercalations, in which characteristic ammonites have been found.

In the **Crimea** the Valanginian deposits are more widespread than the Berriasian sediments and in some places they overlie transgressively older rocks. In the Theodosia region the stage comprises the middle part of the Lower Cretaceous outcrops. It is represented by calcareous claystones with marl intercalations. This type of sediments is traced in the west until the valleys of the rivers Tonas and Indol.

Transgressive position of the Valanginian glauconitic clayey sandstones over the Tithonian flysch is observed in the valley of Burulča river. In the southeast, in the valley of Belbek river, the Valanginian transgressively overlies the Tavric series. Conglomerates are developed at its base, followed above by clayey-calcareous sandstones with different faunas, including ammonites.

In **Northwestern Caucasus** the Valanginian comprises clayey-marl sediments and limestones with different faunas. In Central Caucasus the stage is built of micrograined limestones, often recrystallized and poor in fossils. These carbonate sediments gradually decrease in thickness and in Dagestan they are 25-30 m thick. In the southern part of Dagestan the limestones become sandy and intercalations of marls appear. Near Hanagčai river they are replaced by sandy coastal facies, and in some places they are completely wedged out.

Clayey-carbonate and carbonate sediments of insignificant thicknesses occur in the **Georgian** zone. They contain characteristic ammonites. A formation of cryptocrystalline limestones and dolomitized limestones with scanty gastropod fauna is developed in the upper part of the Stage.

In **Caucasus Minor** the Valanginian is developed in several zones, the sections in the Kafan zone being the most clearly seen, where terrigenous-carbonate sediments with typical Mediterranean fauna are developed.

In **Bulgaria** the Valanginian is represented by neritic carbonates, extensively developed in the Moesian Platform, by flyschoid sediments — in the greater part of the Fore-Balkan, the Kula region and the Kraište, and by clayey-calcareous deposits in the Western Fore-Balkan, the Lom Depression and Western Balkan Mountains (the Gubeš syncline).

In the **Dinarides** and **Hellenides** the Valanginian is connected with carbonate and flysch sediments.

The Valanginian sediments demonstrate considerable variety in the zone of **Šumadia** and **Eastern Serbia**, where neritic to deep-sea facies are observed.

In the southeast, towards **Turkey** and the **Middle East**, the Valanginian sediments are developed in neritic carbonate or terrigenous-carbonate facies with scanty fauna.

Only in some regions of Turkey, especially in Anatolia, the Valanginian is connected with deeper-sea clayey-carbonate sediments.

To the east of Iran, towards Afghanistan and Pakistan, many Himalayan species appear among the Valanginian faunas.

3. HAUTERIVIAN

The Hauterivian sediments have considerable distribution and they are with very varied facies.

In the Atlantic Ocean, in the **Cape Verde Islands**, the Hauterivian comprises the upper part of the slightly metamorphosed deep-sea limestones, covered with basalt lava which was poured at the end of the Hauterivian.

In the north, in the continental base of the **Moroccan Meseta**, the Hauterivian is connected with part of the thick Lower Cretaceous flysch complex, whereas between the Canary Islands and Cape Bojador it is connected with aleuritic argillites containing siderite concretions. These sediments contain many remains of fishes, echinoderms, gastropods and cephalopods, and they manifest deltaic facies.

In the region of the **Canary Islands** the Hauterivian is represented by cross-bedded siltstones.

The Hauterivian section in the **Agadir zone** starts with aleuritic marls and claystones, with reef limestone-dolomite formation in their middle part. Above them there are again aleuritic marls and claystones.

Variegated sediments containing small gastropods, bivalvs and rare agglutinated forms — foraminifera, are developed in the north, in the **Essaouira zone** in the Lower Hauterivian. These brackish-lagoonal sediments are followed above by marine marls with Upper Hauterivian ammonites and many foraminifera.

In the **Safi region** Hauterivian sediments are very rich in ammonites, whereas a Wealdian-like facies (sandstones and red claystones) is developed in the Meseta.

Hauterivian sediments reappear in the allochthonous part of the **Moroccan Reef**, where they are represented by flysch facies.

Neritic terrigenous-carbonate sediments are developed in the **High Plateaux.** Purely terrigenous deltaic facies are also developed in the western part, while terrigenous-carbonate sediments are imposed in the east-northeast, including reef limestones in a number of places.

In the Tellian Depression the Hauterivian is connected with deep-sea clayey-carbonate sediments containing in some places intercalations of sandstones and siltstones.

In the Constantine region there are predominantly carbonate and terrigenous-carbonate sediments, among which characteristic ammonites occur. In the north, in the Cabile zone, the Hauterivian comprises part of the thick flysch complex.

In the **Sahara** the Hauterivian is represented by continental terrigenous sediments with evaporites, which are traced to the east in Tunisia.

Wealdian facies: sandstones, dolomites and claystones with gypsum, are developed in Tunisia, to the north of the Sahara zone. They contain remains of vertebrates, bivalvs and gastropods, as well as rare marine species.

In the **Tunisian Depression** the Hauterivian is represented by neritic and pelagic sediments. The neritic facies are developed in the peripheral parts of the Depression and they are well exposed in the Zagouan Massif, where they are represented by organogenous-detritic limestones and sandy marls. The pelagic facies are widespread in the middle part of the Depression and they are represented by clayey-carbonate sediments of Vocontian-Salaš type, with many ammonites.

In **Portugal** the Hauterivian is well developed in the region of Sintra and Brouco. It is built at its base by marls and clayey limestones with echinids and rare ammonites. In the east these sediments are replaced by subreef limestones which are widespread in the upper part of the stage. Marls and sandstones above which there are limestones with rudists are exposed in the north near Ericeira. To the north of Torres Vedras the Hauterivian comprises part of the Wealdian complex.

In the **Subbetic Depression** the Hauterivian sediments are of the deep-sea type. Predominantly clayey limestones are represented in the greater part of the Depression, as well as flysch in its southwestern margins. The pelagic sediments contain many ammonites.

In the **Iberian Mountains** and in the Basco-Cantabrian zone the Hauterivian sediments are in Wealdian facies.

The Hauterivian in the **Pyrenees** is connected predominantly with carbonate sediments which are particularly widespread in the Corbier.

Deep-sea clayey-carbonate sediments with many cephalopods are developed in the **Vocontian trough**. Relatively more shallow-water sediments appear in the southern end, passing to the south into the neritic carbonate facies of Provence.

The neritic facies of **Jura Mountains** are imposed in the north, after a transitional zone between the Subalpine Range and the Central Massif. A characteristic feature of the Hauterivian sections in Jura Mountains is that their lower part is built of relatively deeper-sea marls in *Spatangus* facies with abundant fauna which, however, is of the more shallow-water type compared with the Subalpine region. Above them are the Neuchâtel zoogenic, oölitic and detritic limestones.

The Hauterivian *Spatangus* marls are widespread in the **Paris Basin** as well, where Wealdian facies are only partially developed in the Hauterivian.

In the **Swiss Alps** the Hauterivian sediments are more varied compared with the Berriasian-Valanginian deposits. The *Spatangus* marls of the French Subalps pass in the Wildhorn nappe into a powerful formation of deep-sea clayey limestones. In the Ultra-Helvetic nappe the Hauterivian comprises part of the so-called Neocomian with cephalopods from the outer Fore-Alps.

In the Fore-Alpine nappes the Hauterivian comprises part of the complex of shales and calcareous shales with aptychi, as well as part of the siliceous limestones with radiolaria.

In the **Eastern Alps** the Hauterivian is represented by terrigenous-carbonate sediments.

In the **Moravian-Silesian Beskydy** the Hauterivian is connected with the Hradište (Grodziszcze) Sandstone Formation, as well as with siderite-bearing argillites.

In the flysch zone of the **Polish Carpathians** the Hauterivian sediments are in the same facies as in the Beskydy, whereas in the Pieniny zone deeper-sea sediments are developed: limestones with flint and shale interbeds.

In the **Eastern Romanian Carpathians** the Hauterivian is represented in varied facies: marls with cephalopods in the Perşani zone, sublithographic and clayey limestones with flintstone in Dîmbovicioara, Sinaia-type terrigenous-carbonate beds in Baraolt, Zamura and the inner nappes. In the shales zone the Hauterivian comprises part of the sphaerosiderite complex.

In the **Southern Carpathians** (Reşiţa zone) the Hauterivian is built of shaly marls which are poor in fossils. Sublithographic limestones with cherty concretions, analogous to the Salaš facies, are developed in the Sviniţa zone.

Very varied, but almost exclusively neritic are the Hauterivian sediments in the **Crimea**, where they are more widespread compared with the Berriasian-Valanginian deposits. They are absent in the valleys of Sarisu and Bodrak, as well as in some other regions of Northern Crimea.

Claystones with aptychi are developed in Eastern Crimea in the Theodosia region. Packets of sandstones appear among them in the west, towards the rivers Kučuk-Karas and Tonas. Along the rivers Burulča and Bešterek the Hauterivian is represented by sandstones, conglomerates and claystones with rare ammonites, as well as by sandstones in the upper part of the section in Bešterek. Conglomerates and sandstones are distributed in the valleys of Kača and Belbek rivers, in some places also claystones containing rich and predominantly neritic fauna.

The Hauterivian in **Northwestern Caucasus** comprises sideritic claystones, sandy-clayey sediments, sands, sandstones and conglomerates. A decrease of the clastic material and deepening of the basin are observed from west to east.

In **Central Caucasus** the Hauterivian is represented by a monotonous formation of siltstones and claystones with intercalations of limestones. Neritic faunas predominate among these sediments. Ammonites occur rarely.

In the east, in **Dagestan**, the Hauterivian is built of sandy-clayey sediments, zoogenic, oölitic and oölitic-detritic limestones. In the western part of Dagestan and in Čečeno-Ingušetia predominantly aleuritic and fine-grained sandstones are developed, below which there are marls with intercalations of aleuritic claystones and siltstones.

To the south of the Main Caucasian Ridge, in the **Georgian zone**, the Hauterivian is known in the Dibrar region, where it is connected with the Kusnet Flysch Formation.

Tufogenic sandstones, in some places with intercalations of clayey-sandy limestones, are widespread in Caucasus Minor.

The Hauterivian in **Bulgaria** is represented by terrigenous sediments which are widespread in the Fore-Balkan, by clayey-carbonate deposits of neritic type in the Moesian Platform and by pelagic clayey-calcareous sediments of the Salaš type, developed in Western Bulgaria.

In the **Venetian Alps** the Hauterivian comprises part of the light limestones with flint, in Lombardy — clayey limestones with aptychi (Maiolica facies).

Clayey limestones and limestones with flint, rich in cephalopods, are developed in Sicily and in Sardinia.

In the **Dinarides** the Hauterivian is represented by carbonate and flysch sediments.

Various facies — from sublittoral to pelagic — are developed in the **Šumadia zone** and in **Eastern Serbia.**

In the **Hellenides** the Hauterivian has not been differentiated but it is evidently present in the Lower Cretaceous sections built of carbonate or flysch sediments.

In **Turkey** the Hauterivian is represented by terrigenous, terrigenous-carbonate and clayey-calcareous sediments.

In most countries in the **Middle East** the Hauterivian is not developed, or it is represented by epicontinental terrigenous or carbonate rocks.

4. BARREMIAN

The Barremian is characterized by very varied facies, among which neritic ones predominate. The extensive development of the Urgonian facies, which is a typical Mediterranean phenomenon, started during the Late Barremian.

In the region of the **Cape Verde Islands** the Barremian is represented by bituminous marls with ammonites and bivalvs. Clayey sandstones are developed in the northwest.

In the continental base of the **Moroccan Meseta** the Barremian comprises part of a thick flysch complex. In the **Mazagan Plateau** the Lower Cretaceous sedimentation starts with Barremian dolomites and calcareous sediments. A thick complex of continental sandstones and conglomerates, which overlie the Jurassic or Triassic, is dated to the Barremian in the Tarfaya Basin.

In the north, in the **Agadir zone**, the Barremian is represented by aleuritic marls and claystones. Only the upper part of the stage, represented by clastic sediments in deltaic facies, is developed in the northeastern part of this zone. Relatively deep-sea clayey-calcareous sediments are developed in the **Safi region.** In the coastal part of the **Moroccan Reef** there are typically deep-sea clayey limestones, rich in radiolaria, whereas in the allochthonous part of the Reef there is flysch.

The Barremian in **Algerian Sahara** is of continental type. Terrigenous-carbonate sediments are developed in the north, in the **High Plateaux.** A decrease in the terrigenous admixtures is observed from west to east.

Clayey-calcareous sediments with many pyritized ammonites are discovered in the Tellian Depression.

In the north, in the Amrouna Massif, the Lower Barremian is in the same clayey-calcareous facies, whereas the Upper Barremian is connected with terrigenous-carbonate sediments of Urgonian and Paraurgonian facies.

In the region of the **Big and Small Cabil Massifs** the Barremian comprises part of the flysch complex.

In the northern part of **Tunisia** the Barremian sediments are developed in pelagic facies connected with the Tunisian Depression. Many pyritized ammonites occur. In the south, in Central Tunisia, there appear sandstones and their amount increases in southern direction, where the marl-sandy sediments gradually pass into the lacustrine-fluvial sands of Boudinar. In the Sahara the Barremian comprises part of the continental Lower Cretaceous sediments.

The Lower Barremian in **Portugal** is developed at Sintra and Brouco, where it is represented by limestones with *Choffatella* and algae. The Upper Barremian is more extensively developed, being connected with sublittoral terrigenous-carbonate sediments (Almargen Beds). Continental sediments are developed to the north of Tores Vedras, being also widespread in the shelf of Portugal. Marine clayey sediments appear only in the continental base.

The **Subbetic Depression** is filled with bathyal sediments containing many ammonites, most of them pyritized. These are clayey limestones in the Grenada province, which pass in the Seville province in the direction of Cadix into marls with pyritized ammonites.

In the **Fore-Betic zone** the Barremian facies are still deep-sea (marls) with ammonites in the Haen region, becoming gradually more neritic in the east, with the appearance of marls with *Ostrea*. This facies shows that the neritic Barremian already appears in the Mediterranean margin of Spain.

Some transitions between the Subbetic and Fore-Betic facies are observed between Alicante and Barcelona. Marls with pyritized ammonites, which are covered by Urgonian limestones and marls with Orbitolinidae, are developed in the strip between Alicante and Cape Nao. In the west, in the direction of Castilia Nova, the Barremian comprises a varied continental formation with charophytes, among which there are rare intercalations of sea marls with *Choffatella*.

In the Maestrazgo region the Lower Barremian is still in littoral facies, whereas the Upper Barremian is built of marine limestones with *Choffatella*. To the south of Barcelona the Barremian is represented by the same facies with Orbitolinidae and small rudists.

In the **Balearic Islands** the Barremian is connected with limestones and clayey limestones with ammonites (Majorca), as well as marls with pyritized ammonites (Southern Ibiza). In the northern part of Ibiza the Barremian is part of the Urgonian complex which comprises almost the entire Lower Cretaceous. At Minorca the Lower Barremian is represented by marls with ammonites, the Upper Barremian — by Urgonian limestones.

In the **Eastern Pyrenees** the Barremian corresponds to the lower part of the Urgonian complex.

After a hiatus in the Central Pyrenees, the Barremian is rediscoverd in the **Basco-Cantabrian zone**, where it is connected with continental Wealdian and marine Urgonian and Paraurgonian facies.

Barremian deposits in **France** are of three facial types: Vocontian — pelagic clayey-calcareous sediments developed in the Vocontian trough; Urgonian — massive organogenous limestones with rudists and bioclastic limestones, extensively developed in Vercors, along the periphery of the Central Massif, in Ventoux, Provence, Jura Mountains and the southern periphery of the Paris Basin; and Wealdian — continental sands and clays developed in the northern part of the Paris Basin. Intercalations of marls, siltstones and sandstones with Orbitolinidae are observed among the Urgonian limestones in Jura Mountains and Vercors. In the middle part of the Paris Basin the Barremian is represented by transitions from coastal to continental sediments. The Barremian in the **Swiss Jura Mountains** is analogous to the French part of the mountain. The outcrops of this stage can be traced in the east in the **Alps** (after a big hiatus in the region of the Geneva Lake, in the massifs

Aar and Gotar), as well as on the southern bank of the Rhône river in the Helvetian and Sub-Helvetian nappes. The stage starts with varied glauconitic marls, sandstones and limestones with ammonites, bivalvs, gastropods and echinids (Altmann Beds). The Druzberg Beds follow above them, consisting of clayey limestones and marl shales, among which there occur bivalvs and echinids, as well as rare ammonites. These sediments pass upwards and to the northeast into Urgonian facies.

In the inner zones of the Alps it is difficult to differentiate the Barremian, due to the extremely complex tectonics and the scanty fossil finds. A pelagic facies different from the autochthone and from the Helvetian and Sub-Helvetian nappes is developed here. This facies is of the Italian Maiolica type. It is represented by argillites, sandy or siliceous limestones.

Altmann and Druzberg Beds, and Urgonian facies, known from the Swiss Alps, are traced in **Austria.**

In the flysch zone which is traced until Vienna the Barremian is represented by detritic limestones, sandy limestones, calcareous sandstones and marl shales, which are part of the flysch complex.

The Barremian in the Puez Alps is predominantly of deep-sea type with many ammonites.

The Barremian sediments in the southern part of **Hungary** are discovered in Vilany (Harsany), where Upper Barremian limestones and breccias with Orbitolinidae and rudists overlie the karstic surface of the Valanginian.

Glauconitic marls and sandy limestones, exposed in the northern part, are developed in Bakony. To the north these sediments become markedly coastal, whereas to the south marls with radiolaria gradually develop.

In Geresce the Barremian comprises a sandstone formation which passes from the Hauterivian and contains upwards intercalations of clayey-calcareous sandstones and sandy limestones. The section ends with conglomerates intercalated by zoogenic limestones with Orbitolinidae, rudists and corals.

The Barremian in **Czechoslovakia** is developed in the Carpathians. In the Inner Carpathians it is represented in different facies. In the Lower Sub-Tatran nappes it comprises the upper part of the light limestones (Biancone type). Marls with intercalations of Urgonian limestones follow above them. Only Urgonian limestones are developed in the Tatras.

In the klippes zone the Stage is connected with the upper part of the limestones of the Biancone type, above which limestones and clayey limestones covered by Urgonian are developed. In the Moravian-Silesian Beskydy it is represented by the Veřsovice (Wierzowice) Shales and partially by the Hradište Sandstones.

In the **Polish Carpathians** the Barremian is widespread in the flysch zone, in the Pieniny zone and in the Tatras. In the flysch zone it is connected with the Veřsovice (Wierzowice) Shales and with the Hradište Sandstones. In the Pieniny zone it comprises part of the limestones with aptychi, whereas Urgonian limestones are developed in the Tatras.

This stage is well developed in the **Romanian Carpathians** as well. In the inner flysch zone it is connected with the Sinaia Beds. Only in the northern part of this zone the Barremian greatly resembles sections in Silesia.

Coarse flysch with olistostromes is developed in the Perşani zone. Marls with cephalopods and reef limestones with rudists are developed in Dîmbovicioara. In Baraolt, Bucegi and Piatra Mare there is a marly-sandy or sandy flysch, among which there appear wedges of Urgonian limestones. The lower part of the Comarnic Beds in Zamura also belongs to this Stage.

In the Reşiţa zone of the South Carpathians the Barremian is represented at its base by limestones with flint, which rapidly pass upwards into Urgonian limestones. Marls with many ammonites are developed in the Sviniţa zone; in the zones

Cerna and Coşuştea there are Urgonian limestones. Romanian geologists date to the Barremian and Aptian tuffite and andesite lavas with inclusions of Jurassic limestones which are covered by Upper Cretaceous flysch. In the Turnu Severin region the Barremian sediments are in facies of the Comarnic type.

In the Northern Apuseni the Barremian comprises part of the flysch among which reef limestones are developed in some places. Sublittoral limestones, reef limestones in some places, with marl and sandstone interbeds, are developed in the south.

In the **Soviet Carpathians** the Barremian comprises the lower part of the Urgonian complex.

In the **Crimea** the stage is usually represented by conglomerates and limestones containing very varied fauna. Boreal species appear among the conglomerates. Everywhere the Barremian facies are of neritic type, perhaps with the only exception of the Theodosia region, where the lower part of a monotonous clayey formation is dated to the Barremian, accepted earlier to be entirely Aptian.

The Barremian in **Northwestern Caucasus** is represented predominantly by terrigenous sediments (sandstones and conglomerates), sandy-clayey sediments, claystones with intercalations of sandstones (Fonar type), and on a more limited part — by sideritic claystones.

The Barremian in **Central Caucasus** is represented predominantly by sandstones, siltstones, oölitic and sandy limestones, and more rarely by claystones. These sediments contain rich neritic fauna, whereas among the ammonites there are Boreal species. In Čečeno-Ingušetia and Dagestan the Stage is connected with terrigenous-carbonate sediments.

To the south of the Main Caucasian Ridge the Barremian is developed in cephalopod facies, close to the Razgrad type in Bulgaria.

Terrigenous-carbonate sediments with intercalations of Urgonian limestones are widespread in Caucasus Minor.

In **Bulgaria** the Barremian is represented by several facial types: Urgonian and Paraurgonian, clayey-calcareous Razgrad neritic type (in Northeastern Bulgaria) and clayey-calcareous Salaš pelagic type (in Northwestern Bulgaria), and terrigenous.

The pelagic facies of the Barremian (Maiolica type) reaches in the south in the **Apennine Peninsula** to the places south of Rome. Various neritic facies are developed in the south.

The Barremian is not differentiated in **Sicily**, but its presence is probable in the upper part of a bathyal formation. Predominantly Urgonian facies is developed in **Sardinia.**

In the **Šumadia zone** and in **Eastern Serbia** the Barremian is represented by varied facies: from bathyal to neritic of Urgonian type. Urgonian and Paraurgonian sediments are very characteristic of the Dinarides.

In **Albania** the Barremian is connected with crystalline or breccia-like limestones.

In **Greece** the identification of this Stage is difficult, but its presence is indisputable in a number of zones where limestones with corals and algae are developed. Clayey limestones and limestones with ammonites are known from Western Argolid. In the Pind zone the stage is connected with a marly-sandy flysch among which there are marls with radiolaria.

Urgonian limestones with intercalations of sandstones are developed in the Black Sea coast of **Turkey.** Clayey and sandy limestones with Barremian ammonites are widespread to the south of Zonguldak. Flysch sediments are developed south of Trabzon, while in the Menderes Massif there are shales and limestones among which ammonites have been found. In the western part of Taurus the Barremian is in carbonate facies.

Continental fluvial, deltaic and sometimes coastal facies are widespread in the **Lebanon, Syria, Jordan** and **Israel.**

In the east, in **Iraq** and **Kuwait** the Barremian is connected with neritic sediments among which oysters, gastropods, Orbitolinidae and *Choffatella* occur.

5. APTIAN

The Aptian is known in the entire Mediterranean Region — from the Atlantic Ocean to the Middle East. It is developed in different facies, particularly characteristic among them being the Urgonian facies.

In the region of the **Cape Verde Islands** the Aptian is represented by variegated clayey shales, slightly metamorphosed limestones and basalts.

Aleuritic marls, pelagic radiolarites and limestones rich in nannoplankton are developed to the southwest of the **Canary Islands**, whereas in the continental base of the Moroccan Meseta the Aptian Stage comprises part of the flyschoid complex.

Clayey limestones with nannoplankton are discovered in the **Mazagan Plateau.** Marine sedimentation in the **Agadir Basin** started during the Aptian. Marls and aleuritic claystones with ammonites of Clansayesian age were formed.

In the **Agadir zone** the Lower Aptian is represented by dolomitic limestones and sandstones with ammonites. Upwards the Middle and Upper Aptian beds are condensed. In the Northeastern part of this zone (the Tizi region in the High Plateaux) the Lower Aptian comprises part of the formation of epicontinental clastic sediments formed under deltaic conditions. Upper Aptian and Albian fossils are found above them in condensed beds.

In the **Essaouira zone** the Aptian is represented at its base by continental sandstones and conglomerates, by Middle Aptian marls and aleuritic claystones, followed above by Upper Aptian aleuritic and sandy marls with ammonites and many foraminifera.

Continental sediments are established in the **Moroccan Meseta.** In the **Reef** the Aptian is not differentiated and it is probably absent, with the exception of the allochthone, where it is represented by flysch.

Aptian sediments in the northern part of **Algeria** are of pelagic (flysch or clayey-carbonate) type. To the south they gradually pass into neritic facies in order to reach the continental formations of the Sahara.

In the **Ouarsenis region** and to the north there are Urgonian limestones which are associated everywhere with terrigenous sediments: marls, siltstones and sandstones with siltstones.

Aptian sediments in **Northern Tunisia** are pelagic, becoming gradually neritic to the south. In Northern Tunisia the Lower Aptian is connected with limestones and clayey limestones, followed above by Middle and Upper Aptian marls, and clayey limestones with many ammonites.

Neritic facies appear in southern direction, sometimes with reef limestones, while still further south there also occur gypsum inclusions in the transition to purely continental sediments.

The Aptian in **Portugal** is connected predominantly with terrigenous carbonate sediments (Almargen Beds), and with continental formations to the north of Torres Vedras.

Bathyal sediments are developed in the Subbetic Depression, their distribution being limited mainly to the Cadix province and on the **Balearic Islands** (Ibiza and Formentera). At Hodar (Haen province) and on Formentera Island there appear

Paraurgonian sediments with Orbitolinidae, as well as Urgonian limestones. Thus, the Aptian marks the end of this big depression zone.

In the northern part of the **Subbetic depression** there are sediments of transitional type: from the bathyal facies in the southeast to the neritic facies in the northwest. For example, limestones with Orbitolinidae, intercalated by marls, are exposed between Alicante and the valley of Ebre river, while packets of Urgonian limestones also appear in the northwest.

The Urgonian facies is extensively developed in the **Eastern Pyrenees,** represented by limestones with rudists and Orbitolinidae, which also contain cherty concretions and become clayey in their upper part. A similar facies is discovered in the Central Pyrenees, with thickness of the Urgonian about 1000 m. This thickness decreases in the south and in the west, where the Urgonian limestones are covered by marl shales of Aptian-Cenomanian age. The Aptian sediments are gradually completely wedged out in the west around the St. Goden meridian.They reappear in the **Basco-Cantabrian zone,** but in a completely different facies. A powerful complex of conglomerates, sandstones and calcareous sandstones, shaly marls with lignites and sandstones, is formed here. Lenses of reef limestones of Urgonian type are observed among these sediments. French geologists characterize this complex as flysch, though in fact it possesses all characteristics of the molasse. It is predominantly marine in its northern part, whereas in the south it includes more and more considerable continental intercalations.

In the **Southern Subalpine Ranges** the Aptian is of clayey-calcareous type with ammonites, developed in the Vocontian trough. The Bedoulian is built of limestones with ammonites, including large forms. Gargasian marls with pyritized ammonites follow above the Bedoulian. The Clansayesian ends the section of the Stage with clayey-sandy sediments.

In the Southwest the Aptian sediments rapidly decrease their thickness, but they preserve their facies by disappearing quickly to the south of Castellane and Verdon in the **Low Alps**, probably as a result of post-Aptian denudation. The latest outcrops reach the valley of Tine river, where marls with pyritized ammonites are developed.

In the southwest, in the area of the Durance vault, there is a transition from Vocontian facies to the reef facies of the Urgonian, which occurs in a strip with biodetritic limestones in the region of Montagne de Lure and immediately to the south of Ventoux.

In the **Marseilles region**, where the Urgonian facies is only in the Barremian, the Lower Aptian is built of slightly clayey limestones with ammonites (Bedoule — Cassis). A strip of biodetritic limestones indicating the proximity of the Durance vault is developed around this clayey-calcareous facies from Toulon to the Rauf tunnel, northwest of Marseilles.

Urgonian facies, developed northward from Vercor, reappears to the north of the Vocontian trough in the Northern Subalpine Ranges and in Jura Mountains. The Urgonian limestones are intercalated by marls and sandstones with Orbitolinidae. The Gargasian usually comprises the upper Orbitolinidae beds and part of the so-called "Lumachelle of the Gault" which belongs to the Clansayesian.

In the southeastern part of the Paris Basin the Aptian manifests interesting facies which mark the progress of the transgression to the northwest.

In the **Alps** this Stage probably comprises the upper part of the Urgonian complex, which is entirely dated to the Barremian by most Swiss and French geologists. At Lutier Zug, close to Wolfenschissen, the Urgonian is followed above by condensed beds in which Gargasian and Clansayesian ammonite zones are established.

Core limestones and clayey-calcareous shales are dated to the Aptian in the Puez Alps.

In **Hungary** the Aptian is known in Gerecse (Tata area), Vertes and Bakony, where clayey-sandy and calcareous sediments are represented.

In the **Moravian-Silesian Beskydy** the Stage is connected with the Hradište sandstones and with the Veřsovice (Wierzowice) Beds, which are also traced in the flysch zone of the **Polish Carpathians.** In the Pieniny group the Aptian comprises part of the Urgonian limestones with rudists. This facies is developed in the Polish Tatras as well.

In the **Soviet Carpathians** the Aptian is connected with the upper part of the terrigenous-carbonate complex which also includes Urgonian limestones.

The Aptian in the **Eastern Carpathians in Romania** is represented by terrigenous-carbonate flysch or by clayey-calcareous sediments with ammonites. The Gargasian and the Clansayesian correspond to the lower part of the Bucegi Conglomerates, Gargasian sediments being absent in some places.

Flyschoid sediments (Comarnic type) and Urgonian limestones are developed in the **South Carpathians.**

In the **Apuseni** the Aptian comprises the upper part of the Barremian-Aptian flysch which is rather coarse in some places.

In **Northern Dobrogea** the Lower Aptian is predominantly of littoral type, whereas the Middle and Upper Aptian are represented by limestones with ammonites, sandstones and claystones.

The Aptian in the **Crimea** is developed in clayey facies with cephalopods. In **Northern Caucasus** the Aptian sediments are clayey-marly and sandy, with rich ammonite faunas and great thickness (up to 3400 m).

To the south of the Main Caucasian Ridge, in **Georgia**, the Aptian sediments are predominantly clayey-calcareous with many ammonites. Urgonian limestones are developed in some places. Basic volcanism occurred in Caucasus Minor during the Aptian. The sediments are terrigenous-carbonate, being with Urgonian limestones in some places.

Aptian sediments in **Bulgaria** are very varied, but belonging to several basic types: terrigenous, terrigenous-carbonate, clayey-calcareous, Urgonian and Paraurgonian.

In **Eastern Serbia** and in the **Šumadia zone** the Lower Aptian is most frequently connected with Urgonian or Paraurgonian sediments, followed above by marls, limestones and sandstones. Powerful terrigenous sediments, in the Barremian-Aptian part of which there are lenses of Urgonian limestones, are developed in the southern part of the Šumadia zone.

In the **Dinarides** the Aptian is entirely connected with carbonate facies of Urgonian type.

Zoogenic limestones with rudists and dolomites are developed in the southeastern part of the **Apennines,** similar to the ones found in Sicily near Palermo.

In **Sardinia** the Aptian starts with limestones, silicified in some places, followed above by clayey limestones which pass into marls with flint. The Gargasian is represented by glauconitic marls and clayey limestones with flint, which pass into the Clansayesian as well.

In **Greece** the Aptian is present in the Ionic zone, in the Gavrovo, Pind and Vardar zones, where it is connected with limestones with algae, Orbitolinidae, corals and gastropods, in some places also with limestones containing radiolaria. Probably part of the slightly metamorphosed complex in the Southeastern Rhodopes and the ophiolite complex on Samothrace are of Aptian age.

The Aptian sediments in **Turkey** are exposed between Eskishehir, Zonguldak and Samsun in the northern part of the country, and between Ordu and Artvin in the eastern part. Marls with Orbitolinidae are developed in the first region, being covered by sandstones with ammonites. Glauconitic sandstones appear near Artvin.

Shales and limestones with Orbitolinidae are exposed in Southern Anatolia. An analogous facies is developed in Western Taurus as well.

In **Syria** and in the **Lebanon** the Aptian is represented at its base by sandstones, clayey sandstones, marls and limestones, which overlie continental deposits. Above them there are limestones and an alternation of limestones and sandstones. The Aptian sediments are rich in bivalvs, gastropods and echinids. This stage is not differentiated in Jordan, but it is connected with a continental sandstone formation which is developed in Negev as well.

In Northeastern **Iran** the Aptian comprises bathyal sediments (limestones and clayey marls) with cephalopods (Balambo Formation). To the west these sediments pass into neritic limestones in the Sarmord and Camshuka Formations.

To the south-southwest, towards the valley of the Tigris river, there are limestones, in some places clayey and with Orbitolinidae. Pelletic limestones and chalk-like limestones, passing upwards into shales, are widespread in the southernmost part, towards the Persian Gulf.

In **Saudi Arabia** the Aptian is entirely continental.

6. ALBIAN

This is the last stage of the Lower Cretaceous. Compared with the other stages, its distribution is the most limited, being connected with post-Aptian regression or with post-Albian denudation.

In the southern part of the North Atlantic, around the **Cape Verde Islands,** the Albian is connected with variegated clayey shales, slightly metamorphosed limestones and basalts. Black shales, with diabases in some places, are almost generally distributed in the north of the continental base. Opposite the Moroccan Meseta the Albian comprises the upper part of the flysch complex.

In **Tarfaya** only the Upper Albian is represented, being built of claystones, marls, siltstones and clayey limestones with many ammonites.

Marls rich in planktonic foraminifera are discovered in the **Agadir zone.** The formation of carbonate sediments among which the ammonites and the planktonic foraminifera disappeared, started during the Late Albian in the **Essaouira region.** In the allochthonous part of the Reef the Albian is represented by flysch sediments.

Continental sediments are developed in the **Sahara.** In the north, in the **High Plateaux** there appears a wide strip of terrigenous and terrigenous-carbonate neritic sediments, passing into flysch sediments which are extensively developed in the **Tellian Depression** and in the **Cabiles.**

A similar facial zonality is established in **Tunisia** as well, in the northern part of which pelagic clayey-calcareous sediments are developed, similar to the Hassi ben-Ziane Formation in Ouarsenis.

The Albian has limited distribution on the **Iberian Peninsula.** In the Subbetic Depression it is represented in flysch facies in the southwestern part, and by marly-sandy sediments with Orbitolinidae and partially with dolomites in the northern strip.

Shallow-sea limestones are developed in the Castilian zone and in Teruel province, whereas between Barcelona and Taragona there are marls with Orbitolinidae and rare ammonites.

In the **Pyrenees** the Albian sediments are very varied: predominantly carbonate in Corbière and partly in the Central Pyrenees, clayey-carbonate in the depression zone of the Central Pyrenees, and terrigenous in the Basco-Cantabrian region and in the Aquitanian basin. The Albian is represented by black shales in the outer continental margin of the Iberian Peninsula.

In the **Vocontian trough** the Albian is connected with black marls which are replaced in the south towards **Provence** by glauconitic sandstones, in some places with phosphorite concretions. Deeper-sea sediments with ammonites are again formed to the west of the Durance vault near Marseilles. They already belong to a bay in the Provence Basin and not to the Vocontian trough.

In the western part of the Vocontian trough, close to the Central Massif, there are glauconitic detritic limestones, marls and thin-bedded sandstones, which transgressively overlie the older basement.

In **Jura Mountains** the Albian deposits lie transgressively and are represented by glauconitic sandstones (Perte-du-Rhône and St. Croix).

The Albian in the **Paris Basin** is of clayey-sandy type.

In the **Alps** the Albian appears in several scattered outcrops. It is represented everywhere by clayey-sandy sediments with glauconite.

In **Czechoslovakia** and in the **Polish Carpathians** this Stage is represented by deep-sea sediments: black shales, silicified marls, variegated shales and radiolarites.

Flysch sediments are developed in the **Eastern Carpathians,** being covered in some places by polygenous conglomerates (Bucegi). A molasse-type sandstone-conglomerate complex is developed precisely in the Bucegi — Piatra Mare zone, whereas in the flakes zone there are shales, quartzitized and glauconitic sandstones, which pass into the Cenomanian as well.

In the **Southern Carpathians,** in the Reşiţa zone there are conglomerates, glauconitic sandstones and claystones (molasses); in the Sviniţa zone — polygenous silicified conglomerates with sandstones and shales (Arjana type).

Sandy-glauconitic sediments are developed in **Northern Dobrogea.**

Albian sediments are discovered in **Eastern Crimea** between the Theodosia region and Buruľča river. They are represented by black claystones with rare sandstone intercalations.Sandstones are developed in Southwestern Crimea (to the southwest of Alma river).

To the south of Simferopol, along Salgir river and around Partizanskoe village (Manguš) Albian sediments fill ingression valleys and contain gravels almost everywhere in their base.

In **Northwestern Caucasus** Albian sediments are known from the valley of Ubin river, where claystones are developed. In the east, along Pšiš river, the Albian is known from only one deposit (Mirnaja Balka), where only the Lower Albian is represented by claystones with siderite concretions and clayey calcareous sandstones. The Middle Albian is also exposed in the east, being built of black sandy claystones with marly intercalations.

In **Central and Eastern Caucasus** the Albian is connected with two lithological complexes. The lower complex corrosponds to the Lower Albian, while the upper one comprises the Middle and Upper Albian. The Lower Albian is represented almost everywhere by siltstones and claystones. The Middle and Upper Albian are built of claystones which are calcareous in most cases. Intercalations of marls also appear in the Upper Albian in some places (Dagestan). Bivalvs, echinids, gastropods, belemnites and more rarely ammonites are extensively represented.

In **Georgia** the Albian is built of tufogenic and glauconitic sandstones (Rača zone), with siltstones, tuffites and glauconitic sandstones found in some places (Okrib, Čerimel river).

Tufogenic sandstones, argillites and marls are discovered in **Caucasus Minor.**

In **Bulgaria** the Albian is represented by glauconitic sandstones, marls and mixed rocks.

In **Eastern Serbia** and in the **Šumadia zone** there are conglomerates, sandstones, glauconitic sandstones, sandy marls and in some places sandy limestones as well.

In the **Dinarides** the Albian is represented only by its lower substage in the Bosnia flysch and probably by its three substages in the carbonate complex.

This stage is not precisely differentiated in **Greece**, though it is probably present in some zones, especially where Lower Cretaceous radiolarite formations are developed.

In the east, in **Turkey**, Albian sediments are known in several separate deposits in glauconitic-sandy facies.

In the **Middle East** the Albian is most widespread compared with the other Lower Cretaceous stages. It is represented by clayey-sandy sediments, with intercalations of sandstones in some places. They contain many bivalvs, gastropods, echinids and more rarely ammonites. Continental terrigenous sediments are developed as well over considerable areas, mainly in the southern part.

V. EVOLUTION AND PALAEOBIOGEOGRAPHY OF THE EARLY CRETACEOUS MARINE ORGANISMS IN THE MEDITERRANEAN REGION

1. GENERAL NOTES

It is known that the International Stratigraphic Scale of the Mesozoic Erathema is elaborated on the basis of the evolution of ammonites. They correspond to the basic requirements for guiding fossils: (1) fast rates of evolution; (2) considerable horizontal distribution; (3) relative independence from the facies; (4) good state of preservation.

In fact, a number of other marine organisms have wider distribution than ammonites, but they manifest slower rates of evolution and therefore they may be used to identify zones of much greater duration than the ammonite zones.

The wide stratigraphic practice, especially over the past 20-25 years, has demonstrated the great stratigraphic significance of some other groups of organisms which permit detailed differentiation and division of the Lower Cretaceous: foraminifera, radiolaria, calpionellids, dinoflagellates, algae, nannoconus, bivalvs, echinids, brachiopods, etc.

Here we shall consider only the evolution of several groups of marine organisms which are widespread in the Lower Cretaceous and contribute most to the stratigraphic division and correlation of the series, of its individual stages and/or of definite types of facies (e. g. the widespread Urgonian facies). Moreover, we shall focus our attention only to those aspects of the evolution of these groups of organisms which are most essential for the formation of the palaeontological successions, and not to the problems connected with the phylogenetic relationships within the different groups.

In modern palaeontology there is a tendency to create the so-called **evolutionary species**, i. e. an opinion which develops separately from the others and which has its own consistent evolutionary role and its own tendencies. However, the shortcomings of the palaeontological chronography do not always make it possible to attain this goal. Therefore, in practice the species in palaeontology is morphospecies in many cases. The hiatuses in the vertical successions of the populations of organisms are a much more frequent phenomenon than the uninterrupted phylogenetic series.

2. MAIN FEATURES IN THE EVOLUTION OF THE EARLY CRETACEOUS MARINE ORGANISMS

Irrespective of the considerable regression which occurred over considerable areas in the Mediterranean Region at the end of the Jurassic, there is a gradual transition from the Jurassic to the Cretaceous world of organisms. An essential renovation is observed only among the molluscs, characterized by the disappearance of many Jurassic species and genera, and by the appearance of new taxa.

2.1. Microflora

Marine algae, which were such a flourishing group in earlier epochs, demonstrate a certain decline in the Early Cretaceous seas. Nevertheless, several groups play a considerable role in the Early Cretaceous marine ecosystems, namely: *Charophyta, Chlorophyta, Cyanophyta* and *Rhodophyta*.

Of particular significance for the stratigraphy of the Lower Cretaceous carbonate complexes are the representatives of the **green algae**: Dasycladacea and Codiacea, as well as some other algal groups (Маслов, 1956; Radojčić, 1960; Praturlon, 1964; Elliot, 1968; Бакалова, 1971-1976; Conrad, Peybernes, 1978; Jaffrezo, 1981).

Widespread Dasycladacea are: *Clypeina, Cylindroporella, Salpingoporella, Triploporella, Angioporella, Likanella, Acroporella, Suppiluliumaella, Acicularia, Neomeris, Heteroporella, Actinoporella,* etc.

Prominent among the Codiacea are: *Gayeuxia, Boueina, Arabicadium, Bacinella, Coptocampylodon, Thaumatoporella, Carpathoporella, Lithocodium, Marinella, Ehelia, Diversocalis,* etc., whose systematic status is not yet clear, demonstrate considerable development.

Charophyta are not of essential significance for the stratigraphy of the marine Lower Cretaceous, but with their help it is possible to differentiate well Wealdian facies.

Moreover, plant organisms connected with the algae participate in the structure of the carbonate rocks. These are above all different coccolithophorids and the **nannoplankton** associated with them, i. e. remains of organisms whose systematic status is not yet clear. They participate considerably in the Early Cretaceous plankton and are particularly varied in the pelagic facies of the Lower Cretaceous. Thierstein (1973) has generalized the main regularities in the nannofossils successions of the Lower Cretaceous.

Dinoflagellates are an important group in the Early Cretaceous microplankton, being at the boundary between the plant and animal kingdoms (Defrandre, 1935-1937; Eisenack, 1958; Gocht, 1958-1959; see references in Alberti, 1961). Dinoflagellate cysts occur in different types of rocks: limestones, claystones, flint concretions, outlining clear successions through rich associations.

2.2. Protozoa

2.2.1. Radiolaria

The radiolaria have a more limited distribution than during the Late Jurassic, though in the Early Cretaceous plankton there are numerous species of Spumellaria and Nasseilaria. In most cases they participate in the deposition of deep-sea radiolarites, but sometimes their development is connected with submarine volcanic activity and in such cases they may propagate to different bathymetric zones, including in the sublittoral.

2.2.2. *Foraminifera*

Foraminifera are among the most important Early Cretaceous groups of microorganisms, playing a great role both in rock-formation and for the stratigraphy of the series (B a r t e n s t e i n, 1962-1979; S i g a l, 1965; 1977; M o u l l a d e, 1966; К о в а ч е в а, 1968-1986, and others).

There are two important specificities in the evolution of the Early Cretaceous foraminifera: (1) the populations explosion of the so-called conic foraminifera — Orbitolinidae, whose root is in the Late Jurassic, and (2) the sharp increase in the planktonic *Globigerina*-like groups,which started during the Hauterivian and reached its maximum during the Aptian and Albian, in order to prepare the extensive development of *Globigerina* and the explosion of *Rosalina* during the Later Cretaceous (S i g a l, 1965).

2.2.3. *Calpionellids*

Calpionellids are the only group of organisms which competes with the chronostratigraphic significance of the ammonites. However, they are more general compared with the ammonites, therefore permitting detailed division and precise correlation (R e m a n e, 1963-1974; A l l e m a n n et al., 1971). Calpionellids are extremely widespread in the Mediterranean Region. The following genera outline characteristic successions in the Lower Cretaceous: *Tintinnopsella, Crassicollaria, Lorenziella, Calpionella, Remanniella, Calpionellopsis* and *Calpionellites*. They are most widespread in pelagic clayey-calcareous sediments, but they occur, although more rarely, among neritic clayey-carbonate rocks as well.

2.3. Some Invertebrates Metazoa

2.3.1. *Ostracoda*

The first considerable phenomenon in the evolution of the Early Cretaceous marine ostracods is the explosive development of the Trachyleberidinae populations with many species belonging to the genera *Cythereis, Isocythereis* and *Platycythereis*. *Protocythere* forms characteristic associations.

The following taxa form clear successions: *Protocythere*, Schuleridea, *Dolocythere, Cythereis, Cytherella, Centrocythere, Protocythere, Vaenia, Platycythereis, Neocythere, Xestoleberis, Bairdia, Monoceratina* and Cytherelloidea (D o n z e, 1958-1975; O e r t l i, 1965; D a m o t t e, 1965, 1979).

2.3.2. *Spongia and Coelenterata*

These are mainly facial organisms whose distribution is tied predominantly to neritic sediments. This is particularly characteristic of Ca-spongia and corals.

Si-spongia flourished on clayey and clayey-calcareous bottom, predominantly in deep-sea zones or in calm waters.

A characteristic feature of the Mediterranean Lower Cretaceous is the development of coral reefs. Single corals are also extensively developed.

Hydrozoa also take a considerable part in rock formation during the Early Cretaceous.

2.3.3. *Echinodermata*

The crinoids are widespread, but they play mainly a rock-forming role. The so-called spathic limestones in Jura Mountains, the Alps and the Carpathians are mainly built of crinoid members.

Echinids manifest a considerable upsurge in their evolution with the considerable spreading of the irregular sea-urchins which are tied mainly to the clayey-calcareous bottom. Most characteristic among them are Spatangoidea, genus *Toxaster* being the most frequent and represented by many species from the Valanginian to the Aptian.

A number of genera belonging to Disasteridae (*Cardiopelta, Collyrites, Disaster, Tithonia, Corthya, Dialaster* and *Acrolusia*) and to Toxasteridae (*Toxaster, Epiaster, Heteraster* and *Hemiaster*) outline successions in the Lower Cretaceous and are used for stratigraphic purposes. The most important change which the echinids undergo during the Early Cretaceous is the evolution of their apical apparatus, which is markedly elongated in the Berriasian to become gradually almost quadrangular during the Albian (D e v r i e s, 1965).

2.3.4. Brachiopoda

Irrespective of their extensive distribution in the Lower Cretaceous, brachiopods are less studied in this series than in the Jurassic. Indeed, their Early Cretaceous evolution manifests a certain decline, but careful investigations indicate that brachiopods form well-outlined successions which, although comprising greater intervals, may be used successfully in the Lower Cretaceous stratigraphy. In a generalization A l m e r a s (1965) has demonstrated clear brachiopod successions in the Lower Cretaceous of France and the neighbouring countries.

Pygope is a particularly characteristic genus for the deep-water facies. *Rhynchonella* and *Terebratula,* which define the appearance of the Early Cretaceous brachiopod ensembles, occur very frequently, as well as *Terebratulina, Magelanila* and *Terebratella* (K i l i a n, 1907-1913; С м и р н о в а, 1960; A l m e r a s, 1965).

2.3.5. Mollusca

Gastropoda occur frequently among Lower Cretaceous sediments, but few of their representatives are of interest to stratigraphy. Their evolution is characterized by slow rates and usually forms specialized species which are adapted to definite facies, most often carbonate or terrigenous-carbonate.

Most widespread are *Natica, Pleurotomaria, Nerinea, Bathrotomaria, Purpuroidea, Ampullina, Conotomaria, Tylostoma* and *Ampullospira,* which are tied to neritic facies (K i l i a n, 1907-1913; Д и м и т р о в а, 1974).

Bivalvia are one of the most widespread groups during the Early Cretaceous, with considerable systematic and morphological variety which competes with the cephalopods. However, they have slower rates of evolution, most of them are stenotopic and they are adapted mainly to neritic environment. Only genus *Nucula* occurs almost exclusively among the deep-sea Mediterranean sediments, whereas *Arca* and *Leda* are found less frequently.

Cucullaea, Arcomytilus, Lithophaga, Pinna, Propeamussium, Camponectes, Chlamys, Prohinnites, Hinnites, Pholadomya, Gonyomya, Arctica, Glossus, Pronoella, Veniella and *Venicardia* have considerable development. *Plicatula* occurs frequently among marl sediments.

Ostreidea are extremely developed: *Ostrea, Exogyra* and *Alectryonia* are frequent forms among the Early Cretaceous neritic faunas. In a number of cases they build entire calcareous packets (oyster banks), though they also occur among marl sediments in the peripheral part of the sublittoral zone and very rarely in deep-sea sediments.

Of the Bivalvia Family Trigonnidae flourished during the Early Cretaceous, moreover including both Mediterranean and cosmopolitan forms. They rapidly declined after the Cenomanian. Owing to its relatively faster evolution, this family forms characteristic succesions of great stratigraphic significance (G i l l e t, 1965).

In the northern province of the Mediterranean Region there occur species belonging to genus *Aucellina*, which are immigrants from the Boreal area.

Genus *Aucellina*, which is a dominant genus in the Bivalvia ensembles of the Volga province, has a considerable distribution among the other Bivalvia in the Late Aptian and Albian.

The representatives of genus *Inoceramus* mark two evolutionary lines during the Early Cretaceous: with radial ribs (*I. sulcatus*) and with concentric ornamentation (*I. concentricus*), and they are frequent forms among Albian sediments.

Particularly interesting is the evolution of suprafamily Hippuritacea (pachyodonts or rudists) which are a dominant group among the carbonate reef facies of the Mediterranean Cretaceous. More than 100 rudistid genera are known, whose ancestor is the Late Jurassic genus *Diceras*.

The rudists outline four well differentiated successions (D o u v i l l é, 1935; C o o g a n, 1969):

1. Neocomian rudists represented by the last diceratids, the first monopleurids and early *Requienia*.
2. Barremian-Aptian (Urgonian) rudists whose association is formed by the genera *Requienia* and *Toucasia* (predominating), *Monopleura, Praecaprina* and *Offneria,* as well as early representatives of Caprinidae and Radiolitidae.
3. Upper Aptian-Albian rudists (sometimes designated as Urgo-Aptian). They are characterized by a number of species belonging to *Toucasia, Polyconites* and *Horiopleura*, among which there are species from the earlier levels. The first sharper increase in the populations of Radiolitidae is noted at this level.
4. Rudists are most widespread from the Cenomanian to the end of the Late Cretaceous. Moreover, they form very clear successions of great stratigraphic significance.

The Early Cretaceous evolution of the **belemnites** forms clear successions of great stratigraphic significance (K i l i a n, 1907-1913; С т о я н о в а - В е р г и л о в а, 1964, 1970; C o m b e m o r e l et al., 1981).

The first association taking shape in the Early Cretaceous (Berriasian-Valanginian) is characterized by few belemnites, mainly from the genera *Duvalia* and *Hibolites*.

The Hauterivian in the entire Mediterranean Region marks a clear cladogenesis in the belemnite evolution with wide radiation of many species belonging to *Hibolites* and *Duvalia,* single *Curthohibolites* and *Conobelus,* and rare *Pseudobelus.*

The Barremian is characterized by the mass development of *Mesohibolites* and *Curthohibolites. Hibolites* and *Duvalia* continue their development. Immigrants from the Volga province occur in the northern province of the Mediterranean Region.

Mesohibolites are the predominant group among Early Aptian belemnites as well, being diversified by the appearance of genus *Neohibolites* which determines the character of the Upper Aptian and Albian belemnite faunas. Genus *Parahibolites* appeared during the Late Albian and individual species from this genus continued during the earliest Cenomanian.

Ammonites are extremely varied in the Mediterranean Early Cretaceous. Their evolution forms clear successions which permit most detailed division of the series.

The Berriasian is characterized by the wide adaptive radiation of Berriasellidae, which are accompanied by Olcostephanidae, Lytoceratina and Phylloceratina. In the northern province there are immigrants from the family Craspeditidae, coming from the Volga province.

The Valanginian ammonite faunas are enriched by new families of Berriasellidae (explosion in Neocomitinae), appearance of Oosterellidae and Olcostephaninae, diversification of Bochianitidae and early Ancyloceratinae.

The Hauterivian marked a new stage in ammonite evolution with the mass development of Ancyloceratidae (*Crioceratites, Balearites, Aspinoceras* and *Menuticrioceras*), flourishing of late Neocomitinae (*Lyticoceras, Neohoploceras, Acanthodiscus, Eleniceras, Karakaschiceras, Leopoldia* and *Suboosterella*), early Desmoceratidae (*Eodesmoceras, Subsaynella* and *Valdedorsella*), early Holcodiscidae (*Spitidiscus, Plesiospitidiscus* and *Astieridiscus*) and rare immigrants from the Volga province (*Endemoceras, Distoloceras, Speetoniceras, Dichotomites* and *Neocraspedites*).

The ammonite evolution at the beginning of the Barremian marks a new stage: extensive cladogenesis of Pulchellidae, Hemichoplitidae and Desmoceratidae, and mass explosion in the Barremitinae populations. Together with Phylloceratina and various Lytoceratina, they determine the appearance of the Barremian ammonite faunas.

Aptian ammonite faunas are outlined with the appearance of new families: Parahoplitidae and Cheloniceratidae, the disappearance or the strong reduction of some phylla known during the Barremian (Hemiholitidae, Crioceratidae and Pulchelliidae) and the diversification of Desmoceraceae (Aconeceratidae), accompanied by different Lytoceratina and Phylloceratina.

The Albian marks the penultimate peak in the Cretaceous ammonite evolution (the last peak is at the beginning of the Cenomanian).

Albian ammonite faunas are extremely varied. Together with Phylloceratina and different Lytoceratina (mostly Tetragonitidae and Turrilitidae), there also appear Leymeriellidae, Douvilleiceratidae, Hoplitidae, Brancoceratidae and Lyelliceratidae; Desmoceratidae *(Puzosia, Beudanticeras* and *Desmoceras)* are extensively developed.

Concluding this brief survey on the development of the Early Cretaceous marine organisms, which does not include vertebrates due to scanty finds, it is necessary to emphasize the following: the modern research approach requires a complex analysis of the data which may be obtained from all fossil groups. Indeed, the fast rates of evolution and the intensive cladogenesis of some organisms determines their great significance for the chronology. However, chronology is not the only task of stratigraphy.

The history of the investigation of the different fossil groups has shown that some of them, which were neglected earlier, proved to be of great stratigraphic significance in the widest sense of the term (e. g. nannofossils, calpionellids, ostracods, dinoflagellates, algae, etc.).

3. PALAEOBIOGEOGRAPHY OF THE EARLY CRETACEOUS

3.1. Starting Principles

The geographic distribution of the organisms depends on a number of factors, among which the climate is the most essential. There is a close connection between the geographic distribution and the ecological factors: currents, character of the bottom, bathymetry, sedimentation features, presence or absence of barriers, relationships with other organisms, trophic relations, etc.

Migration is a characteristic feature of all organisms. Together with natality and lethality, it is one of the most important elements determining the growth of the populations and their density.

Once emerging in an area, every species can migrate to other regions. This depends on the concrete conditions and on the mobility, which is different for the various groups of organisms. It is known that 70 per cent of the sea benthonic invertebrates have pelagic (planktonic) larval stage of development, which guarantees to them a possibility for rapid and wide migration by means of the ocean currents. This is why, many Early Cretaceous benthonic organisms (e. g. a number of gastropods, bivalvs, echinids and Orbitolinidae) may be found from one end to the other of the Mediterranean Region. Consequently, the stratigraphic significance of the species is determined not by the rate of their migration, which is considerable, but by the rate of their evolution, which depends on many genetic and ecological factors.

3.2. Ammonite Provincialism during the Early Cretaceous

Today it is considered an unanimous opinion that the biogeographic boundaries of the different groups of organisms do not coincide. Moreover, the lower the rank of the palaeobiogeographic category, the greater the differences in the boundaries according to the various groups.

Therefore, we shall discuss only the ammonite distribution during the Early Cretaceous, which traces the basic lines of Early Cretaceous palaeobiogeography. Naturally, it is possible to add to this many interesting data about the belemnites, foraminifera and rudists, which introduce remarkable features in the panorama of Early Cretaceous life in the Mediterranean Region.

The ammonite distribution at the beginning of the Early Cretaceous bears the main features of the Tithonian ammonite provincialism. Together with this new features are imposed, changing the configuration of the areas and especially of the provinces.

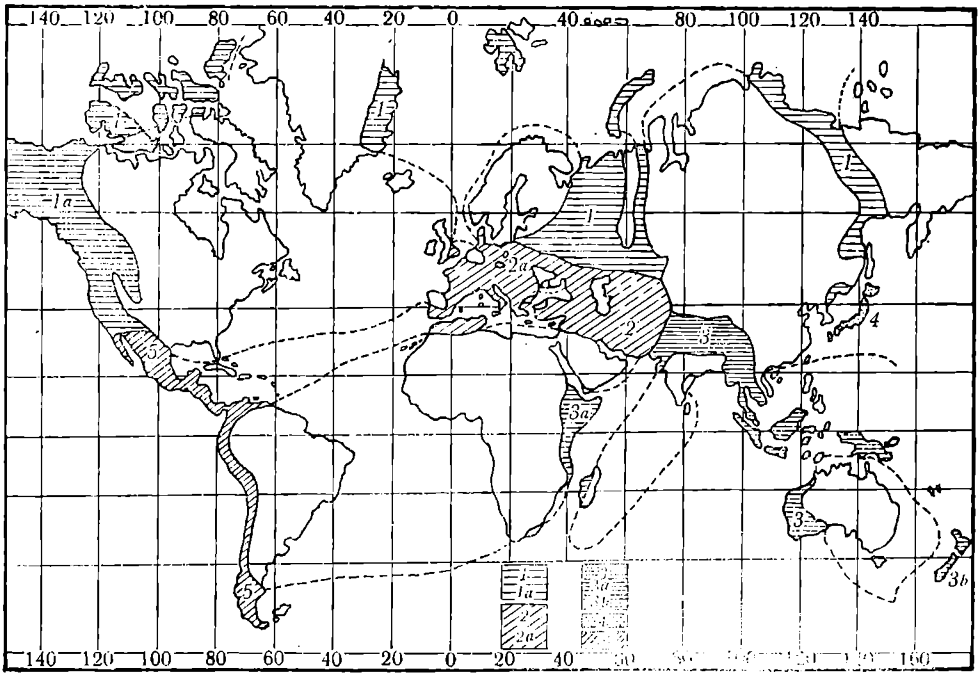


Fig. 23. Faunistic provinces during the Late Jurassic and Early Cretaceous (after Uhlig, 1911)
1 — Boreal Realm; *1a* — Northern-Andean Province; *2*—Mediterranean-Caucasian Realm; *2a* — neritic marginal zone; *3* — Himalayan Realm; *3a* — Ethiopian Subprovince; *3b* — Maori Subprovince; *4*—Japanese Province; *5* — Southern-Andean Realm

U h l i g (1911) proposed the following division of the sea realms for the Late Jurassic-Early Cretaceous (Fig. 23):

1. Boreal Realm, including also the Northern Andean Province.
2. Mediterranean-Caucasian Realm in which a northern "peripheral neritic zone" is outlined.
3. Himalayan Realm with the following subprovinces: Himalayan, Ethiopian and Maori.
4. Japanese Province.
5. Southern Andean Realm.

The new studies on the Early Cretaceous faunistic distribution, and especially of ammonites, have changed U h l i g' s idea in many respects, although the outlines of some of his provinces are preserved. As A r k e l (1956) has pointed out, the basic shortcoming in the reconstructions of N e u m a y r (1883) and U h l i g (1911) is the lack of a clear historical approach. This approach, applied in more modern research, demonstrates a developing palaeobiogeographic panorama. It is diversified by the emergence of different geographic barriers which isolate the populations of the different regions, and, if these barriers are longer-lasting, they result in a complex provincial differentiation. In such cases it may be assumed that the changes in the faunas are the result of evolution influenced by the geographic isolation.

An example in this respect may be the isolation of the Mangislak Basin by the emergence of a land barrier to the east of the Caucasus. This barrier played an important palaeobiogeographic role during the Early Cretaceous and contributed to the development of specific faunas in Mangislak and Turkmenia, with many endemic elements and immigrants from the Boreal Basin. Consequently, geographic isolation results in differentiation and formation of endemic faunistic associations.

The palaeobiogeographic environment develops also on the basis of the ammonite distribution and it is possible to distinguish two main intervals: Berriasian-Barremian and Aptian-Albian, with certain fluctuations within them.

The Barremian marks a natural boundary in the changing picture of the ammonite distribution. Until the end of this Age the ammonite biogeography bears the features of the model formed during the Late Jurassic, whereas essential changes in the palaeobiogeographic panorama were imposed after the Barremian. These changes are connected with substantial alterations in the distribution of the dry land and shelf seas (R a w s o n, 1980).

The beginning of the Early Cretaceous indicates bipolarity in the ammonite distribution outlined during the Late Jurassic (E n a y, 1972). The Tethys Ocean occupied a median position in the Earth's hydrosphere, developing in subequatorial direction between the two basic continental masses. To the north is the Boreal, to the south — the Perigondwana Basin.

The development of the Perigondwana Basin as a palaeobiogeographic belt (realm) is disputed by some authors, but it is supported not only and not so much by the ammonite horology, as by the distribution of the Early Cretaceous belemnites (S t e v e n s, 1973), bivalvs (K a u f f m a n, 1973) and other groups of invertebrates.

The Mediterranean Region occupies the central part of the Tethys Ocean, starting from the southern part of the North Atlantic Ocean and continuing in the east to the Caspian Sea.

A number of authors (e. g. W i e d m a n n, 1982b) expand the Mediterranean Region through the Caribbean Basin in the southwest to Peru. The Berriasian ammonite faunas of Peru, Central Argentina and Patagonia contain many endemic genera, which is the base for the differentiation of a common Caribbean-Andean area with two provinces: Caribbean (Mexico, Cuba and probably California), where there are Tethys genera (*Lytoceras, Phylloceras, Silesites* and *Desmoceras*) and Boreal forms (*Polyptychites* and *Simbirskites*), and Andean (Peru, Argentina and Patagonia).

On the other hand, some authors (R a w s o n, 1980) expanded Uhlig's Mediterranean-Caucasian area so as to include the Himalayan Province as well. This

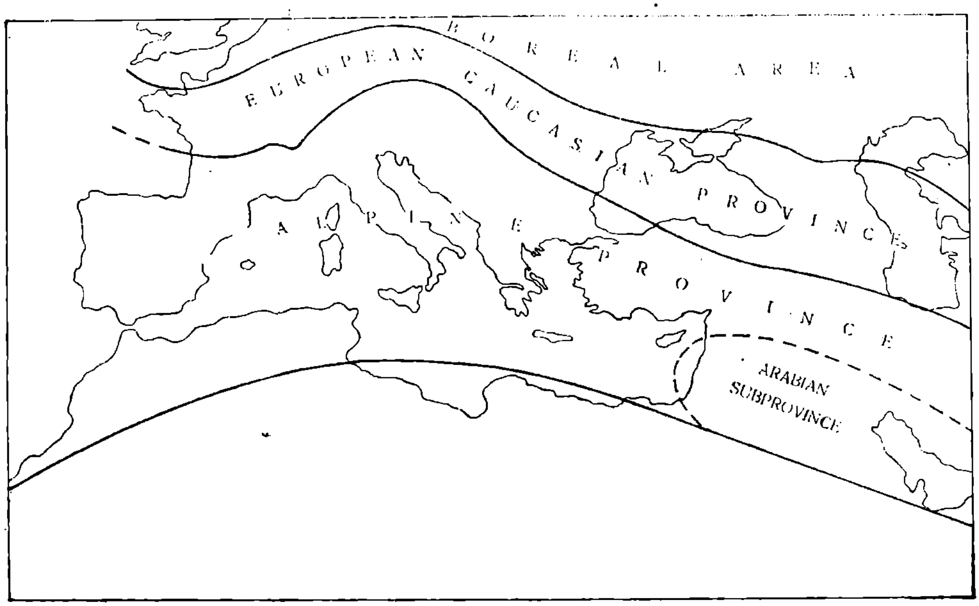


Fig. 24. Ammonite provinces in the Mediterranean Region during the Berriasian-Barrrremian

is not justified, because associations began to be imposed to the east of the Caspian Sea and Iran, whose similarity coefficient with respect to the Mediterranean Region is between 55 and 70 per cent. This is why, U h l i g's Himalayan Realm has the right to independence, evidently with the rank of an area in the Tethys. Thus, the Mediterranean Region appears to be a relatively homogeneous palaeobiogeographic area from the Berriasian to the Barremian inclusive, with the following provinces (Fig. 24):

1. Alpine Province. It is designated by this name in the present monograph in order to avoid tautology with the name "Mediterranean Province" used by some authors. This is the central province of the Mediterranean Region, comprising *grosso modo* the two branches of the Alpine orogenic belt from the Atlantic Ocean in the west, including Northwestern and North Africa, the Iberian Peninsula, the Pyrenees, the southernmost part of France, the Alps, the Pannonian Massif, the Dinarides, the Hellenides, the Southeastern Rhodopes, Turkey, to Iran in the east.

In this Province the ammonite faunas are very homogeneous, predominantly of the deep-sea type, accompanied by extensive development of planktonic foraminifera, calpionellids and radiolaria.

The Alpine Province comprised the deepest zones of the Mediterranean Region.

The Arab Subprovince (or region) is differentiated in the eastern part of the Alpine Province. It is characterized by the predominant development of continental sediments during the Berriasian-Barremian and neritic deposits with many endemic species during the Aptian and Albian. The Subprovince comprises the lands from the Middle East to the Persian Gulf.

2. The European-Caucasian Province spreads to the north of the Alpine province. It is designated by Uhlig as "peripheral neritic zone", but this name is not accurate. Some authors designate it as Submediterranean Province. It has Mediterranean faunas, but with some Boreal immigrants which occur more in the Paris Basin, Jura Mountains, in the northeastern part of Southeastern France, the southern part of the Federal Republic of Germany, the Crimea and the Caucasus. The Šumadia region, Eastern Serbia, the Carpathians and the Balkanides are in the buffer zone between the Alpine and the European-Caucasian Provinces, and although they are characterized by typical Mediterranean faunas, they also contain rare Boreal immigrants. This is why, these territories should be considered as the southernmost part of the European-Caucasian Province.

A common feature for both provinces in the area is the development of Urgonian sediments which represent a typical Mediterranean biofacies with rudists, corals and large foraminifera.

3.2.1. Berriasian-Barremian Ammonite Horology in the Mediterranean Region

During the entire Early Cretaceous the ammonite faunas in the Mediterranean Region were formed by Phylloceratina, Lytoceratina and Ammonitina. Moreover, Phylloceratina and Lytoceratina are typically Tethys inhabitants, although they sometimes reached Greenland with considerable populations.

The distribution of Ammonitina provides especially important data about the ammonite provincialism. The heteromorph ancyloceratids are an interesting group. Their fast evolution starting during the Tithonian resulted in colonization of all Early Cretaceous basins in the area. Moreover, these ammonites are well represented in the Boreal Belt as well, where they sometimes replace the ammonites with normally curved shell.

Perisphinctaceae are most widespread among Ammonitina, coming with large phylla from the Late Jurassic. Together with them, different Hoplitaceae whose earliest representatives (Eodesmoceratidae) appeared during the Valanginian, began to be imposed gradually but convincingly.

The Berriasian ammonite faunas in the area are characterized by the wide adaptive radiation of Berriasellidae and Olcostephanidae (Spiticeratinae). Their representatives are dominant in the ammonite associations in the two provinces of the area. The abundance of the genera *Berriasella, Fauriella, Jabronella, Tirnovella, Malbosiceras, Neocosmoceras, Dalmasiceras* and *Spiticeras* becomes apperent. Generally speaking, Berriasian ammonite faunas have a rather homogeneous composition in the entire area. Some particular specificities in their horology are imposed mainly by the influence of local factors, above all by the bathymetric differentiation in the basin and/or by the influence of the sedimentation environments. A characteristic example in this respect is the distribution of *Pomeliceras* (*Pomeliceras*) and some large *Spiticeras* which are particularly widespread in neritic biotopes with terrigenous-calcareous sedimentation, unlike *Pomeliceras* (*Mazenoticeras*) whose representatives occur mainly in pelagic biotopes.

During the Berriasian the Crimean-Caucasian Basins were well connected with the Volga Basin from where Boreal genera such as *Riasanites* and *Surites* penetrated. And whereas *Riasanites* is a branch of the Mediterranea berriasellids, which flourished in the Boreal Belt, *Surites* is of purely Boreal origin. Another berriasellid ammonite — *Euthymiceras* — migrated from the Mediterranean Region into the Boreal Basin. The typical endemic genus *Tauricoceras* is also developed in the Crimean-Caucasian Region.

Immigrants from other provinces occur in the region, e. g. *Spiticeras* and *Himalayites* from the Himalayan Province, *Pseudargentiniceras, Corongoceras* and *Parapallasiceras* from the Andean Province, etc.

A number of Mediterranean berriasellid species (*Berriasella, Fauriella, Jabronella, Neocosmoceras* and *Dalmasiceras*) are also known from the Himalayas, Madagascar, Central and South America. *Malbosiceras* and *Tirnovella* have been found in Madagascar as well.

Pomeliceras, Mazenoticeras, Delphinella and *Subalpinites* are endemic Mediterranean species.

Leptoceras and *Bochianites* are developed among the heteromorphs (in both provinces), while *Protancyloceras* occur only in the Alpine Province (Tunisia and Southeastern France).

Valanginian Mediterranean faunas continue to be characterized by berriasellids, accompanied by Olcostephanidae, Phylloceratina and Lytoceratina.

The representatives of *Thurmanniceras, Kilianella, Neocomites, Sarasinella, Busnardoites* and *Lupovella* determine the appearance of the Valanginian faunas in the area. In addition to them, various olcostephanids become prominent, especially *Olcostephanus*, which had two explosive propagations during the Valanginian, clearly marked in France, Jura Mountains and FRG (K e m p e r et al., 1981). *Saynoceras* occur in the Mediterranean Region, in FRG and Mexico, *Valanginites* — in Bulgaria and Southeastern France, *Dobrodgeiceras* — in Bulgaria, Southeastern France and Peru.

Heteromorphs have a more limited distribution during the Valanginian. *Himantoceras* is known in Southeastern France and Bulgaria; *Bochianites* is most widespread and its individual specimens have reached Eastern Greenland in the north (R a w s o n, 1980).

Extensive migration of Boreal ammonites into the Mediterranean Region took place during the Valanginian. They occur more frequently in the European-Caucasian Province (R a w s o n, 1980), though some of them penetrate also considerably further south into the Alpine Province. Great invasion of Boreal species took place in the northeastern part of Southeastern France and Jura Mountains, on the one hand, and the Crimean-Caucasian Region, on the other. *Delphinites, Paquiericeras, Julianites, Paratollia, Polyptychites, Prodichotomites, Dichotomites, Neocraspedites, Simbirskites* and *Craspedites* are discovered in Southeastern France (T h i e u l o y, 1977). *Polyptychites, Dichotomites* and *Neocraspedites* occur in the Crimea and the Caucasus.

Of particular interest is the spreading of *Platylenticeras* which is considered by many authors to be a Tethys branch settled and flourishing in the Boreal Belt. There are some species belonging to this genus which reached Algeria via Southeastern France and Spain. *Dicostella*, which is of Boreal origin, is well developed in Southeastern France. Different Neocomitinae migrated from the Mediterranean Region to the north into the southern provinces of the Boreal Belt. Consequently, closer contacts existed during the Valanginian between the Boreal and Mediterranean Basins, which facilitated the migration of the faunas. There was not only considerable invasion of Boreal ammonites into the Mediterranean Region, but the opposite process as well, i. e. penetration of Mediterranean taxa into the Boreal Provinces.

Similar contacts existed with neighbouring provinces in the Tethys Belt as well (Himalayan, Malgasian and Andean). Thus, the relatively sharp palaeobiogeographic boundaries observed during the Berriasian disappeared during the Valanginian, giving way to more gradual transitions.

The Hauterivian ammonite faunas in the Mediterranean Region include varied heteromorph genera (*Crioceratites, Balearites, Pseudothurmannia, Aspinoceras,* *Aegocrioceras* and *Menuticrioceras*), late Neocomitinae (*Neohoploceras, Acanthodiscus, Lyticoceras, Eleniceras, Karakaschiceras, Leopoldia* and *Suboosterella*), early Desmoceratidae (*Eodesmoceras, Subsaynella* and *Valdedorsella*), early Holcodiscidae (*Spitidiscus, Plesiospitidiscus* and *Valdedorsella*), Osterellidae and Olcostephanidae. These genera are represented by many species in both provinces of the area. In the Alpine Province there are some endemic taxa (*Breitstrofferella*).

A strong Boreal influence continued to be felt during the Hauterivian in the northern European-Caucasian Province, this influence being particularly pronounced in the Crimea and in North Caucasus. Boreal genera were widespread in the North-Caucasian Hauterivian Basin, among which *Speetoniceras, Simbirskites* and *Craspedodiscus* reached mass flourishing which guaranteed a dominating position for them with respect to numbers and variety over the Mediterranean species (Друщиц, Кудрявцев, 1960).

Some genera, e. g. *Lyticoceras, Endemoceras, Distoloceras* and *Acanthodiscus*, which are of Mediterranean genealogy, are widespread in the northern province of the Mediterranean Region and in the southern provinces (Northwest-European and Volga Provinces) of the Boreal Belt. Some of them even manifest considerable cladogenesis in the Boreal Basins (*Endemoceras* and *Acanthodiscus*).

Strong affinities exist with the Malgasian and Andean Provinces. For example, heteromorphs are very well represented in Madagascar and Argentina, which indicates the period of their greatest expansion in the Tethys, coinciding with the middle of the Hauterivian.

Barremian ammonite faunas in the Mediterranean are of a more homogeneous character, and it is difficult to distinguish the two provinces from the previous ages. Moreover, the Boreal invasions are felt only in Northern Caucasus and partially in the Crimea. The character of Barremian ammonite faunas is determined by the almost general distribution of late *Crioceratites, Acrioceras, Paracrioceras, Pseudothurmannia, Hamulina, Anahamulina, Hemicrioceratites, Leptoceratoides, Toxoceratoides, Audouliceras, Heteroceras, Hemihoplites* and *Matheronites*, as well as varied Barremitinae, *Torcapella, Holcodiscus, Spitidiscus, Astieridiscus, Silesites, Pseudosaynella, Heinzia, Nicklesia, Pulchellia, Subpulchellia* and *Abritusites*.

The variety among Barremian ammonites is considerably greater than during the previous two Ages. It is comparable only to the Berriasian, but even in comparison with this age during the Barremian there was a considerably greater generic differentiation, especially among heteromorphs.

There are grounds for assuming (Котетишвили, 1978) that bathymetric factors and the character of the sedimentation environments had a strong influence on the distribution and diversity of the Barremian ammonites (and not only Barremian), though this is most marked among them.

Characteristic Barremian ammonites, such as *Colchidites, Emerites* and *Eristavia*, emerged in the Transcaucasian basins of Georgia, spreading from there to the entire Mediterranean Region. In addition to Georgia, these ammonites are particularly abundant in Northeastern Bulgaria, Romania and Southeastern France.

Barremites, Pulchellia, Nicklesia, Holcodiscus, Silesites and *Hemihoplites* stand out among Barremian ammonites with their extensive distribution. Most of these genera are known from Japan, throughout the entire Tethys Region to Central and South America, but they avoided Boreal waters.

Boreal immigrants: *Simbirskites, Speetoniceras* and *Craspedodiscus*, are found in the northern part of the Mediterranean Region (mainly in the Crimea and Northern Caucasus).

Generally speaking, the distribution of Barremian ammonites in the Mediterranean Region manifests a decrease in generic diversity from south to north, so that in the northernmost part of the European-Caucasian Province there are more heteromorphs, whereas ammonites with normally curved shell are very rare. According to data reported by R a w s o n (1980), approximately 50 per cent of the Barremian ammonite genera in Southern Europe are heteromorphs, in Northwestern Europe — 75 per cent, in Arctic Canada — 83 per cent.

Soviet biostratigraphers in the Crimea and in the Caucasus have found extremely rich faunas of Mediterranean type, but with many Boreal genera (*Riasanites, Simbirskites, Speetoniceras* and *Craspedodiscus*), as well as endemic species, e. g. *Tauricoceras* (filiation of *Riasanites*), *Auritina* and *Epacrioceras*, the Central Asian *Turkmeniceras* and *Transcaspiites*, etc.

K o t e t i š v i l i (К о т е т и ш в и л и, 1982) has made a very detailed analysis of the Caucasian ammonite spectra, but it is surprising that in her conclusions she has included the Caucasus in the so-called Eastern Mediterranean Subregion (for the Valanginian and Hauterivian). K o t e t i š v i l i has demonstrated that the similarity coefficient within the Caucasian Basin (Northern Caucasus and the Transcaucasian Region) is 77-100 per cent. In this case, however, the statistical evidence is not only and not so much important, as the essential dynamic specificities in the ammonite populations of the Caucasian Lower Cretaceous, which was formed in a basin — part of the Tethys, but open through Caspia to the Boreal Basin.

3.2.2. Aptian-Albian Ammonite Horology in the Mediterranean Region

Since the beginning of the Aptian, ammonite distribution manifested considerably greater homogeneity, without intraprovincial differentiation in the region until the Middle Albian. In this interval (Aptian-Early Albian) the Mediterranean Region was well outlined mainly by the development of reef facies with corals, rudists and benthonic foraminifera. With respect to ammonites, however, there is no boundary — even as a wide transitional zone — between the southern part of the Boreal Belt and the Mediterranean Region.

R a w s o n (1980) has pointed out that *Deshayesites* — one of the most characteristic Early Aptian ammonite genera — is found throughout the entire Mediterranean Region, as well as in the Boreal Belt from Pečora to Eastern Greenland and the Arctic, whereas *Tropaeum* — a heteromorph genus which occurs more rarely in the Mediterranean Region — moved northwards to Spitzbergen and Arctic Canada.

The two main ammonite families — Parahoplitidae and Cheloniceratidae — which form the appearance of the Aptian ammonite faunas, are common to the Boreal and Tethys Belts. The differences between these two belts are seen at generic level, moreover with respect to such genera as *Toxoceratoides, Pictetia* and *Uhligella*, which are known mainly from the Mediterranean Region (Europe and Africa). It is necessary to add to them also *Prodeshayesites, Megatyloceras* and *Roloboceras*, which are known only in Europe and the Transcaucasian Region.

The generic composition of the Aptian ammonite faunas in the Mediterranean Region is richer compared with the Barremian, though with considerably fewer endemic genera. Most of the taxa from the generic group are common with adjacent provinces of the Tethys and the Boreal Belt. The Mediterranean Region is individualized by the spreading of some endemic species and mainly by the development of reef facies.

The Aptian model in ammonite chorology is preserved along general lines during the Early Albian as well.

The Middle Albian marked the beginning of a new and essentially different ammonite differentiation, which continued during the Late Cretaceous as well

(R a w s o n, 1980). The boundary between the Tethys and the Boreal Realms is very smooth and a number of Boreal species penetrated in the south. This sharp change in the palaeobiogeographic picture is the result of the Austrian folding in the Mediterranean Region and the subsequent great Middle Cretaceous (Albian-Cenoma-

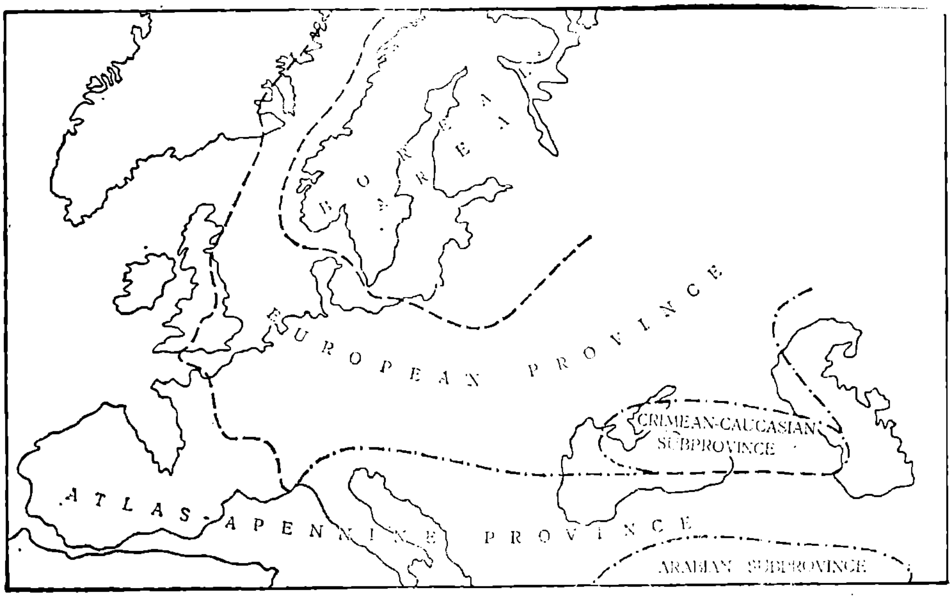


Fig. 25. Ammonite provinces in the Mediterranean Region during the Albian

nian) transgression. Ammonite faunas disperse widely and therefore the palaeobiogeographic provinces and regions lose their character of subequatorially oriented belts. This is particularly valid of the wide **European Province** (Hoplitinid faunal Province — O w e n, 1973), which is defined by the predominant development of Hoplitinae. This province comprises the Anglo-Paris Basin and the entire European-Caucasian Province from the Berriasian-Barremian (Fig. 25).

The Atlas-Apennine Province stretches to the south of the European Province. It is characterized by the presence of many Gondwana species (*Knemiceras, Forbesiceras, Flickia, Manuaniceras,* etc.). This province comprises the Middle East as well (Arabian Subprovince).

There seems to be no justification for differentiating the Crimean-Caucasian Basins into an independent province during the Albian, as assumed by K o t e t i š v i l i (К о т е т и ш в и л и, 1982). From the works of R e n g a r t e n (Р е н г а р т е н, 1951), E r i s t a v i (Э р и с т а в и, 1960), D r u š č i c and M i h a j l o v a (Д р у щ и ц, М и х а й л о в а, 1966) it is known that there are relatively few ammonites among the Albian sediments in this region, but the main Albian genera occur, including Hoplitinae, although they are more scarce. Thus, the **Crimean-Caucasian Albian Basins** should be assumed to be a **subprovince**, i. e. a transition from the European to the Mangislak-Turkmenian Province which is characterized by many endemic genera (*Vnigriceras, Bellidiscus, Anadesmoceras, Karamaiceras* and *Gasdaganites*).

A similar endemism in the Albian ammonites is found on the western coast of Africa and in Brasil (*Elobiceras, Neokentroceras,* etc.) (R a w s o n, 1980).

3.2.3. Main Factors of the Ammonite Ecology

Since ammonites are a predominantly nektonic group, many researchers assume even now that they do not depend on the facies. Indeed, most ammonites are relatively independent of the facies, but as shown by the studies of S c o t t (1940), Z i e g l e r (1967) and others, many ecological factors control the distribution and the way of life of ammonites. Their wide adaptive radiation has resulted in great systematic and morphological variety, though definite morphological types manifest affinity to concrete biotopes. This demonstrates the influence of the ecological factors.

1. Depth. Such important factors as light, pressure, temperature and nutrient resources are connected with the depth. Usually the smooth involute forms, e. g. *Phylloceras, Silesites, Subsaynella,* etc., are capable of considerable vertical movements, therefore they can be found in both neritic and pelagic sediments. However, some groups, such as the large *Ancyloceratina,* large Deshayesitidae, *Douvilleiceras,* etc., do not transcend the boundaries of the neritic zone.

Bathymetric control does not influence essentially the ammonite differentiation, but in combination with other factors it affects ammonite distribution. This may explain the difference in the ammonite spectra in the Barremian of Northeastern and Northwestern Bulgaria. A neritic biotope with clayey-calcareous bottom and extremely rich trophic resources is developed in Northeastern Bulgaria. This is the reason for the exceptional flourishing of ammonite faunas, including large vagile-benthos forms. Such a biotope also exists in Southeastern France, in Montagne de Lure, as well as in Ardèche, the Crimea and Georgia, where the ammonite association is the same, whereas bathyal biotopes with sludge bottom and more scanty food resources are developed in Northwestern Bulgaria and in the Vocontian trough.

It should be pointed out that ammonites occur most frequently in the neritic zone at a depth exceeding 40 m, and in pelagic sediments mainly from the bathyal zone. In the Mediterranean Region no ammonites have been found in abyssal sediments, which is probably connected with the influence of the calcium carbonate compensation.

2. Temperature. It is a basic factor for the ammonite differentiation. Different definitions of $\rho\,^{18}O$ indicate an average of 20-22°C for the European-Caucasian Province, and 27.7-28.1°C for the Alpine Province (according to data from Albian belemnite rostrums from the High Alps) (B o w e n, 1961; T e i s et al., 1975). Irrespective of the temperature maximum during the Albian Age, which is doubtful, the Early Cretaceous was always with a warm climate. Islands in the Alpine Province were with markedly humid climate, an indication for which is the formation of a number of bauxite deposits.

Temperature influenced the variety of the faunas, which decreased from south to north. The amounts of limestones also decreased in the same direction.

3. Character of the sea bottom and degree of activity of the water. To a considerable extent these factors have a determining influence on ammonite morphology. Among terrigenous or shallow-sea carbonate sediments formed in a high-energy environment, ammonites are usually with coarse ribbing, being in most cases with depressed cross-section. An interesting example in this respect is the Berriasian genus *Pomeliceras* whose nominate subgenus, inhabiting sublittoral biotopes with terrigenous sediments, has a coarse morphology but with depressed section, whereas subgenus *Mazetoniceras*, inhabiting deeper-sea biotopes with ooze bottom, has lighter ribbing and compressed cross-section.

Moreover, the stability of the environment has a positive effect on the population density. This is why, the variety of ammonites is greater considerably in the open parts of the seas than in the coastal shelf zones.

4. Barriers. These may be different island arches or oceanic currents which hamper migration and which may result in isolation of the populations. Probably the separation of the Alpine Province from the European-Caucasian one in some regions was influenced by the combination of island arches with a strong oceanic current.

The Mediterranean elements among the Valanginian ammonites in Eastern Greenland are assumed to be due to an early Gulf Stream.

5. Salinity. It is difficult to determine accurately the influence of this factor, but ammonite finds show that they are typically stenohaline forms and occur only among marine sediments.

6. Lithofacies. Ammonites have a definite tolerance limit with respect to lithofacies. Therefore, they manifest marked affinities to some types of sediments: claystones, marls, clayey limestones, sublithographic and micritic limestones, glauconitic clayey and sandy sediments. Ammonite finds are extremely rare among pure, washed sandstones, whereas reefs are an alien environment for them. Pyritized ammonites, usually minimal in size, are often widespread in clayey-calcareous sediments. This is connected with the low oxygen content in some depressed sections of the basin and with the increased H_2S amount.

7. **Biofacies.** Ammonites may be associated with various other organisms: foraminifera, radiolaria, calpionellids, brachiopods, echinids, a number of bivalvs (without rudists and ostreids) and rare gastropods. The character and the configuration of their biotopes may also be different and they are influenced not only by the indicated factors, but also by competition with related and/or ecologically similar species in the biocoenoses.

3.3. Some Main Early Cretaceous Biotopes

The Early Cretaceous biotopes in the Mediterranean Region are extremely varied. Depending on the character of the bottom, the type of food and the means for obtaining it, on the way of life, on the degree of vagility, on the specificities in the multiplication and the relationships with other groups, the organisms in a biocoenosis are usually represented by different adaptive types which occupy separate sections within a biotope.

Since it is not possible to examine Mediterranean biotopes in detail, here we shall discuss briefly only some basic Early Cretaceous biotopes in Bulgaria, which are very representative ecologically.

The Early Cretaceous sea basin in Bulgaria manifests progressive bathymetric differentiation. Thick **Berriasian** flysch sediments are developed in the Fore-Balkan Depression, most numerous among which being the ammonites in the sandy flysch (Ammonitina, Lytoceratina and Phylloceratina), rare belemnites and bivalvs. In the northern strip of the Fore-Balkan the biocoenoses are diversified with the extensive participation of calpionellids, as well as foraminifera and radiolaria.

Two main facies of the Berriasian are known to the northwest of the Jablanica line: (1) Neritic biomorphic, biodetritic and algal limestones from the carbonate platform of the Brestnica Formation, among which there are a number of gastropods, bivalvs and brachiopods (biotope of the carbonate platform). This type of biotopes is very widespread in the Mediterranean Region; (2) Pelagic limestones with many representatives of Ammonitina and Phylloceratina (biotope with clayey-calcareous ooze bottom).

Neritic biotopes with different combination of bivalvs, gastropods, brachiopods, echinids, corals, serpulae, algae and benthonic foraminifera were developed in the Moesian Platform from the Berriasian to the Early Hauterivian.

Pelagic limestones are the richest in macro- and microfauna (biotope with chayey-calcareous ooze bottom). This type is also widespread in the Mediterranean Region.

The configuration and the character of **Valanginian** biotopes are very similar to the Berriasian ones. The sandy flysch zone (biotope with clayey-calcareous bottom) began to widen gradually in the Fore-Balkan. Among the ammonites the Ammonitina representatives are exceptionally widespread, whereas Phylloceratina and Lytoceratina have a considerably more limited distribution compared with the Berriasian.

Among the neritic Valanginian biotopes there are bivalvs: *Camptonectes, Cucullaea, Prohinnites* and *Hinnites*; gastropods: *Nerinea* and *Natica*, many serpulae, which build in some places entire limestone beds. Benthonic foraminifera are rare.

Four main **Hauterivian** biotopes are established: (1) bathyal biotope with clayey-calcareous bottom in the Fore-Balkan, inhabited by Ammonitina and Lytoceratina, concurrent belemnites and rare bivalvs; (2) neritic biotope with clayey-calcareous ooze bottom in Northeastern and Central North Bulgaria, inhabited by extremely rich ammonite and belemnite faunas, characteristic brachiopods and foraminifera, concurrent bivalvs and rare echinids; (3) bathyal biotope with ooze (marly) bottom in Northwestern Bulgaria, inhabited mainly by ammonites and concurrent belemnites. Here ammonites are much more varied compared with the other biotopes and especially compared with the first biotope; (4) transitional biotope between the neritic and the bathyal biotope. It is characterized by unstable conditions. The biotope is inhabited by different Ancyloceratidae, late Neocomitinae, some *Hibolites* and *Duvalia*, as well as bivalvs (*Arcomytilus, Camptonectes* and *Chlamys*), gastropods (*Pleurotomaria, Purpuroides* and *Ampullina*), brachiopods and benthonic foraminifera.

The development of the **Barremian** ecosystems manifests considerable differences between the Early and Late Barremian in the Fore-Balkan, whereas stable biotopes were developed throughout the entire Stage in the Moesian Platform.

The Early Barremian biotopes in the Central and Eastern Fore-Balkan are with clayey-sandy bottom, and they are inhabited by a number of ammonites (*Costidiscus, Crioceratites, Acrioceras, Paraspinoceras*, Leptoceratidae, various Barremitinae, *Pseudothurmannia*, Holcodiacidae, *Anahamulina, Hamulina*, etc.) and comparatively rare belemnites.

Biotopes were formed on carbonate platforms (Urgonian facies) during the Late Barremian, inhabited by rudists, various other bivalvs, gastropods, corals, echinids, brachiopods, Orbitolinidae, as well as other benthonic foraminifera and algae. Various microbiotopes with specific population and different density were formed within the Urgonian biotopes.

Three basic biotopes are outlined in the Moesian Platform: (1) Southern biotope with ooze (marly) bottom with extremely many belemnites (mainly *Mesohibolites*) and ammonites; (2) Middle biotope with ooze (clayey-calcareous) bottom, inhabited mainly by ammonites. This is biotope of the outer shelf, which is the richest in ammonites, including large forms. There are concurrent belemnites, rare brachiopods, echinids and bivalvs. Benthonic foraminifera are also found; (3) Biotope with calcareous bottom, inhabited by sublittoral benthos bivalvs, gastropods, concurrent echinids and rare corals. This biotope is well outlined in Northeastern Bulgaria (Ruse Formation.) The biotope of the Urgonian in Provence (France) is of the same type.

Bathyal biotope with clayey-calcareous (marly) bottom, inhabited mainly by ammonites, is developed in Western Bulgaria.

Aptian biotopes are extremely varied and they changed in the course of that Age. The Urgonian and the Paraurgonian biotopes with their characteristic biocoenoses are clearly outlined in the Fore-Balkan. These biotopes are typical for high-energy environment and they are rather unstable in space. This often led to the elimination of the Urgonian character of the different microbiotopes and the formation of niches with ooze bottom over brief periods. Some ammonites — migrants from other biotopes — were developed in such niches.

In Northeastern Bulgaria Aptian biotopes inherited the basic physical properties of the Barremian biotopes. A purely Urgonian biotope developed along the Danube.

Biotopes of a typical Paraurgonian character were formed in the Iskăr Depression and in the Dragoman region, inhabited by many Orbitolinidae and other benthos foraminifera, bivalvs, gastropods, corals, echinids and rare ammonite migrants.

A biotope with ooze bottom is developed in the Moesian Platform to the west of Jantra, inhabited mainly by varied ammonites, characteristic belemnites and rare bivalvs.

Until recently the **Albian** in Bulgaria was considered to be rather homogeneous facially. However, the analysis of the litho- and biofacies has demonstrated a hitherto unknown variety. A marly background prevails generally, against which several specific biotopes are outlined: (1) Biotope with ooze bottom which is most widespread and is of bathyal type (Lom Depression); (2) Biotope with clayey-sandy bottom; (3) Biotope with glauconite-sandy bottom with phosphorites. The richest faunas are in the first and in the third biotopes. The taphonomic features of the fossil occurrences and the development of phosphorites in the third biotope suggest a possible effect of upwelling.

The analysis of the main Early Cretaceous biotopes in Bulgaria indicates developing palaeoecological environments. Rare Boreal features began to be imposed over the typical Mediterranean picture, gradually intensifying after the Barremian Age.

To the examined basic Early Cretaceous biotopes in Bulgaria it is also necessary to add the deep-sea (pelagic) biotopes with extensive development of radiolaria. They are widespread in the axial part of the Mediterranean Region and are often associated with ophiolites. The submarine volcanic phenomena and the palaeohydrothermal phenomena stimulated the development of radiolaria and Si-spongia. Of particular interest is the combination of silicites (radiolarites and spongolites) with manganese oxides, which was found for the first time in the Aptian sediments of Northeastern Bulgaria (Горанов, 1965). Similar phenomena have been described later in other regions of the Mediterranean area (Lemoine et al., 1982). Real submarine oases are connected with such palaeohydrotherms, known both in deep-sea and in shelf biotopes.

VI. MAIN FEATURES IN THE GEOLOGICAL DEVELOPMENT OF THE MEDITERRANEAN REGION DURING THE EARLY CRETACEOUS

1. PATTERNS OF THE PALAEOGEOGRAPHIC ENVIRONMENTS

In a general historical-geological plan the Early Cretaceous in the Mediterranean region seems a relatively calm Epoch. Among the global Mesozoic marine cycles it is included between the Late Jurassic regression and the Cenomanian transgression (Ager, 1981).

During the Early Cretaceous the Mediterraneen seemed to be "taking its breath" after the Late Kimmerian activation. This general picture,widely discussed in general monographs on the Phanerozoic development of the Alpian-Himalayan Belt, conceals essential features in this development.

1.1. Evolution of the Continents and of the Continental Margins

The Early Cretaceous sea basins in the Mediterranean Region are within the scope of the Tethys Ocean. It is linear in shape, with subequatorial direction, but with elaborate arc-shaped bends and a number of intermediary massifs (continental fragments).

The two supercontinents — Gondwana and Laurasia — determined the spatial configuration of the Tethys. The Mediterranean Region developed in the space between the African-Arab and the Eurasian Platforms.

Vast areas in Africa represent dry lands with continental deposits — Sahara "continental intercalaire" (continental alternations) and the Numidian Sandstones, among which there are evaporites and remains of silicified trees and vertebrates.

In Eurasia the continental formations also occupy vast territories from Angara, the Russian Platform and Western Europe, where Purbeckian-Wealdian sediments developed.

The Early Cretaceous migration of reptiles started from Angarida, where the first Cretaceous Sauropoda and Iguanodons emerged. From there they rapidly migrated to Southern Asia, Africa, Europe and North America (Termier, Termier, 1960).

The peripheral parts of the continents were entrained within the limits of the Mediterranean geosyncline and several fragments were separated from them, building the Apulian, Iberian, Carno-Pannonian and Aegean Platforms (Dewey et al., 1973; Biju-Duval et al., 1976).

The riftogenesis which started in the Central Atlantic during the Jurassic Period became stronger during the Early Cretaceous, expanding to the north and south.

Within the Mediterranean Region itself there were also similar phenomena in the Alps and on the Balkan Peninsula, where conflicting interactions are discovered between the Rhodope Massif, the Kraištides, Balkanides, Carpathians and Dinarides (Bončev, 1977; Laubscher, Bernoulli, 1977; Уиксов, 1981).

The beginning of the Early Cretaceous is marked by epicontinental transgression which is considerably more extensive than the Jurassic one, leaving only isolated insular dry land.

1.1.1. Regional Patterns in the Development of the Continental Margins

The continental margins of the Mediterranean Region during the Early Cretaceous were of Atlantic type (passive). There is a shallow-water terrace almost everywhere between the shore and the continental slope. The neritic sediments of the shelf zone are most widespread. Thick complexes are formed within the continental slope in many areas (North Africa, Betic Cordilleras, Pyrenees, Alps, Carpathians, Balkanides, the Caucasus and the Dinarides).

Two basins were formed at the beginning of the Early Cretaceous in Northwestern Africa: Atlas Basin (Agadir-Essaouira) in Central Morocco and Reef Basin in the northern part of that country. In both basins, as well as in other parts of the Western Mediterranean, at the boundary between the Jurassic and the Cretaceous there was a sharp change in the character of the sedimentation and a rapid transition from platform carbonates to the formation of thick clayey-calcareous sediments. The transgression gradually expanded from the north-northwest to the south-southeast, so as to comprise the High Moroccan Atlas during the Barremian and the Aptian. The Tarfaya Basin was formed in the south during the Late Aptian.

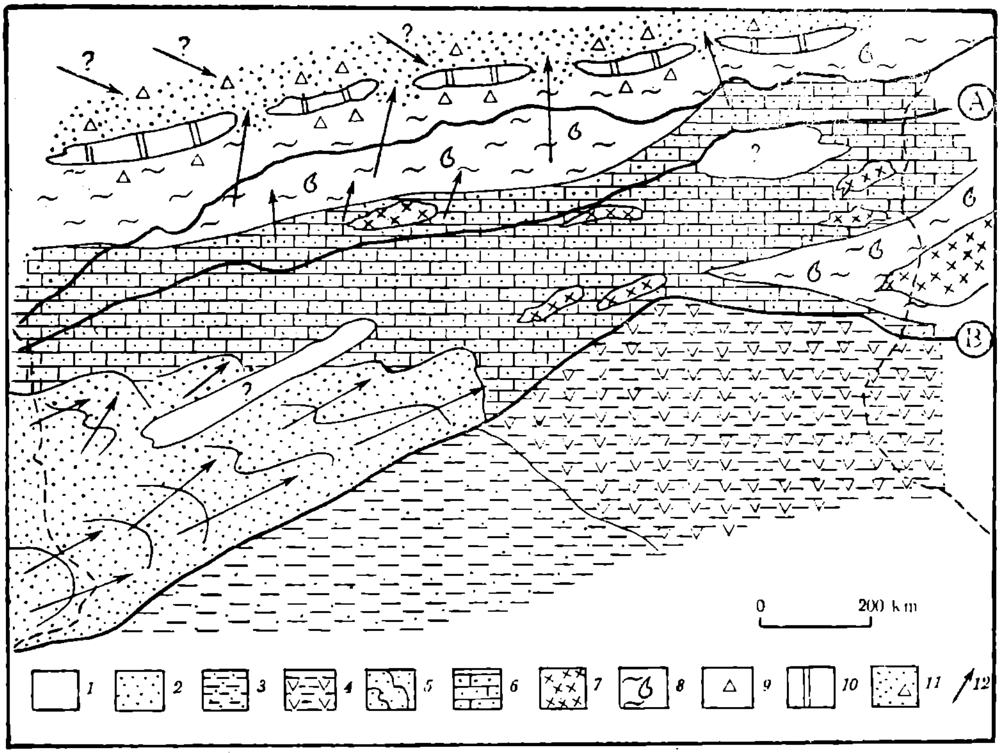


Fig. 26. Generalized palaeogeographic sketch of the Lower Cretaceous in Algeria (after Delfaud in P o m e r o l, 1975)

1 — islands; *2* — massive continental sandstones; *3* — sandy claystones ("continental intercalaire"); *4* — evaporitic sandstones (Sahara type); *5* — zones in deltaic sediments; *6* — sandy limestones; *7* — Urgonian limestones; *8* — clayey limestones (basin facies); *9* — microbreccia (facies of mobile zones); *10* — calcareous chains (chaine calcaire); *11* — flysch trough; *12* — direction of the transport

The Late Kimmerian movements stopped towards the end of the Berriasian when the carbonate platforms were finally destroyed. A thick flysch complex was formed in the northernmost part of the Reef.

Pelagic limestones, marls, green or red argillites are formed in the continental base of Northwestern Africa, intercalated by basalts in their lower part and covered predominantly by alternation of aleuritic marls and limestones with frequent manifestations of bioturbations. The extensive development of black clayey shales became gradually imposed.

The Lower Cretaceous sediments from the Moroccan basins, formed in the shelf or in the upper part of the continental slope, gradually acquired a deeper-marine character to the west-northwest. The Jurassic-Berriasian carbonates were replaced by thick flysch sediments developed in Morocco and in the continental margin.

The uplift of the Atlas was accompanied by intensive depression of its foreland, which is compensated by a thick complex of shelf sediments including thick deltaic deposits as well (Fig. 26).

The discovery of black clayey shales in the Barremian-Cenomanian interval indicates the beginning of a characteristic Early and Middle Cretaceous oxygen depletion in some deep-water zones and the formation of oxygen-free environments.

Condensation is a characteristic phenomenon in the Moroccan Aptian-Albian sections (B e r g n e r et al., 1982), being also observed in other parts of the Mediterranean Region (Iberian Peninsula, the Alps, the Carpathians, the Balkanides and the Crimea). In palaeogeographic plan these condensed sections are connected with the upper part of the continental slope or with the middle part of the shelf.

A wide shelf zone developed in the High Plateaux with thick terrigenous-carbonate complexes in the continental margin of North Africa (Algeria and Tunisia): Bathyal environments predominate in the Tellian Atlas, with local shallowing in the northern part after the Late Barremian and formation of Urgonian facies connected with them.

A zone becomes apparent in the north (Coastal Reef, Cabiles and Calabrides) in which the Lower Cretaceous is entirely connected with flysch sediments.

A transition from the continental and shelf sediments of the Lower Cretaceous in Portugal to the deeper-sea deposits in the southern part of the North Atlantic is observed in the western continental margin of the Iberian Peninsula. The data about the Lower Cretaceous in Borehole 398D manifest intensive depression. The comparative analysis of the development of the series from Portugal to the continental margin demonstrates strongly divided relief and gradual deepening in western and northwestern direction (R e y, 1972; G r a c i a n s k y et al., 1979). Only the black Albian claystones reach a thickness of 400 m (DSDP — 389D), forming an almost uninterrupted sedimentation cover which fills all depressions. It is assumed (G r a c i a n s k y et al., 1979) that the black Albian claystones were formed below the level of $CaCO_3$ compensation.

In the north, in the Cantabrian margin of Spain, there are three zones from northeast to northwest: the intercontinental basin of Soria, the marginal Cantabrian Basin with extremely thick Wealdian sediments, and the marine basin of the Bay of Biscay with pelagic sediments in the central part. Three stages are distinguished in the development of this margin: 1) Oxfordian-Early Aptian, in which the sedimentation compensates the depression, but with predominantly continental sediments; (2) Urgonian (Aptian-Middle Albian) in which a permanent bay (Gasconian) with development of Urgonian carbonates is found; (3) Late Albian-Eocene, in which exclusively flysch sediments are formed (R a t, 1982).

In the southwestern margin of the Iberian Peninsula, between the Betic Cordilleras and the internal zone of the Magrebids, there is the Subbetic Depression — a typical miogeosynclinal trough comprising both the Balearic Islands and Sardinia, with predominantly pelagic sediments. Neritic and continental sediments, often with typically marine ingressions in grabens, develop to the northwest. Active riftogenesis appeared in this zone later — during the Oligocene or Early Miocene (B i j u-D u v a l et al., 1976).

The Early Cretaceous evolution in the Pyrenees is characterized by numerous hiatuses in the sedimentation, erosion phases (at the beginning of the Berriasian, Barremian, Gargasian, Clansayesian, Middle and Upper Albian), during which bauxites were formed and seven transgressive phases were manifested. Discordant correlations within the Lower Cretaceous, resulting from local paroxysms, are also discovered (P e y b e r n e s, 1976). Urgonian limestones are widespread in the Eastern Pyrenees.

The Early Cretaceous palaeogeography of France is modelled by the influence of several massifs: Central, More-Esterel, Mercantour, Mont-Blanc, Belladone-Pelvoux. The Vocontian trough with typically pelagic sedimentation, poor in terrigenous material, is developed among them. The carbonate Provence facies are formed in the south; in the north there is a transition to the neritic facies of Jura Mountains through the transitional facies from the upper part of the continental slope.

The Paris Basin developed in the Morvan-Vosges strait which linked directly the Mediterranean and the Boreal Basins during the Aptian Age (G i g n o u x, 1950).

Towards the end of the Early Cretaceous the Durance vault rose in the south and the Provence Bay was isolated from the Vocontian trough. The Bay of Biscay expanded to the east in the Aquitanian Basin.

The restoration of the palaeogeography of the Early Cretaceous in the Alps is complicated due to their complex structure. However, palinspatic reconstructions indicate a basic regularity: the Lower Cretaceous sediments in the southern zones are typically deep-sea, formed mainly in the bathyal zone and partly in the abyssal one. Shallower marine sublittoral to littoral sediments developed gradually in the north, in Jura Mountains.

Three basic zones developed *grosso modo* in the Carpathians: (1) eugeosynclinal zone in the Inner Carpathians; (2) klippes zone (Pieniny Lineament) in which predominantly marls, argillites and partly limestones are developed, formed in the lower part of the continental slope; (3) flysch zone in the Outer Carpathians, developed in the upper part of the continental slope. There exist a number of local specificities against this general background, including the development of Urgonian limestones.

Typical neritic sediments are developed in the Foreland.

Predominantly pelagic limestones of the Biancone (Maiolica) type are formed in the Pannonian Massif, as well as a terrigenous and terrigenous-carbonate sediments, mainly in Geresce.

The Early Cretaceous basin in the Crimea is characterized by complex bathymetric differentiation, many local depositional hiatuses and frequent occurrences of ingression along canyons in the shelf. In a general plan a southern miogeosynclinal zone is outlined, being well expressed in Eastern Crimea. A wide shelf region extends to the north (Д р у щ и ц, К у д р я в ц е в, 1960).

The palaeogeographic situation in the Caucasus is very complex. The following basic zones are outlined in a general plan: (1) Novorossijsk geosyncline; (2) Geosynclinal zone to the south of the Main Caucasian Ridge; (3) Abhasian trough; (4) Rača trough; (5) Georgian block; (6) Fore-Caucasian Depression; (7) Eugeosynclinal zone of Caucasus Minor with mixed facies in the Kafan region (Э р и с т а в и, 1962).

The thickest sediments are formed in the first two geosynclines which are of the type of miogeosynclinal troughs.

Predominantly clayey-calcareous sediments from the outer shelf zone are developed in the Abhasian and Rača troughs, whereas the Georgian Block is covered by carbonates of the inner shelf. The Fore-Caucasian Depression is filled with neritic sediments.

The southern margin of the Russian Platform, the Large Caucasian anticlinorium, the Azerbaidjan and Armenian Blocks are of great significance for the Early Cretaceous sedimentation in the Caucasian Basins.

In the northern part of the Black Sea Basin there was considerable uplift during the Lower Cretaceous — Euxinian uplift (Б о н ч е в, 1957a), which played a definite palaeogeographic role, serving as a barrier which hampers the penetration of Boreal species to the south.

During the Early Cretaceous the sea basin developed over the continental margin of the Moesian Platform. In the south there was a permanent dry land whose contours and dimensions changed gradually, but it remained the main source of terrigenous material. The influence of the northern dry lands (Dobrogea and the Euxinian uplift) is essential not so much as a source of terrigenous material, but rather as a geographic barrier. During its initial stages this sea basin inherited the main depositional characteristics of the Late Tithonian (Н и к о л о в, Х р и с ч е в, 1965b). A considerable depression was formed in its southern part, as well as a wide shelf region in the north. This is responsible to a great extent for the facial specificities of the sediments as well, without excluding the additional influence of the general tectonic background which affects both their maturity behaviour and the quantitative distribution of the terrigenous material (Р у с к о в а, Н и к о л о в, 1984).

Two main depositional environments existed in the sea basin in Bulgaria during the Berriasian: geosynclinal and platform. The geosynclinal depression has the character of a deep trough in which thick flysch deposits are accumulated, whereas the Moesian Platform is characterized by predominantly shallow-water carbonate sedimentation.

Coastal coarse terrigenous sediments are deposited in the southernmost part of the flysch trough close to the dry land, being replaced by mixed rocks in some places (south of Elena) in the higher levels and further south. They are followed by the fat rhythmical unit of sandstones and marls deposited in the moderately deep zones of the rapidly deepening trough. Then follows the normal thin rhythmical flysch in which the presence of the turbidites with characteristic flysch structures is evidence of sedimentation in the deepest part of the basin. Further north is the transition to the subflysch whose lithological and faunistic composition is indication about sedimentation under the conditions of the adjacent continental slope. Similar deposits (marls, clayey limestones with intercalations of siltstones and sandstones) exist in the Eastern Fore-Balkan as well, where they are connected laterally along the Gerlovo line with the typical and the sandy flysch (Н и к о л о в, Х р и с ч е в, 1965b). Their presence is indication of the different depositional regime in the depression basin, probably resulting not only from the different depths of deposition, but also from the character of the material transported.

The depositional regime was different in the adjacent area in the north (comprising the Moesian Platform and the present-day structures of the Western Balkanides and the Western Srednogorie region). Exclusively carbonate sediments are deposited, but in two different genetic types which are joined laterally to the Kozloduj-Kneža diagonal line (the transitional zone) which continues until Umarevci (Н и к о л о в, Р у с к о в а, 1972) and stops at the northern edge of the flysch trough (Fig. 27). To the northeast of it is the epicontinental shallow-water, normally salty part of the basin, in which the characteristic Kaspičan Limestones were formed. Their predominant lithological composition (limestones with micrite supporting structures and matrix), as well as the fauna, testify to deposition taking place in the low-energy shallow subtidal flat (R u s k o v a, 1982). There are few high-energy limestones with sparry calcite cement in this region. They appear at different levels in the section and characterize isolated and impulsively occurring shoals with bathymetric levels in the zone of the intertidal flat. Dolomites occupy predominantly the base of the sections, and in a general plan (if we accept, although partially, the hypothesis about their primary origin) they are evidence of a regressive development process of the basin towards its gradual desalinization. Moreover, against the general humid "background" of the Early Cretaceous Basin, the brief aridization of the climate is assumed to have taken place only at the beginning of the Berriasian, comprising the central and eastern parts of the Moesian Platform.

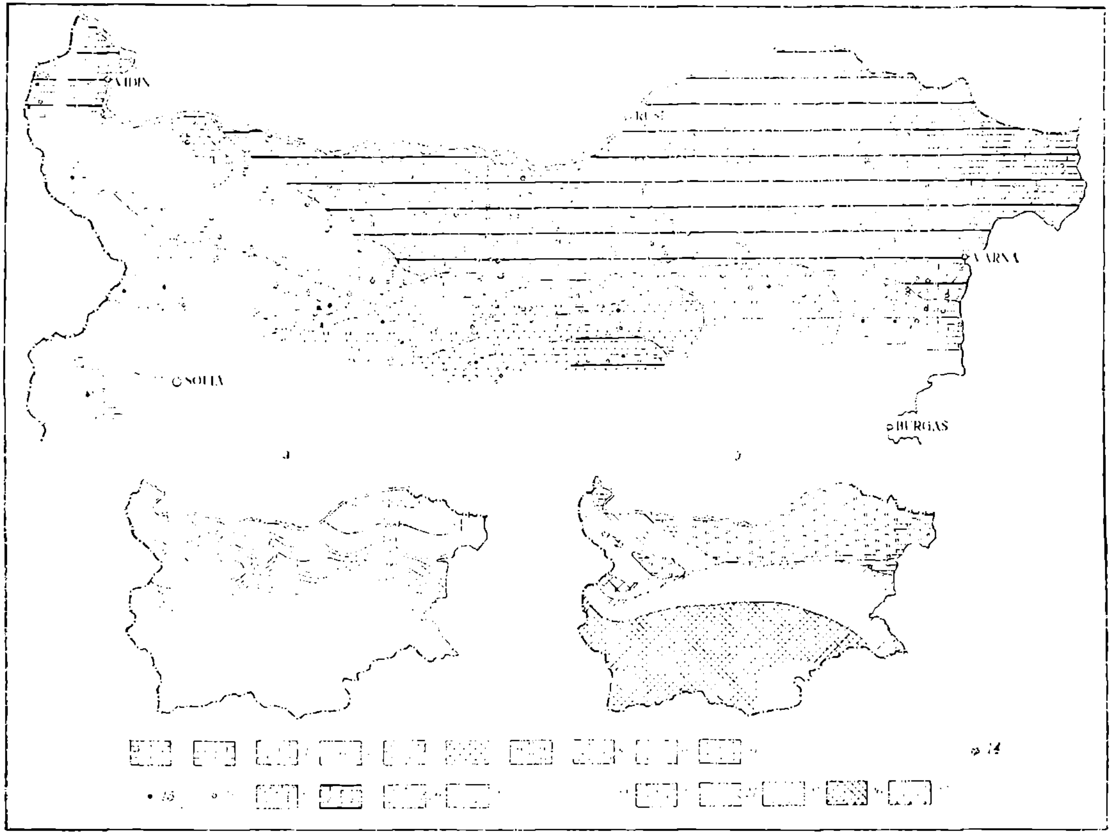


Fig. 27. Lithofacies map with sketches of the equal thicknesses and the palaeogeographic environments. Berriasian (after Рускова, Николов, 1984)

Lithofacies map: *1* — limestones; *2* — clayey limestones; *3* — marls; *4* — marls with rare intercalations of siltstones; *5* — dolomites; *6* — sandstones; *7* — siltstones; *8* — conglomerates; *9* — breccia-conglomerates; *10* — mixed rocks; *11* — spicules of Spongia; *12* — Calpionelidae; *13* — biodetrite; *14* — Algae; *15* — investigated sections in outcrops; *16* — investigated sections in drillings; *17* — lithological complexes with repeated rock types in the section; *18* — lithological complexes with pointed out basement and upper part; *19* — boundary between the lithological complexes; *20* — boundary between the lithological complexes in regions of total denudation or dry land. *Sketch of the equal thicknesses (a)*: *21* — proved; *22* — probables. *Sketch of the palaeogeographic environments (b)*. Marine environments: *23* — shallow shelf — carbonates platform; *24* — deep shelf; *25* — flysch trough (comparatively deep-sea sedimentation); Continental environments: *26* — mountain relief; *27* — plate-like relief

To the southwest of the Kozloduj-Kneža line the Berriasian deposits are developed in pelagic facies which corresponds to the deep-water part of the shelf with respect to its lithological and faunistic content. Parallel with this, however, in the Western Fore-Balkan and in the Western Srednogorie region there appeared areas — insular dry lands — in which Berriasian (as well as Valanginian) sediments are absent and the Hauterivian over lies directly sediments of Tithonian age (М а н д о в, 1969; 1970). The Brestnica Limestones (north of Jablanica) were formed under similar conditions, but as a submarine shoal. Their solid carbonate reef builtup rises as a submarine island amidst the deep part of the shelf. The highly dynamic facies in it are abundant and indicate exclusively shallow-water regime with the characteristic intertidal or shallow subtidal facies.

The investigation of the lithological composition of the Berriasian indicates that the influx of material was from the south where the elevated dry land was located. (It provided the main mass of the quartz which is abundant in the coarsely terrigenous formation.) It is possible part of the material to have originated in the Stara Planina zone, bacause, according to the latest comparative data, some metamorphic fragments have analogous composition to the metamorphites from the diabase-phyllitoid formation. The terrigenous material is distributed mainly in the flysch trough which is compensatorily loaded with enormous masses of sediments. The scattering towards the northern elevated parts of the carbonate platform and the basin slope adjacent to it (in the southwest) is practically equal to zero. The small Berriasian thickness in the north testifies to stabilities and slight sinking amplitude.

The depositional environment was preserved in the northern and northwestern part during the Valanginian. Deposition continued here under the epicontinental conditions of the shallow shelf. Changes occurred, however, in the flysch trough: the Gerlovo line disappeared (Н и к о л о в, Х р и с ч е в, 1965b) and marly-sandy rocks were deposited everywhere in a wide range of varieties and combinations. The regime is relatively deep-sea, with concrete features of flysch manifestations and compensatory sinking of the water basin. However, the three small outcrops of conglomerates with corals and reef limestones discovered suggest the existence of local shallow areas in the southern parts (moreover, only during the Late Valanginian), in which the coarsely terrigenous material "coexisted" with the unusual organisms probably brought from the North (П и м п и р е в, 1981).

The depositional environment during the Hauterivian continued along general lines its two-way development from the beginning of the Lower Cretaceous. On the one hand, there was the stable regime of the Moesian Platform from the north and the adjacent pelagic areas (deep shelf) of the present-day Western Balkanides and the Western Srednogorie region, and on the other hand — the depression from the south, including the area of the Central and Eastern Fore-Balkan. During the Early Hauterivian, however, its northern slope along the Jablanica-Umarevci line was shifted further north (Н и к о л о в, Х р и с ч е в, 1965b; R u s k o v a, 1975). Under relatively deep-water conditions and intensive sinking, thick marly-sandy deposits of flyschoid type and marked zonality were accumulated in it, filling the depression and the continental slope (Fig. 28). The sediments increase their terrigenous admixtures in the north, whereas in the northern regions they become gradually pure. In the southernmost outcrops there are mixed rocks whose undifferentiated character is an indication of chaotic and rapid influx of terrigenous material into the coastal parts of the basin which rapidly increase their depth.

Two regions are distinguished in the adjacent area to the north, in which sedimentation occurred under shelf conditions. The northeastern region comprises part of the Central and the entire eastern part of the Moesian Platform. The facies environment is represented in two aspects: (1) carbonate-platform (shallow) shelf of Ruse limestones deposited in the intertidal flat; (2) peripheral, slightly deeper-sea part of the same subtidal flat of the shelf, in which clayey-calcareous sediments with small amounts of glauconite are formed (R u s k o v a, 1982). In the western region the relief becomes gradually lower in the deep part of the shelf (southwest of the Slavjanovo-Totleben line). The characteristic Salaš limestones are deposited there, their faunistic and lithological composition being a confirmation of the indicated bathymetric level. Inheritance of the shallow-water Kaspičan Limestones is found only in two isolated places in the basin (moreover, during the Early Hauterivian — Fig. 28 — at Bărdaski Geran and Kneža, as well as to the north of Novi Pazar). As regards the carbonate-reef builtup of the Brestnica Limestones, which is sharply prominent among the deep shelf, during the Hauterivian it gradually decreased its surface to the west of Iskăr river, sinking progressively with its peripheral parts. (This is indicated on the palaeogeographic sketch of the Early and Late Hauterivian — Fig. 28, whereby the second sketch of the Early Hauterivian clearly demonstrates the entrainment of some of the peripheral deeper-water part of the carbonate builtup towards the slope of the basin with flyschoid sedimentation — Fig. 28 *b*). Insular dry lands (shallow-water areas) are discovered in two regions: at Brest—Gigen and in the northwesternmost part of Bulgaria, in Vidin District (Н и к о л о в, 1972).

The influx of material during the Hauterivian continued mainly at the expense of the rapidly denuded Thracian land. The geosynclinal depression underwent compensatory sinking, with increased gradient in its eastern part. Conversely, the regime was stable in the area of the Moesian Platform, though in the northeasternmost part the supply of material was bilateral, i. e. already involving the participation of the Dobrogea dry land.

The beginning of the Barremian indicates direct depositional continuation of the Hauterivian. This concerns above all the marly-sandy deposits of the depression from the south which progress slightly northward (Fig. 28). The sedimentation environment is practically preserved in the same places. Considerable retention is observed in the Western Balkanides and in the Western part of the Moesian Platform, where only the clayey and partly the terrigenous-clastic components of the sediments increase. In fact, in the more northwestern regions, close to the carbonate lands, the marly sediments are replaced by pure micritic limestones whose faunistic composition already indicates sedimentation under conditions of shallower but also calm waters. This process is probably due to a certain elevation of the deep shelf. A more essential change in the sedimentation environment occurred in the depression region from the south, which already represents a compensated basin of marly-sandy sedimentation. The influx of material, although predominantly terrigenous, was from the same sources in the south and the Dobrogea land in the north (Р у с к о в а, 1970), and it continued, though in reduced amounts. This is evidenced by the reduced thicknesses of the Barremian in general. In the central and southernmost parts (e. g. west of Omurtag) the basin is considerably shallower: the denuded structures with diagenetic type of cement, as in the surface oölites in some places, are evidence even for the existence of bathymetric levels in the zone of the intertidal plane. Towards the end of the Barremian the first symptoms o change in the sedimentation position occurred in the depression zone: Urgonian terrif genous-carbonate sediments became imposed in the Veliko Tărnovo-Loveč area.- Their lithological composition (Bahama-type carbonate) suggests extremely shallow-water environment with impulsive influx of terrigenous material, bilaterally dispersed in the adjacent regions to the east and to the west (Fig. 29) (Х р и с ч е в, 1969; 1972).

The sedimentation situation during the Early Aptian (Fig. 30) is characterized by great variety. In fact, it has inherited the basic sedimentation tendencies from

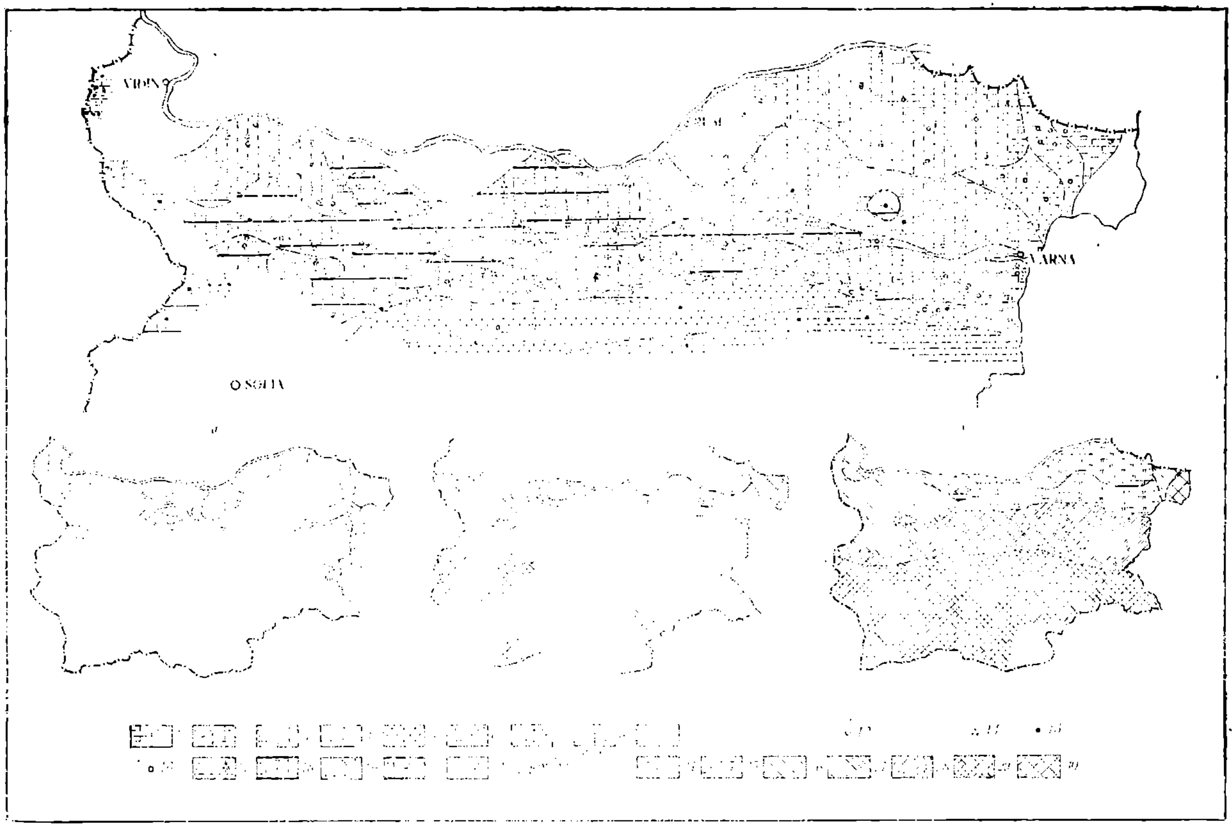


Fig. 23. Lithofacies map with sketches of the equal thicknesses and the palaeogeographic environments. Hauterivian (after Рускова, Николов, 1984)

Lithofacies map: *1* — limestones; *2* — clayey limestones; *3* — marls; *4* — marls with rare intercalations of siltstones; *5* — sandstones; *6* — siltstones; *7* — mixed rocks; *8* — *a* — conglomerates; *b* — breccia conglomerates; *9* — claystones; *10* — fauna; *11* — spicules of Spongia; *12* — biodetrite; *13* — Algae; *14* — glauconite; *15* — investigated sections in outcrops; *16* — investigated sections in drillings; *17* — lithological complexes with repeated rock types in the section; *18* — lithological complexes with pointed out basement and upper part; *19* — boundary between the lithological complexes; *20* — inner washing; *21* — boundary between the lithological complexes in regions of total denudation or dry land. *Sketch of the equal thicknesses* (*a*): *22*—proved; *23* — probables. *Sketch of the palaeogeographic environments*: *b* — Early Hauterivian; *c* — Late Hauterivian. Marine environments: *24* — shallow-shelf carbonate platform; *25* — peripheral deeper part of the carbonate platform (clayey-calcareous sedimentation); *26* — offshore (lagoonal?) deposits; *27* — deep shelf; *28* — flyschoidal basin (marly-sandy sedimentation). Continental environments: *29* — mountain relief; *30* — plate-like relief

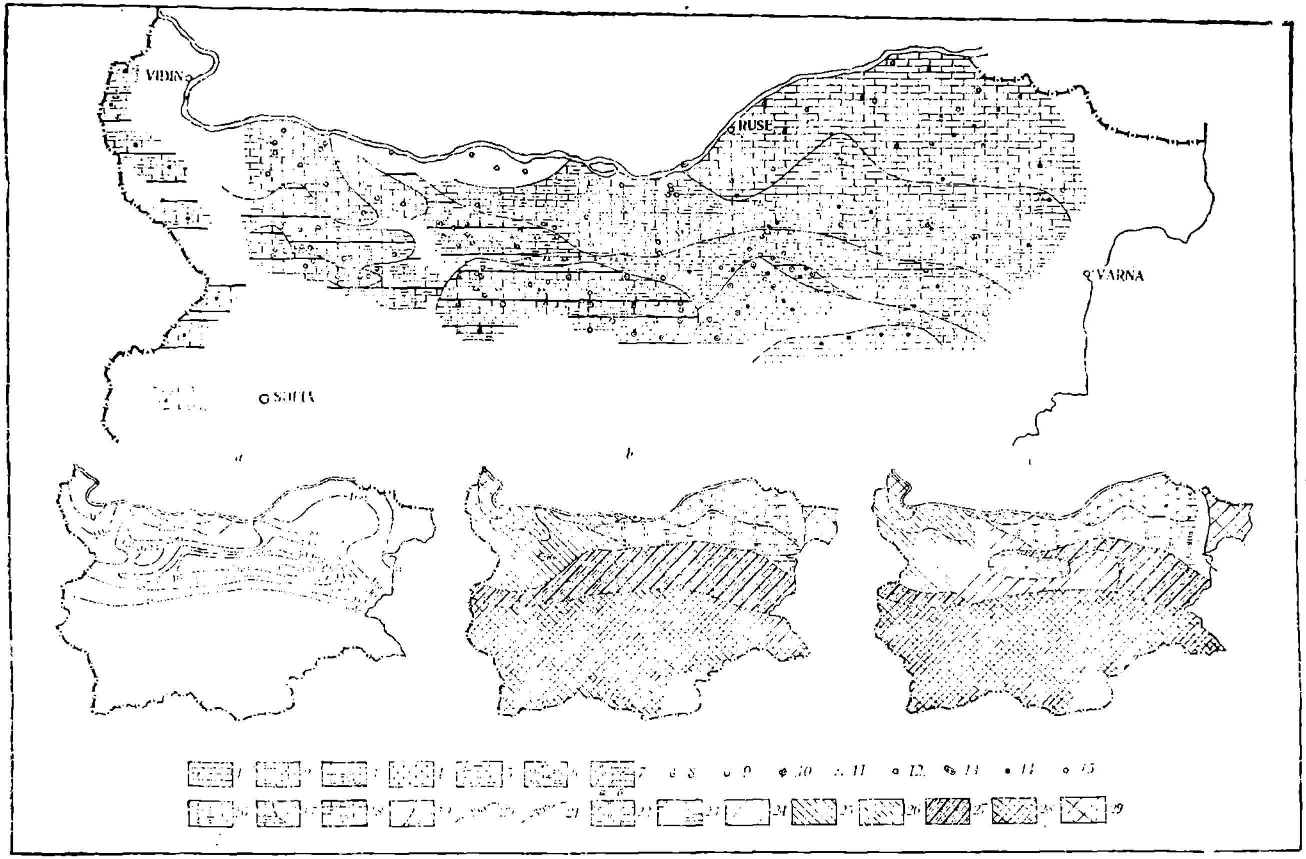


Fig. 29. Lithofacies map with sketches of the equal thicknesses and the palaeogeographic environments. Barremian (after **Рускова, Николов**, 1984)

Lithofacies map: *1* — limestones; *2* — clayey limestones; *3*—marls; *4* — sandstones; *5*—mixed rocks; *6* — siltstones; *7 a* — breccia-conglomerates; *b* — lithoclastic limestones; *8* — fauna; *9* — biodetritic; *10* — Algae; *11* — glauconite; *12* — oölites; *13* — phosphoritic concretions; *14* — investigated sections in outcrops; *15* — investigated sections in drillings; *16* — lithological complexes with repeated rock types in the outcrops; *17* — boundary between the lithological complexes; *18* — lithological complex with pointed out basement and upper part; *19* — boundary between the lithological complexes in regions of total denudation or dry land. *Sketch of the equal thicknesses (a)*: *20* — proved; *21*—probables. *Sketch of the palaeogeographic environments*: *b* — Early Barremian; *c* — Late Barremian. Marine environments: *22* — shallow shelf — carbonate platform: *23* — peripheral deeper part of carbonate platform (terrigenous clayey-clastic fan of the carbonate platform — developed in compensated basin); *24* — shallow (clayey-terrigenous-clastic) fan of the carbonate platform — developed in compensated basin; *25* — deep shelf; *26* — more shallow part of deep shelf (predominance of carbonate sedimentation): *27* — compensated basin (marly-sandy sedimentation). Continental environments: *28* — mountain relief: *29* — plate-like relief the end of the Barremian, but in addition to the Veliko Tărnovo and Loveč area, the classical Urgonian "pulsating" sedimentation of the shallow-water carbonate banks and of the terrigenous deposits intercalated by them conquered parts of the Western and Eastern Fore-Balkan, the Western Srednogorie region, the Western Balkanides and the westernmost part of the Moesian Platform (Vidin District). Laterally from them there are vast fans of the shallow-water, predominantly terrigenous (clayey-clastic) sediments, formed at the level of the intertidal or subtidal shallow-water part of the basin. It increases its thickness towards the places of the carbonate banks, i. e. precisely where the basin is compensatorily loaded by the thickest sediments. Coastal sea deposits are also discovered north of Kotel.

In Northeastern Bulgaria conditions were initially preserved as during the Late Barremian: the platform shallow-water carbonate and clayey-carbonate sediments were separated from the area of the Fore-Balkan Urgonian sediments and their terrigenous fans by more depressed areas (probably around the level of the deep shelf). Claystones or marls were accumulated here. Only a small relict part remains from the basin, which is filled with marly-sandy deposits, as during the Late Barremian. In the east, however, larger and larger areas went out of the range of the sea basin. At the end of the Aptian (according to the lithological composition of the sections in Pleven district and around Svištov) the coastal line reached to the east of Ruse and Loveč. The material continued to be brought from the south mainly, but the great thickness of the sediments (especially in the area of the Central Fore-Balkan and around Pleven) testifies to intensification of the erosion processes on the land, which is also connected with its elevation.

Intensive folding took place in the Central and Eastern Fore-Balkan towards the end of the Aptian followed by a gradual elevation of this area and a fast retreat of the sea basin to the northwest (Б о н ч е в, 1957a; Н и к о л о в, Х р и с ч е в, 1965b; N i k o l o v, 1969).

The sedimentation environment during the Albian (Fig. 31) was rather simplified compared with the other Ages. The sea basin had a limited scope, comprising only the central and western parts of the Moesian Platform, partially the Ruse-Razgrad region, as well as part of the Western Fore-Balkan area. Conversely, the southeastern part reflected most strongly the regressive tendencies during the Early Cretaceous, transcending the scope of marine sedimentation, and Albian sediments are absent here. The lithological composition of the sediments testifies to the existence of several sedimentation situations: (1) in the area of the Lom Depression and in part of the Western Fore-Balkan they were deposited in the deep part of the shelf; (2) in the southeast, toward Pleven, the bottom relief became higher, and the high-energy, partly oölitic sandstones with diagenetic type of cement were formed at the level of the shallow intertidal plane; (3) clayey marls were deposited in a calm bay in the Ruse-Razgrad region.

A remarkable tectonic zone — the Dardanian diagonal (B o n č e v, 1977), defines the basic features in the Early Cretaceous palaeogeographic situation in the western part of the Balkan Peninsula. It divides the Eastern Serbian Massif from the Dinaric zone. The transition takes place in the Šumadia zone covering the northwestern part of the diagonal. This elevation plays the role of a barrier and source of terrigenous material. In the east there follows a depression zone with Kraištide orientation (Lužnicki trough), filled with flysch, after which there is the Kučai-Tupijnica platform with terrigenous-carbonate sediments and the Visočki Basin in the Stara Planina zone with pelagic clayey-calcareous sediments. According to G r u b i ć (1974), the Danubian trough was formed to the east of the Getic Cordilleras as a continuation of the South Carpathians. Carpathian-type flysch (Timok or Sinaia Beds) was formed in the western and central parts of this depression (Krajna area), with pelagic clayey-calcareous sediments in the eastern part.

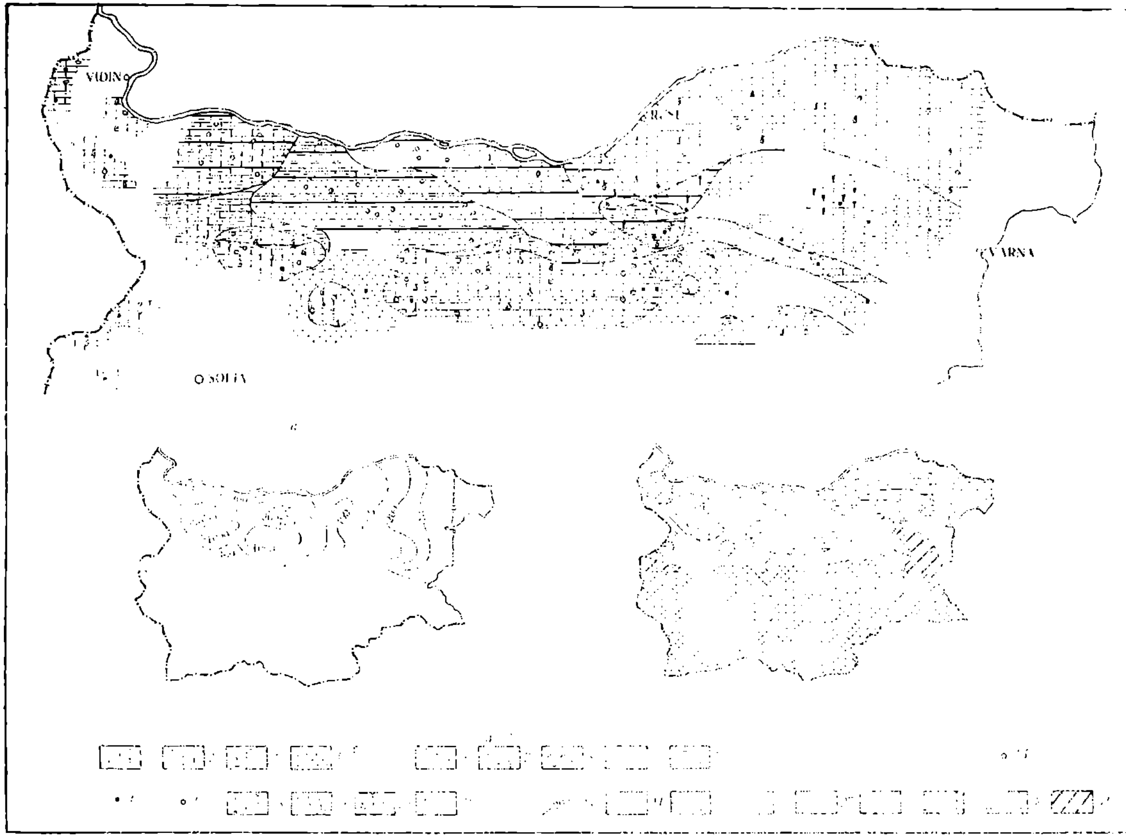


Fig. 30. Lithofacies map with sketches of the equal thicknesses and the palaeogeographic environments. Aptian (after Рускова, Николов, 1984)

Lithofacies map: 1 — limestones; *2* — clayey limestones; *3* — marls; *4* — sandstones; *5*—siltstones; *6* — mixed rocks; *7* — *a* — sandy limestones; *b*—lithoclastic limestones; *8* — breccia-conglomerates; *9* — claystones; *10* — marls with rare intercalations of siltstones; *11* — fauna; *12* — silifications; *13* — glauconite; *14* — Algae and corals; *15* — oölites; *16* — investigated sections in outcrops; *17*—investigated sections in drillings; *18* —lithological complexes with repeated rock types in the section; *19* — boundary between the lithological complexes; *20* —lithological complex with pointed out basement and upper part; *21* —lithological complex without section basement. *Sketch of the equal thicknesses (a): 22* — proved; *23* — probables. *Sketch of the palaeogeographic environment* (Early Aptian) (*b*). Marine environment: *24* — shallow shelf — carbonate platform; *25* — peripheral deeper part of the carbonate platform; *26*—shallow terrigenous (clayey-clastic) fan of the carbonate platform (in compensated basin); *27* — depression in the shelf; *28*—deep shelf. Continental environment: *29* — mountain relief; *30* — plate-like relief; *31* — compensated basin

G r u b i ć (1974) made an attempt to offer a new interpretation of the tectonic evolution of Eastern Serbia in the light of plate-tectonics, accompanied by palinspastic reconstructions for the Late Jurassic and the Early Cretaceous. In the opinion of that author, traces of palaeo-oceanic crust were preserved in the Krajna

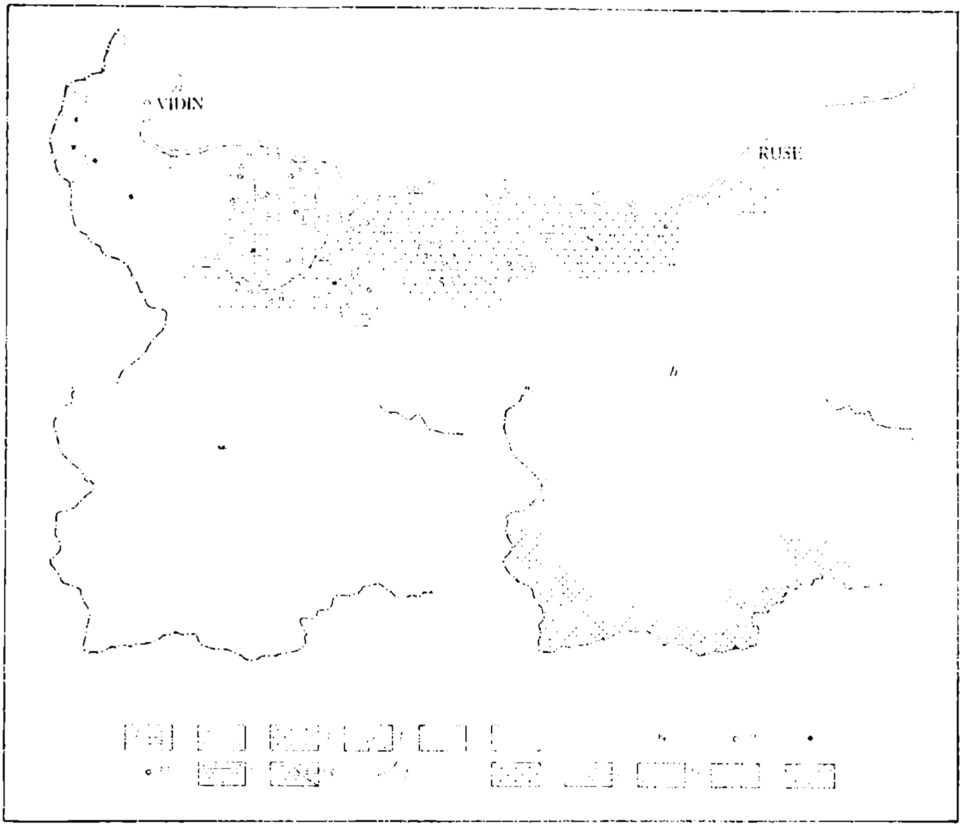


Fig. 31. Lithofacies map with sketches of the equal thicknesses and the palaeogeographic environments. Albian (after Рускова, Николов, 1984)

Lithofacies map: *1* — clayey limestones; *2* — marls; *3* — sandstones; *4* — marls with rare intercalations of siltstones; *5* — claystones; *6* — mixed rocks; *7* — glauconite; *8* — phosphoritic concretions; *9* — oölites; *10* — investigated sections in outcrops; *11* — investigated sections in drillings; *12* — lithological complex with repeated rock types in the section; *13* — boundary between the lithological complexes. *Sketch of the equal thicknesses (a)*: *14* — proved; *15* — probables. *Sketch of the palaeogeographic environments (b)*. Marine environments: *16* — shallow shelf; *17* — peripheral deeper part of the shelf; *18* — deep shelf. Continental environment: *19* — mountain relief; *20* — plate-like relief

area, traces of which appear in Deli Jovan. This opinion is supported: (1) by geophysical data about the existence of a thin granite layer below the pelagic sediments in the eastern part of the Danubian trough, and (2) by the development of volcanogenic-sedimentary rocks (Vratarnica series) with appearance of basic volcanites (Fig. 32).

The Dinarides are located to the west of the Dardanian diagonal and they form a part of the central zone of the Mediterranean Region, which will be discussed below.

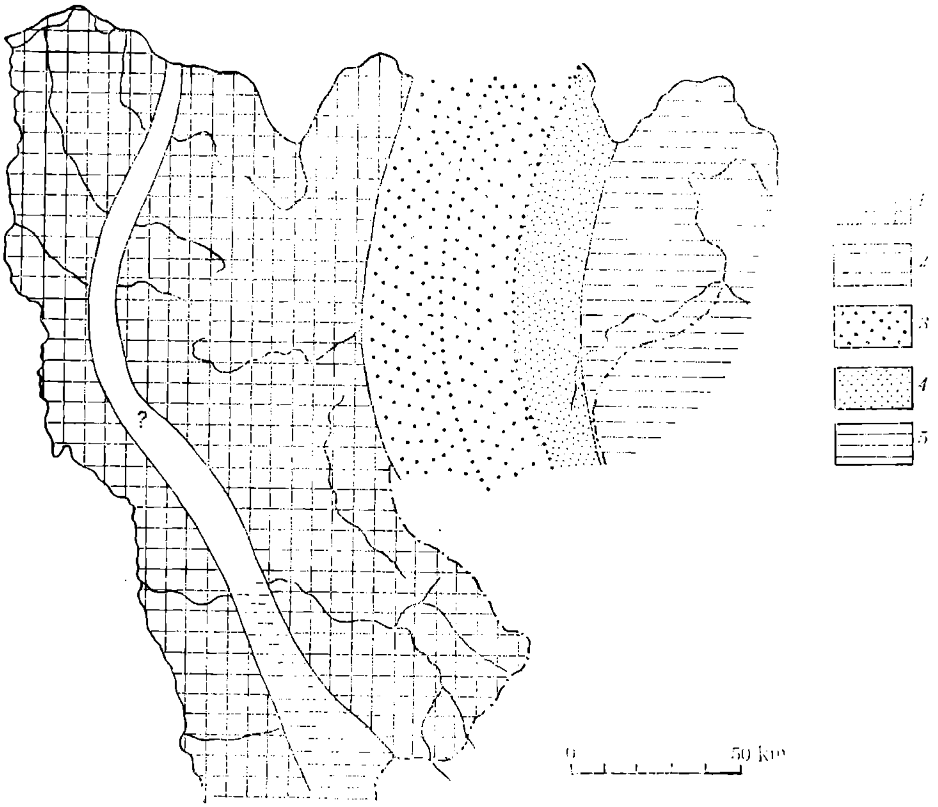


Fig. 32. Palinspastic sketch of Eastern Serbia during the Late Jurassic and Early Cretaceous (after G r u b i ć, 1974)

1 — Getic region and Serbian-Macedonian Massif; 2 — Lujnica flysch trough; 3 — Krajna region; 4 — Danube region; 5 — Moesian region

1.1.2. Distribution of Flysch Sediments

Flysch sediments form one of the most characteristic geogenerations in the Mediterranean Lower Cretaceous. Their distribution coincides with the basic arcs in the Mediterranean Region: the Gibraltar, Alpine and Carpathian-Balkan arcs from the north, and the Calabro-Sicilian and Dinaric-Aegean from the south, which indicates the great role of the tectonic control (D u r a n d D e l g a, 1980).

The flysch is also developed in two characteristic lineaments: Pyrenean and of the Kraištides, as well as in the Caucasian geosynclines.

The flysch sediments in the Mediterranean Region began to be formed at the end of the Jurassic as a result of the change taking place in the geodynamic situation between the two plates: African and Eurasian.

Here we shall examine briefly the Upper Jurassic-Lower Cretaceous flysch as a unified geogeneration in the following sequence, applied by D u r a n d D e l g a (1980) and slighty expanded here: (1) Carpathian flysch, starting with its best studied sections in Poland and proceeding westward to the Perialpine flysch, then eastward (Romanian Carpathians and the Fore-Balkan); (2) Caucasian flysch; (3) Dinaric flysch in the Bosnia-Beotian trough and the adjacent zones; (4) Apennine flysch; (5) Magreb flysch from Sicily to the Reef, with continuation into the Betic Cordilleras.

The Flysch in the Alpine—Carpathian—Balkan Belt

Flysch sediments occupy external position with respect to the orogen. In the **Polish and Czechoslovak Carpathians** flysch sediments occur between the Foreland from the north and the Pieniny lineament (klippes zone), where the Tithonian and the Lower Cretaceous are in pelagic facies.

Terrigenous flysch sedimentation began to be imposed gradually over the common argillite foundation of the Silesian facies. The succession was characterized in Chapter III: (1) Lower Tešin Beds; (2) Tešin Limestones; (3) Upper Tešin Limestones; (4) Wierzowice Beds; (5) Hradište Beds; (6) Lgota Sandy-Pellitic Flysch, largely resembling the facies of the Albian-Aptian flysch in North America. The direction of the transport of terrigenous material is predominantly west to east, though there are a number of local variants around the Inner Cordilleras. Coarse flysch is also formed around them. The basic material, however, comes from the Bohemian Massif (A n d r u s o v, 1965).

The North Alpine flysch is developed between Vienna and Isère, and it represents a westward continuation of the Carpathian flysch. The Lower Cretaceous is represented in this zone by: (1) clayey limestones with aptychi and breccia inclusions; (2) clayey limestones and sandstones (Upper Neocomian? - Aptian) — these two types are developed in the Bavarian Alps; (3) dark shales and glauconitic quartzitized sandstones (Gault-flysch).

The pre-flysch is developed further west (Foralberg flysch after Trümpy), which reaches the Rhein in the same tectonic position between the Helvetian and the Austro-Alpine zone. Carbonate flysch (Hauterivian - Aptian?) is developed in the south — in the Coir area, covering ophiolites (T r ü m p y, 1969). Breccia-like limestones with Orbitolinidae (Barremian-Aptian), Albian green quartzites and black shales are developed in the southernmost part of this zone.

The flysch in the **Romanian Carpathians** is the continuation of the zone of Southern Poland, which passes through the Ukrainian Carpathians and continues to the south. Extreme variety is observed among the flysch sediments in the Eastern Carpathians (see Chapter III), which demonstrate all basic facies.

Interesting is the development of pelagic clayey-calcareous sediments in the **Perşani zone**, among which breccias, conglomerates, calcarenites, sandstones and silicites with radiolaria appear locally, sometimes associated with diabases (М у-д ж я н у et al., 1961). There exist flysch formations both in the Mures geosyncline and in the Apuseni.

Azuga Beds are discovered in the Severin para-autochthone of the South Carpathians: mottled shales in association with serpentinites, diabases and gabbro, which are lense-like in shape (К о д а р ч а et al., 1961).

North of Severin the flysch zone passes into Serbia.

The development of the Lower Cretaceous flysch in **Bulgaria** is well known from a number of publications by Nachev, Nikolov and Khrischev. From the coarse flysch zone (Kostel Formation) there is a gradual transition to the north through sandy flysch (Zlatarica Formation), to typical flysch (Černi Osăm Formation) and subflysch (Tiča Formation and Salaš-Černi Osăm Formation).

Caucasian Flysch

Flysch sediments are widespread in the Crimea and in the Caucasus. A flysch with predominance of cryptomer varieties is developed in Eastern Crimea. In the Novorussijsk geosyncline there are varied flysch facies: from coarse to clayey-aleuritic flysch with siderites. A typical Lower Cretaceous flysch is developed in the Dibrar flysch trough in Southeastern Caucasus (Babadag flysch) (М и л а н о в с к и й, Х а и н, 1963).

Dinaric Flysch

The outer zones of the Dinarides and Hellenides contain carbonate facies. The flysch facies are in the inner zones, being structurally differentiated at the end of the Jurassic and mainly at the beginning of the Early Cretaceous.

The flysch in the **Bosnia-Beotian trough** is represented by two groups: an **external** group which overlies the Triassic or Jurassic, being represented by clayey-sandy flysch with *Hedbergella* and Orbitolinidae, covered by calcareous flysch (Middle -Upper Cretaceous), and an **internal** group situated discordantly over limestones or Triassic-Jurassic jaspers, covered in some places by red radiolarites. This second flysch group starts with conglomerates with ophiolitic fragments, alternating upwards with limestones which reach the Lower Cretaceous. The presence of the Berriasian is proved in the lower part (Durand Delga, 1980).

In the Ulog region (Dinarides) Blanchet (1966) and Cadet (1978) have proved the following flysch succession: (1) clayey-sandy flysch (Neocomian-Barremian); (2) black flysch (Barremian-Aptian and Albian), built of coarse-grained sandstones with ophiolite fragments, black calcareous argillites with calcareous breccias and pelagic limestones; (3) light sandy-calcareous flysch (Upper Albian-Cenomanian).

In the south, in the Hellenides, flysch Lower Cretaceous sediments are developed between the ophiolite zone of Mirditza and the palaeogene from the Pind nappe. This is a continuation of the Gramos zone from Albania.

The Beotian flysch (synonym to the Bosnia flysch) is developed in Greece. It is revealed in Northern Pind, Othrys, Beotia and in Argolid, south of Corinth (Celet, Clément, 1971).

In the north the Dinaric flysch continues into Slovenia.

Flyschoid Lower Cretaceous sediments are developed in the inner zone of the Dinarides, between the Bosnia trough and the Vardar zone. This is the strip of the Serbian ophiolites (Aubouin et al., 1970). In the Early Cretaceous palaeogeography this is the continuation of the Pannonian Depression to the south between Zagreb and Belgrade, stretching even further south into the Pelagonian zone of Greece.

Terrigenous-carbonate flysch is developed to the east of this zone, in Šumadia, parallel to the Dardanian diagonal.

The flysch in the Apennines

The Lower Cretaceous is developed in pre-flysch facies in the inner zone of the Northern Apennines over Jurassic ophiolites and radiolarites. The typical flysch starts at the base of the Upper Cretaceous.

The Maiolica facies (micritic pelagic limestones) is developed in the outer zone.

Lower Cretaceous allochthonous flysch which overlies the external calcareous zone of the Apennines is developed in the southern part of the Peninsula, in the boundary zone between the Apennines and Calabria.

In Lucania there is Lower Cretaceous flysch represented by argillites, phyllites and quartzites which overlie the calcareous Apennines.

Non-metamorphosed flysch (Berriasian-Albian) is discovered between Lucano—Calabria and Cilento.

The Flysch in North Africa

The Magreb orogen stretches from Calabria to the Gibraltar arc. Its northern axial zone represents numerous outcrops of allochthonous flysch (Lower Cretaceous-Lower Miocene).

Two basic types of flysch are distinguished in North Africa: (1) with facies which are relatively coarser (inner), with the Gerouch flysch as a typical example, often designated as Mauritanian flysch; (2) with facies among which phaneromeric varieties predominate, designated as Massilian flysch, revealed very well between Tenes and Constantine (Durand Delga, 1980).

The Magreb flysch zone continues through Gibraltar into **Andalusia**, where Mauritanian, Massilian and Gaditanian (Cadix) types of flysch are discovered in different tectonic positions (D u r a n d D e l g a, 1980).

1.1.3. Molasses

Molasse sediments are of terrigenous type, with a wide range of varieties whose formation is connected with orogenic phenomena. They appear usually during ages of sharply differentiated elevation. Only in rare cases the molasses precede the active tectonic events in some geosynclinal basins. Their appearance and propagation are a law-governed, but not always compulsory ending to the flysch-forming process.

Molasse sediments form complexes up to several kilometres thick and they manifest very high rates of formation (several hundred metres for a million years). The basic types of rocks are: conglomerates, sandstones (most frequently polymictic, calcareous, in some places with cross-stratification), siltstones, claystones (usually calcareous), clayey-aleuritic marls (usually with rich neritic benthic fauna), aleuritic and sandy limestones. Abundant plant detritus and imprints of vegetation are found among these sediments and especially among the sandstones and siltstones. Evaporites and coals are secondary formations.

The problem concerning the presence of molasse formations in the Bulgarian Lower Cretaceous has been discussed in the Bulgarian literature. N a c h e v (in А л е к с и е в et al., 1965 a; Н а ч е в, 1969; Н а ч е в, Я н е в, 1980) included in the "marine lower molasse formation" all Lower Cretaceous sediments from the upper parts of the Berriasian to the Aptian included (i. e. the flyschoid subformation and the Urgonian-terrigenous subformation of the flysch-flyschoid formation reported by K h r i s c h e v (in А л е к с и е в et al., 1965b). The lower boundary between what Nachev designates as Lower Cretaceous "lower molasse" and Tithonian-Berriasian flysch, is marked, in his opinion, by consedimentary tectogenesis at the end of the Berriasian (the so-called "Late Kimmerian orogenesis in the Niš—Trojan trough"), which divided different units with respect to tectonic style and degree of lithification. In our opinion, the so-called "Late Kimmerian orogenesis" at the end of the Berriasian in Bulgaria is only a weak reverberation of the real Early Kimmerian movements, without a clearly manifested tectonic result, especially in the style of the geological structures.

The upper boundary of the lower molasse is marked by clear angular discordance resulting from the Austrian phase in the Central and Eastern Fore-Balkan (Н и к о л о в, Х р и с ч е в, 1965b).

Ensuing from the concrete lithological composition of the Lower Cretaceous sediments, as well as from specific structures, especially in the Valanginian and Hauterivian deposits, K h r i s c h e v (in А л е к с и е в et al., 1965a,b) and K h r i s c h e v and R u s k o v a (1976) assume as molasse only the regressive facies of the shallow-water terrigenous-carbonate deposits of the Urgonian complex and its terrigenous-clastic fans in the volume of the Upper Barremian-Aptian, extensively developed in the Western, Central and Eastern Fore-Balkan, and partly in the Western Srednogorie region. This view has also been expressed in the work of R u s k o v a and N i k o l o v (Р у с к о в а, Н и к о л о в, 1984). The Lower Cretaceous flysch as a direct continuation of the flysch sedimentation from the end of the Late Jurassic comprises only the Berriasian. The entire intermediary range from the Valanginian to the base of the Upper Barremian, in some places the entire Barremian as well, is attributed to the so-called flyschoid transgressive sediments which have preserved in some places, especially at the initial stages (e. g. the Valanginian marly-sandy sediments in the core of the Elena anticline), the characteristic rhythmic nature of the flysch sediments, while elsewhere (e. g. the thick sandy banks in the Hauterivian from the core of the Sevlievo anticline) they contain specific, though separate, flysch textures. These are convolutions, ripple marks, gradational stratification, mechanical and biological hieroglyphs, etc. From a lithological point of view here belongs the Kamčija Formation which is widespread in the Central and Eastern Fore-Balkan, the so-called flyschoid sediments of N i k o l o v and K h r i s c h e v (Н и к о л о в, Х р и с ч е в, 1965b) (Zlatarica Formation — Н и к о л о в, С а п у н о в, 1970), the mixed rocks with intercalations of sandstones from the Hănevci Formation and the marly-sandy (with conglomerates) sediments of the Western Srednogorie region, characterized in Chapter III.

Of particular interest is the Roman Formation which fills the Iskăr Depression and spreads eastward to Gabrovo area. It is built of calcareous limestones, siltstones, clayey-aleuritic marls, sandy limestones with very varied benthic fauna, plant remnants and biogenic (phyto- and zoogenic) detritus. The main factor for the emergence of the Roman Formation is the effect of the mountainous rivers which brought enormous amounts of terrigenous material into the constantly depressing trough. Sediments with thickness exceeding 3000 m were formed for about six million years (Late Barremian-Middle Aptian). The terrigenous sediments of this Formation are with a relatively lower degree of lithification. The Roman Formation represents terrigenous fans of the Urgonian platforms in the Central Fore-Balkan.

Similar sediments are also found in the northeastern part of the Early Cretaceous Basco-Cantabrian Bay (R a t, 1969) where the lower molasse is represented by terrigenous-carbonate sediments (the so-called Cantabrian Urgonian) with thickness up to 6000 m and age range Aptian-Lower Albian. To the southwest these sediments pass into red clayey-sandy deposits of Wealdian type (deltaic facies). They overlie Neocomian marls and are covered discordantly by upper molasse (Upper Albian-Cenomanian).

An interesting transition is observed in the Basco-Cantabrian Region of the Pyrenees between the peripheral molasse, represented by the so-called Cantabrian Urgonian (terrigenous sediments with lenses of Urgonian limestones) and continental molasse (which should be termed more correctly as molassoid complex), represented by continental lacustrine, lagoonal and coastal-marine sediments of Wealdian type.

In the Romanian Carpathians the Lower Cretaceous molasse sediments have a more limited distribution. With few exceptions, they are connected with the nappes in the Eastern-Carpathian central folded belt. In fact, as regards the time of formation with respect to the entire Carpathian arc, this is the first molasse formation of Albian age, which is well represented in the following deposits:

1. Coarse molasse from the Post-Tectonic cover of the Transylvanian and Central (Eastern Carpathian) nappe systems of Albian age. These are coarse deposits of molasse type, predominantly conglomerates and sandstones, covering different structural units of the two nappe systems, and whose formation was preceded by an intensive, though brief period of erosion. Their characteristic features are fast lateral change, as well as considerable variations in the thickness and lithological composition of the sediments.

2. Coarse molasse (Aptian-Albian) in the region of Postavaru Mountain. It appears discordantly as Post-Tectonic cover over predominantly carbonate sediments of the Braşov lithostratigraphic unit. Its composition comprises conglomerates (the so-called "Postavaru Conglomerates"). At their base there are often sedimentary klippes, the most important among them being found in the Pietrele lui Solomon region. The age of the early klippes is Early Jurassic-Neocomian.

3. "Bucegi" conglomerates of the coarse molasse of Albian age, covering Barremian-Aptian flysch sediments (Piscu cu Brazu facies), west of the Prahova valley — in the valley of Urlatearelor river. Its composition comprises polymictic conglomerates with different cementation and grey coarsely-grained massive sandstones whose stratification is often unclear.

4. Coarse molasse of Albian age in the valley of Maieroush, whose substrate (Aptian flysch) is with unclear tectonic position. Its composition comprises conglomerates with a sandy basic mass and fragments of rounded Triassic, Upper Jurassic and Urgonian limestones, and to a lesser degree sandstones.

In the South Carpathians (Reşiţa zone) there are Albian molasse sediments: conglomerates, sandstones and claystones.

The Albian sediments in the Paris Basin, Jura Mountains, the Šumadia zone, Eastern Serbia and the Northwestern Fore-Balkan are of the molasse type.

Upon increasing the distance to the mountain ridges, the Lower Cretaceous molasses lose the conglomerates and are replaced, especially in their lower part, by marine sediments — mainly sandy-clayey or carbonate. This is particularly pronounced in the Basco-Cantabrian region, the Carpathians and the Iskăr Depression.

1.1.4. Carbonate Platforms

Excluding the extensive development of pelagic limestones and clayey-calcareous ediments, in addition to the flysch complexes carbonate platforms are a particuarly characteristic geogeneration for the Mediterranean Lower Cretaceous.

During the Early Cretaceous the depression zones were surrounded almost everywhere by thick limestone massifs and limestone banks, built predominantly of rudists, algae and corals. Similar limestone buildings which are of platform character are developed in some places in the regressive phase of some troughs. In the Bulgarian literature Khrischev (Хрисчев, 1966; 1969) was the first to draw attention to the Lower Cretaceous carbonate platforms.

A characteristic feature of the Lower Cretaceous carbonate platforms in the Mediterranean Region is that they are frequently associated with terrigenous and/or terrigenous-carbonate sediments. Such is the character of the carbonate platforms in the High Plateaux (Algeria — Tunisia), as well as in a number of zones in the Iberian Peninsula, in the Carpathians, the Fore-Balkan, the Crimea and the Caucasus.

The development of several carbonate platforms around the Vocontian trough is characteristic: Cevenol, north of Montpelier, Provence and Jura Mountains. They are characterized by very varied limestone microfacies, with predominance of bioconstructed limestones. In Jura Mountains and in Provence there are terrigenous inclusions (Arnaud-Vaneau et al., 1982a). The development of the carbonate platform in Sardinia is similar to that in Provence.

Carbonate platforms are developed in the Pyrenees as well, being connected predominantly with Urgonian facies (Peybernes, 1982).

Several small Urgonian platforms are known in the Basco-Cantabrian zone (Pascal, 1982).

Carbonate platforms are formed in the Iberian Peninsula, some of which are connected with the Hauterivian as well (Canerot, Cugny, 1982).

There are Urgonian limestones in the Alps and in the Carpathians, but it is difficult to investigate them comprehensively due to the complex tectonics. The only detailed study has been carried out in the Ukrainian Carpathians (Чернов et al., 1980).

The carbonates of the Moesian Platform (Upper Jurassic-Aptian) are prominent, being of the type of the Provence carbonates.

In the Fore-Balkan there are the following carbonate platforms from west to east: Magura (Urgonian), Vraca (Urgonian), Brestnica (Tithonian-Barremian), Dragojca (Urgonian), Loveč (Urgonian) and Straža (Urgonian). Thick terrigenous sediments are usually developed among them, as in straits.

The carbonate sediments in the Crimea and the Caucasus do not build typical platforms. Platform Urgonian carbonates are developed only over the Georgian Block.

Characteristic carbonate platforms occur in the Dinarides and in the Middle East.

A common feature of the Lower Cretaceous carbonate platforms is that they are formed at the expense of biochemical accumulation of carbonates *in situ*, accompanied by mass development of rudists, as well as other bivalvs, corals, gastropods, echinids, large foraminifera and algae.

The following zones are usually distinguished: (1) inner shallow-water zone with low hydrodynamic energy and rich benthos, including many rudists; (2) middle shallow-water zone connected with elevation — it is characterized by high energy and extensive development of corals (in bioherms and biostromes), formation of oölitic and bioclastic limestones accompanied by lense-like micritic limestones; (3) outer, deeper-water zone with low energy (referred to as phondothema or basin), in which carbonate and terrigenous sediments (mainly of pelitic order) often blend (R a t, P a s c a l, 1982).

Several facial belts are differentiated in this general plan, and they are traced from the axial to the outer part of the platform (W i l l s o n, 1975; R a t, P a s c a l, 1980).

K h r i s c h e v (Х р и с ч е в, 1967) has demonstrated on the example of the Loveč Urgonian Group the basic types of relationships between the terrigenous sediments and the carbonate platforms. These types may be observed every where in the Mediterranean Region.

Carbonate platforms testify to warm climate and stable tectonic condition during their formation.

2. Mobile Belts

The development of the Lower Cretaceous in the Mediterranean Region outlines the middle zones of the ocean, which are usually inherited mobile zones from the Jurassic.

To the mobile belts we attribute the central parts of the Mediterranean Region, in which there is ophiolitic magmatism, as well as the zones of the intensive depressions, which are loaded with thick flysch sediments. Frequently the zones of flysch formation are tied to the active continental margins and form flysch wedges in the subduction zone (A u b o i n, 1973). This shows that the Early Cretaceous marks the transition from the regime of extension of the lithosphere in the Tethys to contraction of Pacific type.

1.2.1. Early Cretaceous Ophiolites, Volcano-Sedimentary Complexes and Radiolarites

Early Cretaceous basaltic volcanism is manifested in the continental base of Northwestern Africa and in the Iberian Peninsula (Chapter III).

Peridotites of Aptian-Albian age are observed in the Pyrenees at Bestiac, southeast of Tarascon (P e y b e r n e s, 1976). In this region the Aptian-Albian sediments are slightly metamorphosed.

Alkaline intrusions (nepheline syenites) of Albian age occur in Corbier (Fig. 33).

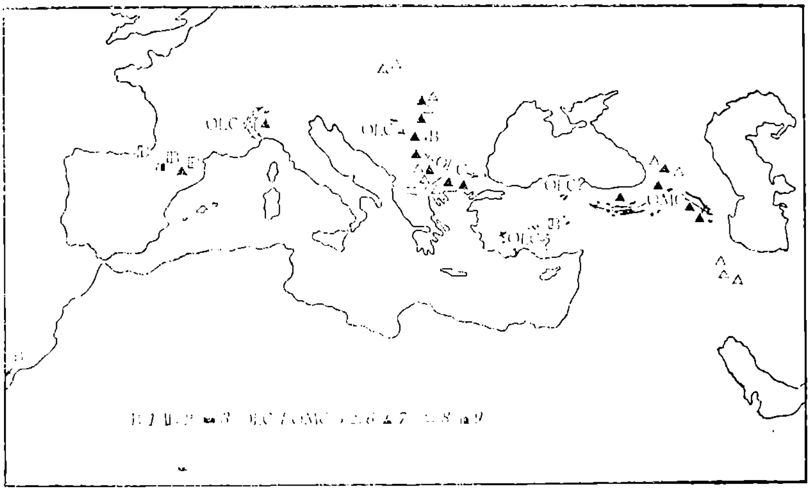


Fig. 33. Distribution of the Cretaceous ophiolite suite, basalts and metamorphism in the Mediterranean Region (based on data of various authors, simplified after D e w e y et al., 1973)

1 — Lower Cretaceous basalts; *2* — Middle Cretaceous (Albian) basalts; *3*—outcrops of ophiolites; *4* — Lower Cretaceous ophiolites; *5*—Middle Cretaceous (Albian-Cenomanian) ophiolites; *6* — Lower Cretaceous volcanism; *7*—Middle Cretaceous (Albian-Cenomanian) volcanism; *8*—Lower Cretaceous metamorphism; *9* — Mddle Cretaceous metamorphism (mainly post-Albian and pre-Cenomanian)

During the Albian-Cenomanian time there was considerable magmatic activation in the Western and Central Pyrenees to the west of Garone, represented by basalts to trachites, sometimes hyperalkaline. This magmatism is connected with considerable faulting of the crust along the Northern Pyrenean fault, which is considerad to be of the transform type (A u t r a n, D e r c o u r t, 1980).

In the Piemont zone of the Alps the Lower Cretaceous is represented by schistes lustrées, radiolarites and limestones with calpionellids, which overlie ophiolites and radiolarites (Triassic-Jurassic). Basalt volcanism is also manifested in this zone (D e w e y et al., 1973).

In the southern part of the Pannonian Massif (Meczek) there are volcanogenic formations in the Valanginian, represented by clayey limestones with calpionellids, trachydolerite tufogenic formation and above them marls with intercalations of sandstones. Their formation is probably connected with a deep transform fault in the northern arc of the Middle Tethyn Ridge (D e r c o u r t, 1971, p. 276).

The Lower Cretaceous volcanogenic-sedimentary complexes are considerably developed in the Apuseni, the Carpathians and Caucasus Minor, where they are associated with ophiolites and radiolarites (Chapter III).

A number of intrusive massifs were also formed in Caucasus Minor during the Early Cretaceous, predominantly quartz-dioritic and granitic, but also with gabbro differentiations. The age of most intrusions is 100-120 million years (Barremian-Albian), of the Cav Massif in the Kafan region — 132-135 million years (Barriasian) (М и л а н о в с к и й, Х а и н, 1963).

Considerable Early Cretaceous ophiolitic magmatism is manifested in Trodos (Cyprus) and Kizil-Dag (Turkey). The age of the Kizil-Dag dolerites is 150-80 million years, being formed most intensively during the Early Cretaceous (130-110 million years). Part of the Kizil-Dag gabbro is also Early Cretaceous (130-100 million years).

Trodos ophiolites are Late Cretaceous, with the exception of part of the Trodos dolerites formed in the interval 130-120 million years (Valanginian-Hauterivian) (D e l a l o y e et al., 1980). The position of the Trodos and Kizil-Dag ophiolites indicates formation in the Tethys oceanic crust, along a zone of ophiolite obduction, which was particularly active during the subsequent Late Cretaceous Epoch.

Deep-sea limestones, often with radiolarite intercalations, are developed in the Alps, especially in the Southern Alps, the northern part of the Apennines, in the Dinarides and in the Hellenides. Their development has inherited everywhere the zone of ophiolites. This is also the type of the Lower Cretaceous rocks in the Southeastern Rhodopes, where they are also slightly metamorphosed.

1.2.2. Orogenic Manifestations during the Early Cretaceous

In the generalized scheme of Mesozoic folding movements the Early Cretaceous follows after the Early Kimmerian phase and ends with the Austrian phase. A number of regional discordances are established between these two widespread phases in the Mediterranean Region, indicating greater tolerance in the time of the folding movements (Fig. 34).

In 1940 E. B o n č e v (Б о н ч е в, 1940) defined a synorogenic (Germanotype) phase between the Barremian and the Aptian in Northeastern Bulgaria.

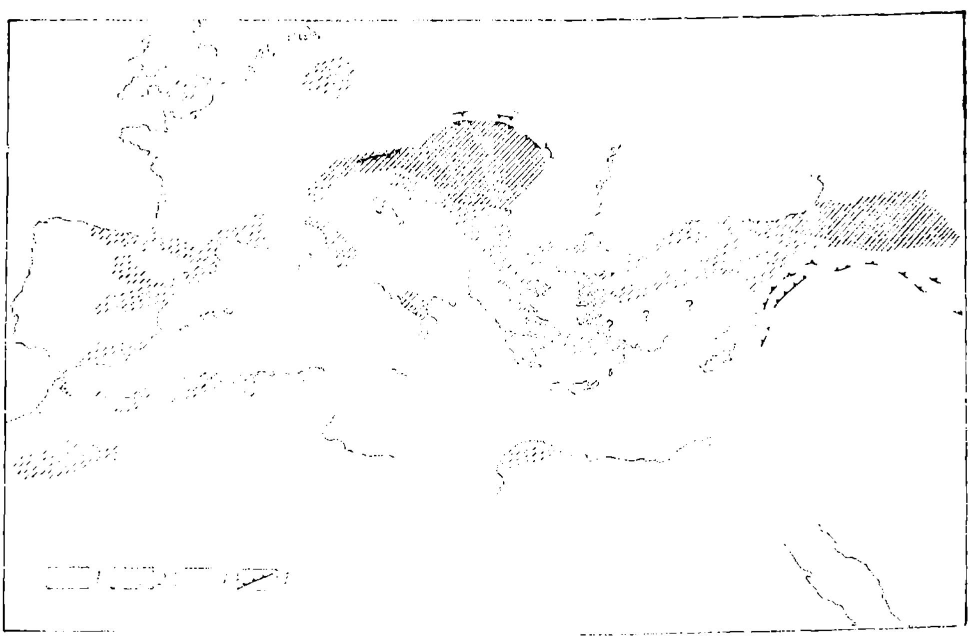


Fig. 34. Sketch-map of the pevelopment of the Early and Middle Cretaceous folding and flysch sediments in the Mediterranean Region (after A r g y r i a d i s, 1974)
1 — flysch; *2* — significant tectogenesis; *3* — moderate tectogenesis; *4* — napping front

Indeed, the facts which this researcher referred to did not prove to be accurate. According to more recent data, in a regional plan, the coastal part of Bulgaria began to rise after the Barremian and the basin gradually retreated to the west (Николов, 1969b).

Comparison with other areas in the Mediterranean Region produced surprising results which suggest the first impulse of tectonic activation in a number of zones as early as the beginning of the Barremian. Strong faulting in several belts and ingression of sea waters into grabens took place in the Iberian Peninsula. Orogenic movement was manifested in the Pyrenees, which is responsible for the discordant position of the Barremian sediments over a varied basement. A second orogenesis appeared during the Gargasian, followed later by Middle and Late Albian orogenesis.

The post-Aptian folding is particularly strong in Eastern Corbier, which lasted in some places after the Late Albian and before the Cenomanian (Durand Delga, 1965a).

Intensive folding occurred in the Central and Eastern Fore-Balkan after the Early Aptian, causing regression of the basin to the north-northwest, and transgressive and discordant position of the Upper Cretaceous over the Lower Cretaceous rocks.

Analogous and synchronous (Aptian-Albian) movements existed in the Caucasus.

The basic orogenic manifestations in the Mediterranean Region during the Early Cretaceous will be discussed briefly below.

In North Africa the Early Cretaceous movements are found in several regions, where they have clear and considerable manifestations. The earliest movements established for the dawn of the Cretaceous Period are manifested in this area (the zone of the Moroccan Atlas and the Cabiles). They are as a refrain to the Early Kimmerian movements in the middle of the Berriasian. These movements are characterized by two types of phenomena: folding and magmatism. Folding causes regression, hiatuses and discordance. Magmatism is manifested in the Moroccan Atlas (Demnate — Beni-Mellal) after the folding and it is represented by intrusions and effusions of basic to alkali rocks of Early Cretaceous (mainly basalts and gabbro) (Michard, 1976).

In the Pyrenees the Early Cretaceous tectonics is well manifested through several considerable activations which have left defining characteristics in the structure of the entire mountain range. There exist different opinions about the character of these movements: (1) according to some authors, these are mainly vertical movements resulting from intensive faulting; (2) according to other sources, these are tectonic movements under conditions of shrinking with appearance of considerable horizontal displacements. The following points are indisputable:

1. There was unusual magmatic activation with formation of basic and ultrabasic rocks in the Northern Pyrenees during the Early Cretaceous, which is related to pre-Aptian tectonics.

2. Several clear regional discordances are established, connected with orogenesis before the Barremian, before the Gargasian, before the Middle Albian and before the Late Albian (Peybernes, 1976).

3. The most considerable folding occurred before the Cenomanian, when probably the Lower Cretaceous sediments were slightly metamorphosed.

As it was noted, traces of clear Early Cretaceous folding were observed in Corbier as well.

In Sardinia, Chabrier (1970) has found folding after the Early Cretaceous, as a result of which basal conglomerates of the Upper Cretaceous lie transgressively and discordantly.

In the Apennines, G r a n d j a c q u e t et al. (1972) have described considerable movements of Albian age.

The Eastern Alps are justifiably accepted as the classical model of Early Cretaceous tectonic manifestations. It is known that in this area the Upper Cretaceous Gosau Beds overlie transgressively and discordantly an older basement. According to T o l l m a n n (1963; 1969), the Cretaceous movements in the Eastern Alps form two main complexes:

— The first complex comprises the pre-Cenomanian (Austrian phase after Stille) and the pre-Gosau (Mediterranean) phase. According to Tollmann, at the time of this folding the large nappes were formed, in which Austrian-Alpine units follow one above the other, on the one hand, and in addition to this — the napping of the Pieniny zone over the Ultrapieniny zone, on the other.

— The second complex groups comprise the post-Gosau phases (Illyrian and Pyrenean).

T o l l m a n n' s interpretation is disputed by many authors (e. g. A r g y r i a d i s, 1974), therefore only indisputable facts will be presented here.

1. Hauterivian-Barremian folding is established (Austrian-Alpine phase), during which the nappe of the Juvanids was formed (the upper complex of the nappes in the Northern calcareous Alps, including the Halstatt and Dachstein nappes), and it overlies the Tyrolides. This is evidenced by the Aptian breccia originating from these nappes, discovered by M e d w e n i t s c h (1955).

2. The Austrian (pre-Cenomanian) folding was established for the first time by S t i l l e in 1924, who defined it as the main phase for the Eastern Alps. This phase marked the formation or the reconstruction of a number of folds and / or nappes, and especially the strong shifting of the upper Austrian-Alpine nappes above the Pieniny zone (T o l l m a n n, 1963; 1969).

3. It is established that there are no traces of rocks earlier than the Lower Cretaceous in the Austrian Alps. A r g y r i a d i s (1974) emphasized the following facts:

— The youngest rocks in the Pieniny are Jurassic.

— In the lower Austrian-Alpine nappes the youngest sediments are Neocomian.

— In the middle Austrian-Alpine nappes the section ends with Upper Jurassic limestones containing aptychi.

— In the upper Austrian-Alpine nappes the section ends with Neocomian sediments which are covered by post-tectonic Gosau Beds.

All this is evidence that the most intensive movements in the Austrian Alps are pre-Cenomanian.

Rather strong Early Cretaceous movements in the Romanian Carpathians are known from Perşany (the southern part of the Eastern Carpathians) and in the South Carpathians. They coincide with the Austrian phase. Considerable horizontal movements are manifested, whereby the Lower Cretaceous rocks are folded and in some places they form nappes. They are covered by Cenomanian sediments. There exist individual local tectonic manifestations even before the Albian, but they are of limited importance.

The Austrian phase is intensively manifested in the Apuseni as well. The basic nappes were formed during this phase, whereas the first clearly transgressive sediments, lying both over the nappes and over the autochthone, are Senonian (S a n d u l e s c u, 1968).

As it was pointed out, intensive Aptian-Albian tectonic movements are discovered in the Caucasus as well.

The brief analysis of the folding movements during the Early Cretaceous in the Mediterranean Region indicates that they were manifested several times in different parts of the region, starting with the Berriasian until the end of the Albian.

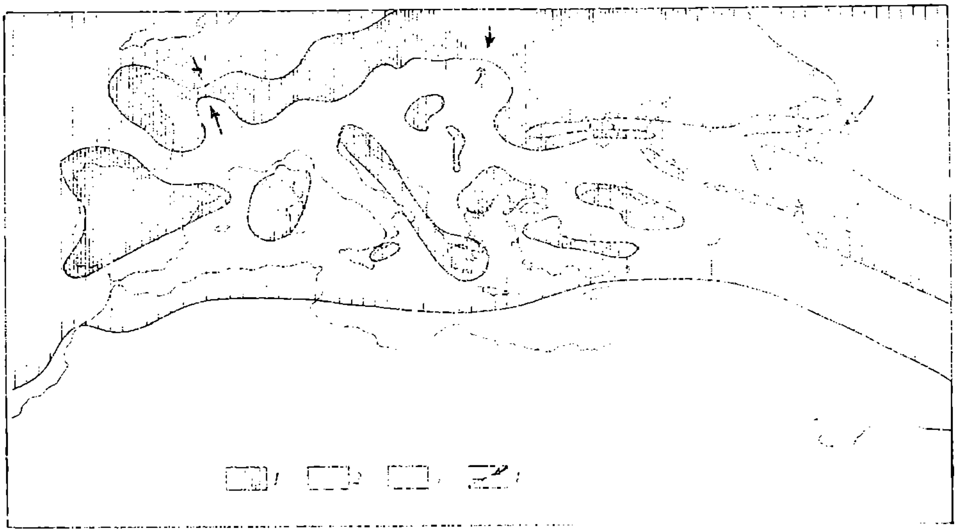


Fig. 35. Palaeogeographic sketch of the Mediterranean Region and the adjacent areas during the Berriasian and the Valanginian

1 — dry land; *2* — marine basin; *3* — Purbeckian-Wealdian continental basins; *4* — zones of intensive faunistic migrations between the Mediterranean and the Boreal Basins

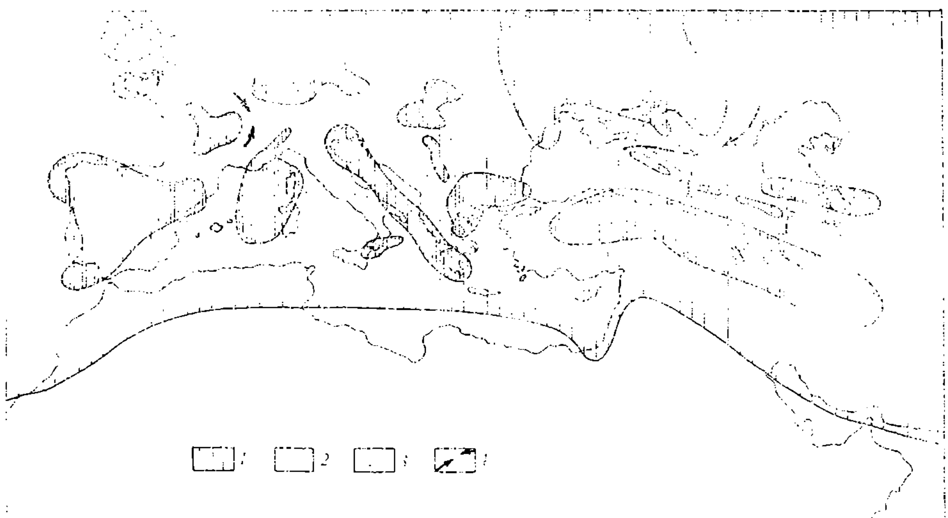


Fig. 36. Palaeogeographic sketch of the Mediterranean Region and the adjacent areas during the Hauterivian and Barremian

1 — dry land; *2* — marine basin; *3* — Purbeckian-Wealdean continental basins: *4* — zones of intensive faunistic migrations between the Mediterranean and the Boreal Basins

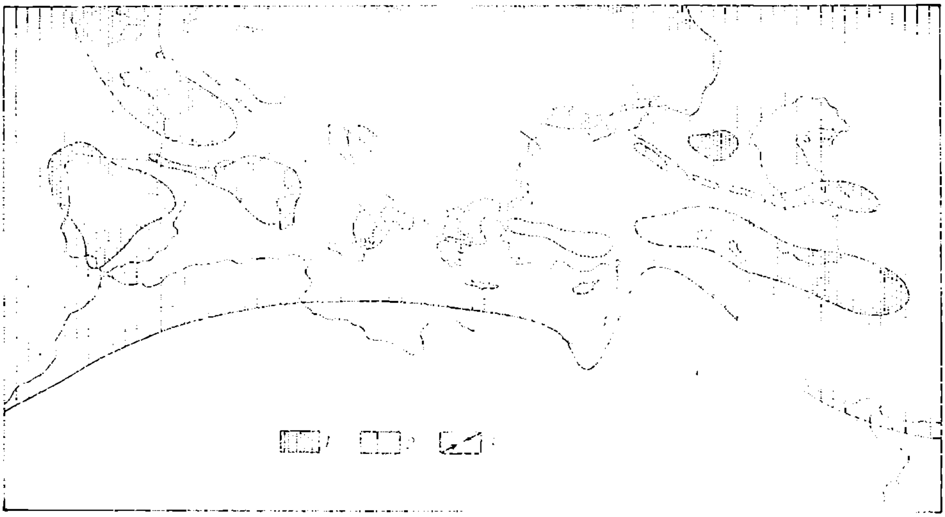


Fig. 37. Palaeogeographic sketch of the Mediterranean Region and the adjacent areas during the Aptian

1 — dry land; *2* — marine basin; *3* — zones of intensive faunistic migrations between the Mediterranean and the Boreal Basins

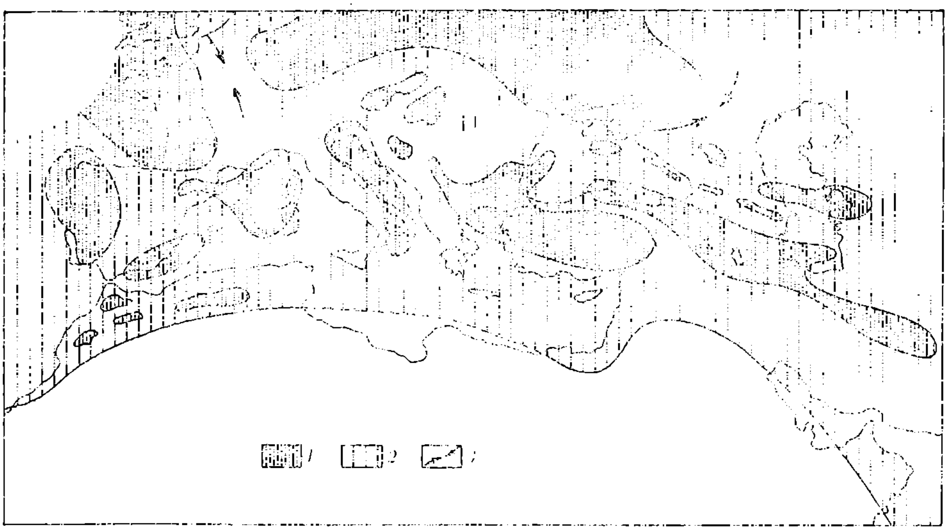


Fig. 38. Palaeogeographic sketch of the Mediterranean Region and the adjacent areas during the Albian

1 — dry land; *2* — marine basin; *3* — zones of intensive faunistic migrations between the Mediterranean and the Boreal Basins

Most considerable activations occurred during the Barremian and Aptian, being however relatively regionally limited, whereas the strongest and the most widespread Early Cretaceous folding took place after the Albian. Consequently, the great Austrian revolution was prepared by a series of regionally limited orogeneses from the Barremian to the Albian, in order to achieve a decisive tectonic transformation in the Mediterranean Region at the end of the Albian and before the Cenomanian.

2. SOME SPECIFIC FEATURES IN THE GEOLOGICAL DEVELOPMENT OF THE MEDITERRANEAN REGION AND THE OPENING OF THE ATLANTIC OCEAN DURING THE EARLY CRETACEOUS

2.1. General Notes

Progress in geophysical research, as well as deep-sea drilling (JOIDES, IPOD) have contributed to the clarification of the geological evolution of the ocean basins.

There are grounds for assuming that the Early Cretaceous evolution of the Mediterranean Region was predestined to a considerable extent by plate-tectonics. Evidently, the conflict between the two large plates — African-Arab and Eurasian — played a defining role. The complex configuration and the specificities of the Early

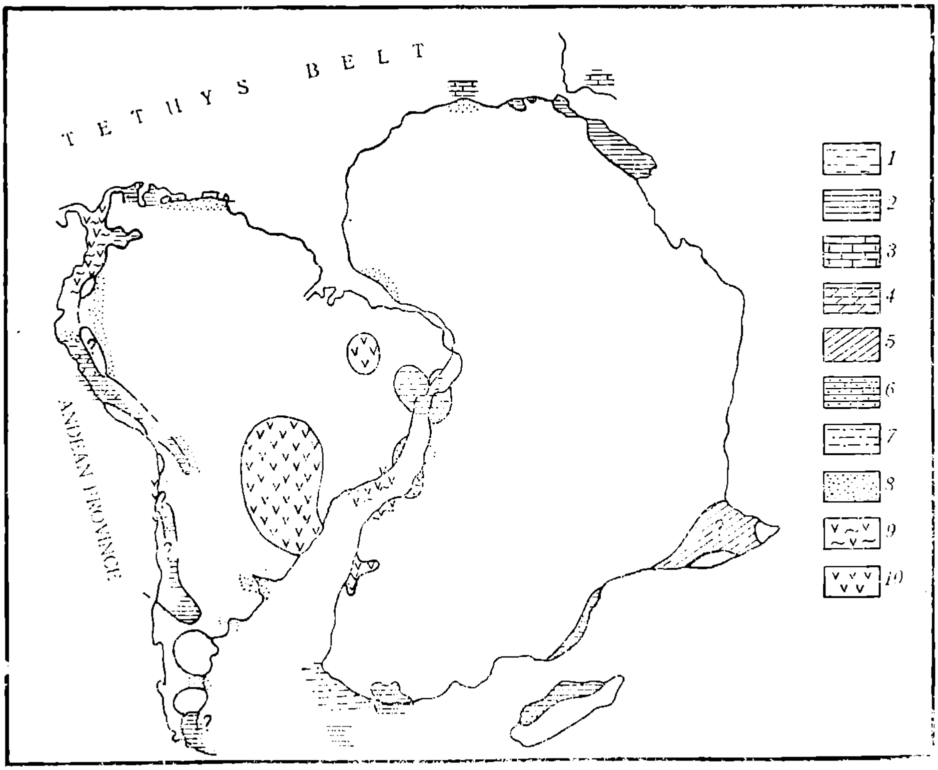


Fig. 39. Sketch-map of the distribution of the Valanginian sediments in South America, Africa and the Atlantic Ocean (after W i e d m a n n, 1982)

1 — clays; *2* — shales; *3* — limestones; *4* — dolomites; *5* — marine (undifferentiated) sediments; *6* — sandstones; *7* — limnic deposits; *8* — continental sands and sandstones; *9* — basin facies with volcanics; *10* — volcanics, undifferentiated

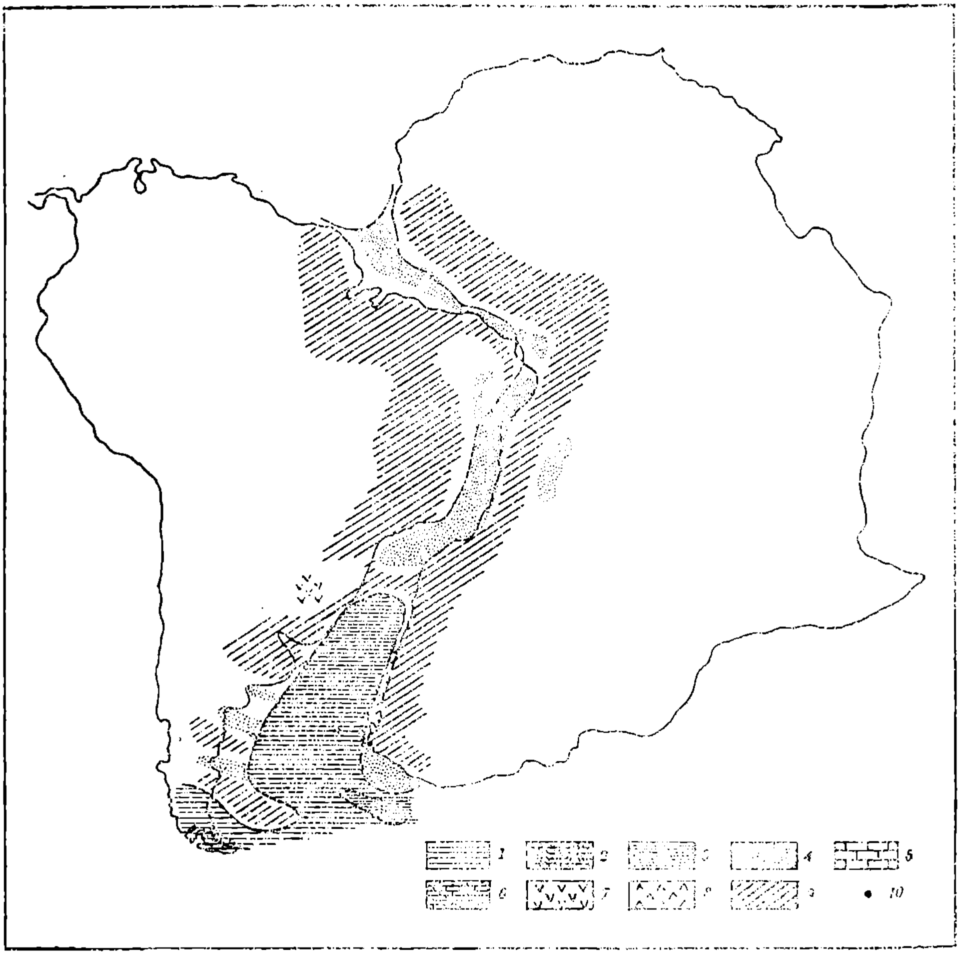


Fig. 40. Palaeogeographic sketch-map of the South Atlantic during the Barremian (after W i e d m a n n, 1982)

1 — marine clayey sediments; *2* — continental claystones; *3* — sapropelites; *4* — sands, continental/marine; *5* — ooze; *6* — reef limestones; *7* — volcanics; *8* — evaporites; *9* — dry land; *10* — DSDP-Sites

Cretaceous basins are a reflection of the mosaic of microplates and the network of faults between them (Fig. 35-38).

Moreover, of great geological significance was the formation of the Atlantic Ocean, whose opening was most intensive during the Early Cretaceous. A number of geodynamic specificities in the Mediterranean are connected with it.

With the awareness that this problem is equally interesting and speculative, only some general specificities will be discussed below.

2.2. Palaeomagnetic Data about the Movement of Microplates in the Mediterranean Region during the Early Cretaceous

It is known that many geologists consider the Alpine folded ranges as a continuous system. In fact, the boundaries between the different zones are most frequently connected to transform faults along which rotation of the plates took place.

C a r e y (1958) was the first to note that the Bay of Biscay and the Pyrenees were formed by counter-clockwise rotation of the Iberian Platform. This has been proved by a number of investigations of palaeomagnetism (D e w e y et al., 1973). This rotation occurred at about 35° with respect to Europe during the Early Cretaceous (135-110 million years). It is not accidental that the Pyrenees were a very active tectonic zone at that time. The development of the sediments in the Bay of Biscay during the Cretaceous suggests that the opening of the bay was completed before the Campanian.

The fragments separated at the beginning of the Jurassic from the northern end of the African Platform (Oranian and Morocco microplates) gradually turned by about 15° to the northwest and became stabilized at the beginning of the Early Cretaceous. The South-Atlas fault formed to the south of them played a major palaeogeographic role during the Early Cretaceous.

Moreover, a relative movement was established between Africa and Europe in the course of the Early Cretaceous, whereby in the Western Mediterranean

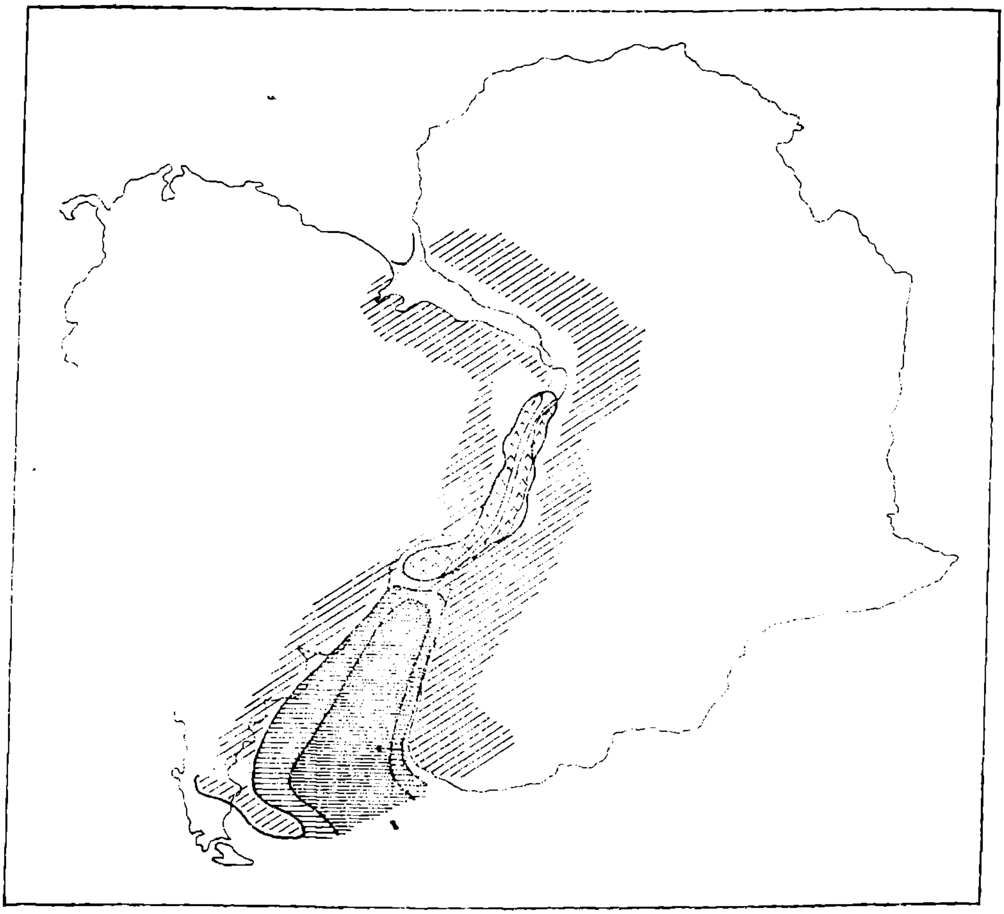


Fig. 41. Palaeogeographic sketch-map of the South Atlantic during the Early Aptian (after W i e d m a n n, 1982). Designations as in Fig. 40

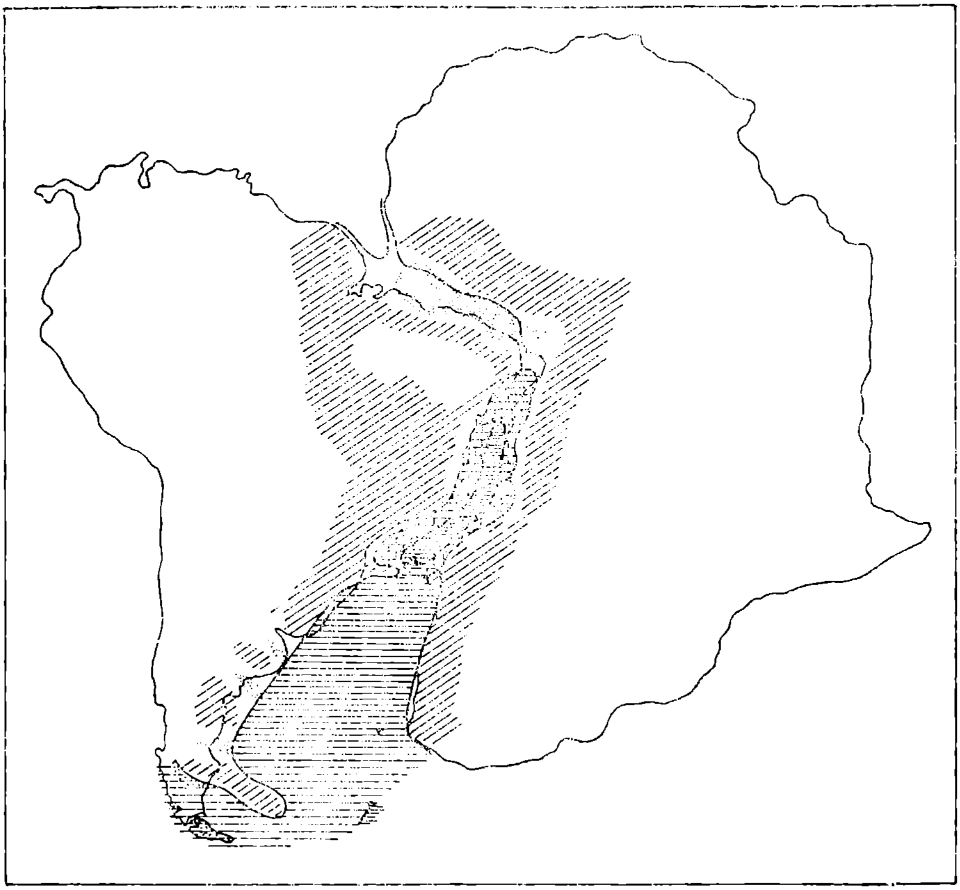


Fig. 42. Palaeogeographic sketch-map of the South Atlantic during the Late Aptian (after W i e d m a n n, 1982). Designations as in Fig. 40

Region this movement was predominantly convergent, and in the Eastern Mediterranean Region — divergent (D e w e y et al., 1973).

2.3. Opening of the Atlantic Ocean

Various authors have emphasized the close connection existing between the evolution of the Tethys (including the Mediterranean Region) and the opening of the Atlantic Ocean.

The evolution of the Atlantic Ocean comprises the following main stages: (1) early riftogenesis accompanied by red sediments and alkaline volcanites; (2) evaporites; (3) black shales; (4) first deltaic sediments; (5) carbonate platforms; (6) intensive depression of the continental margins, which is well demonstrated in the correlation of the sections from Morocco and the Iberian Peninsula with the boreholes in the continental margin (Chapter III); canyons, thick turbidites, athols and condensations in the upper part of the slope and / or in the shelf were formed during this stage; (7) expansion of the pelagic facies and decrease of the facial variety; (8) emergence of the modern system of oceanic currents (D i e t z, H o l d e n, 1970; G r a c i a n s k y et al., 1979; Von R a d et al., 1982).

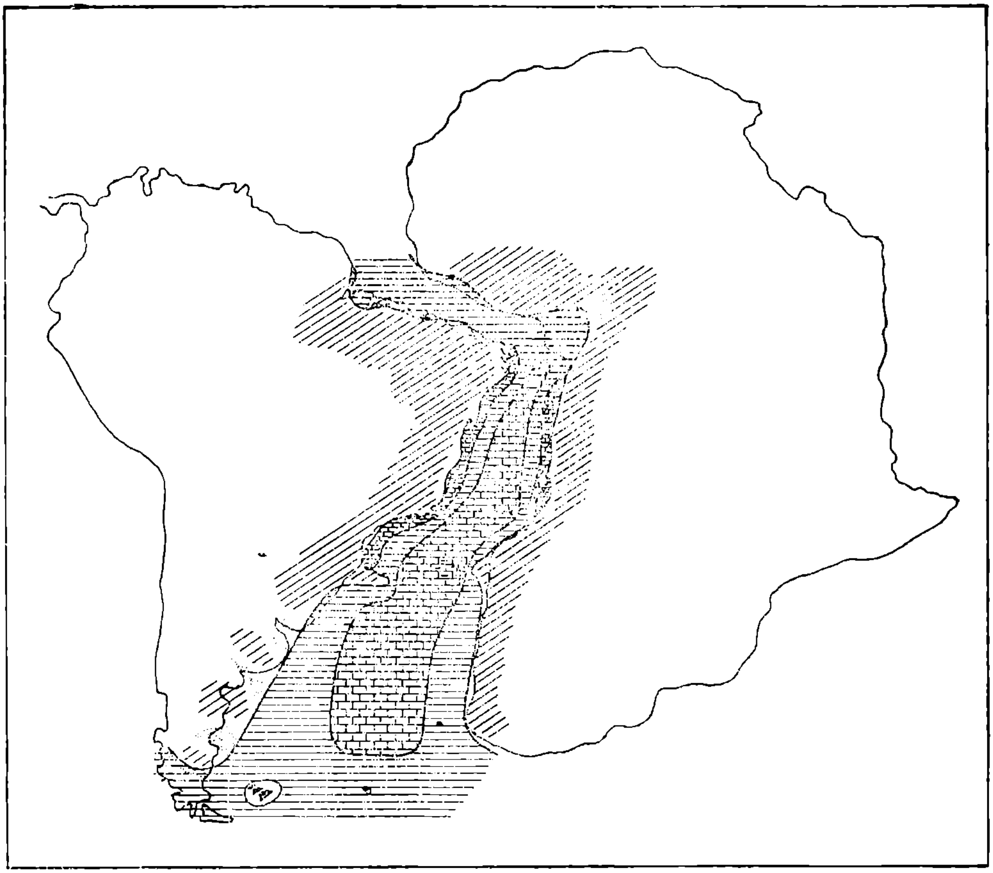


Fig. 43. Palaeogeographic sketch-map of the South Atlantic during the Albian (after W i e d m a n n, 1982). Designations as in Fig. 40

The opening of the Atlantic Ocean took place during the Early Cretaceous. W i e d m a n n (1982b) has generalized the data about the development of the Lower Cretaceous in the South Atlantic, which demonstrate well the noted basic stages in the evolution of the Atlantic Ocean (Figs. 39-43).

D e r c o u r t (1971) assumes with justification that towards the end of the Late Jurassic the Tethys stopped to be the active zone and this is connected with the intensive development of the Atlantic Ocean. This is why, the Early Cretaceous Epoch in the Mediterranean Region is relatively calmer compared with the Late Jurassic and Late Cretaceous.

2.4. Early Cretaceous Evolution of the Mediterranean Region and Its Connections with the Atlantic Ocean

D e w e y et al. (1973) have noted the following main stages in the evolution of the Tethys and the Atlantic: Tethys 1 (before the Late Triassic); Tethys 2 (Late Triassic); Tethys 3/Atlantic 1 (Early Jurassic, Toarsian) — the beginning of the separation of South and North America from Africa and Europe; Tethys 4/Atlantic 2

(Late Jurassic, Kimmeridgian) — the opening of the Atlantic is already considerable in the northern and central parts; Tethys 5/Atlantic 3 (Early Cretaceous, Hauterivian) — South America was completely separated from Africa. This is a particularly important stage in the evolution of the two areas.

During this stage (Hauterivian-Barremian) there was activation of the fault to the north of the Iberian Platform, which passes to the north of Corsica and Sardinia, and with which the Early Cretaceous ophiolites in the Alps (Piemont zone and Dauphine) and in the Apennines are connected. At the same time the most widespread sediments around this fault are of the Maiolica type, being traced from the Northwest Atlantic, through the Southern Alps, the Lombardia zone and the Central Apennines to the Ionic zone in Western Greece (B e r n o u l l i, 1972). The obduction of the Othrys ophiolites from the Vardar zone in the Pelagonian Massif took place during the Barremian (D e w e y et al., 1973; R i c o u, M a r c o u x, 1980). Tethys 6/Atlantic 4 (Aptian-Albian) coincides with considerable activation in the Mediterranean Region (Fig. 44). The Atlantic Ocean was already considerably opened. At the beginning of the Aptian the rate of spreading and of the increase of the plates was about three times greater compared with the initial stage, and this rate was preserved until the middle of the Late Cretaceous (80 million years). Some authors associate the widespread Aptian transgression with this increasing rate. A number of subduction zones were outlined in the Mediterranean Region during this stage: Eastern Alps, Carpathians and Eastern Serbia (G e y s s a n t, 1980; D e w e y et al., 1973; G r u b i ć, 1974). The last stage, i. e. Tethys 7/Atlantic 5, ended 80 million years ago (Santonian).

A general result of the gradual opening of the Atlantic Ocean, which is particularly well manifested during the Early Cretaceous, is the progressive reduction of the Tethys in the Mediterranean Region.

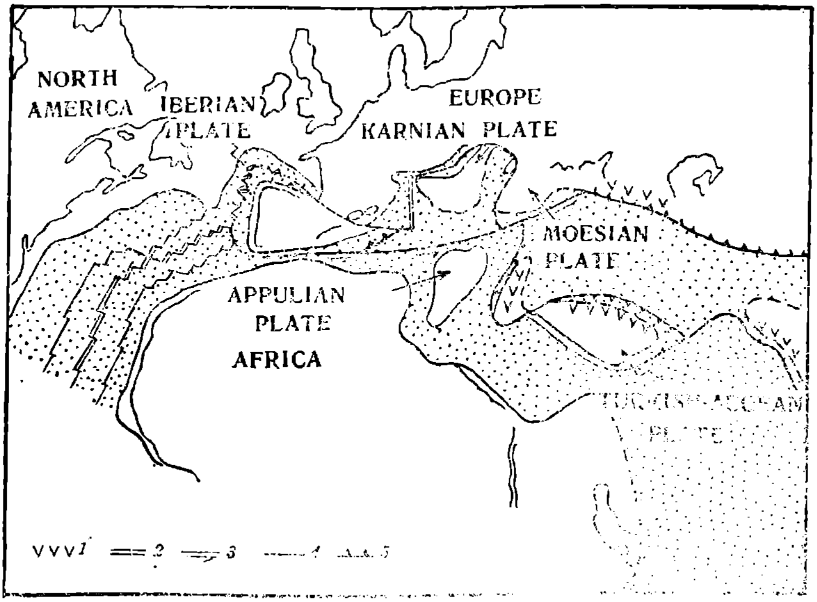


Fig. 44. The Mediterranean Region at the end of the Early Cretaceous (110-100 m. y.) (after D e w e y et al., 1973, Geol. Soc. America Bull., 84, 3137-3180)

1 — subduction zones; *2* — ocean crust; *3* — transform faults; *4* — other faults; *5* — direction of the plate movements

3. CONCLUSIONS

Some general regularities become prominent during the Early Cretaceous evolution of the different zones of the Mediterranean Region.

1. The Region is characterized by warm climate and extensive development of different groups of organisms. A definite zonality is established in their distribution, determined mainly by climatic specificities, as well as by some other specific palaeogeographic parameters. Ammonites, rudists and foraminifera manifest particularly clear provincial zonality.

The developing palaeobiogeographic panorama was revealed during the Early Cretaceous, starting with clearly outlined subequatorial provinces in the Berriasian and ending with the strongly dispersed areas during the Albian.

2. Characteristic rock associations connected with the tectonic specificities of the belt are developed in the different zones of the Mediterranean Region. They are parallel to the main tectonic lines. This is particularly pronounced in the development of ophiolites and the flysch.

Inner zones with deep-sea and strongly deformed, sometimes slightly metamorphosed complexes are outlined, as well as outer zones with extensive development of flysch sediments and/or carbonate platforms and foreland, on which neritic or continental deposits are developed.

Flysch complexes are developed, as a rule, in the continental margins, characterized by intensive compensatory depression. The thickness of the flysch in the different zones is 2000-4000 m.

Carbonate platforms are widespread, being built of rudists, other thick-shelled bivalvs, corals, large foraminifera, echinids, gastropods, algae and bryozoans.

3. The development of the Lower Cretaceous in Bulgaria is interesting owing to the comprehensiveness of the sequences as well as the wealth of fossils and various facies.

The analysis of the lithofacies and of the evolution of the sedimentation environments during the Early Cretaceous in Bulgaria indicates great variety resulting from the considerable dynamism in time and space. In addition to the specific features in the development of the sedimentation environments in the Early Cretaceous basin, there are also some general regularities, part of which were inherited from the Tithonian.

During the Early Cretaceous the basin was situated between two lands: southern — Thracian, representing a peculiar microcontinent in the Tethys Ocean, and northern — Dobrogean, which is a relict of an older massif. A large and prolonged depression is outlined in the southern part of the basin, to the north of which is the vast shelf zone. Compared with the Late Jurassic, the geological evolution of the Fore-Balkan was accelerated, which was marked by activation of the flysch trough.

The Lower Cretaceous rocks in the Southeastern Rhodopes were formed in a bifurcation in the southern part of the Mediterranean Basin.

The Early Cretaceous basin began to narrow around the end of the Hauterivian, and gradually this tendency became stronger. Both eastern and southern parts became dry. To the east there appeared a meridional elevation — the Euxinian one, expanding westward, whereby towards the end of the Aptian the basin already covered only Northwestern and Central Northern Bulgaria, as well as a small strip from the Danubian part of Northeastern Bulgaria in Ruse District.

A rather strong folding movement was manifested at the end of the Aptian in the Central and Eastern Fore-Balkan (Б о н ч е в, 1956; Н и к о л о в, Х р и с ч е в, 1965 a, b). As a result of this, as well as of the general tendencies of the geotectonic evolution, at the end of the Early Cretaceous there was an essential change in the regional structure and of the palaeogeographic environment connected with it.

4. In many places in the inner zones of the Mediterranean Region there were manifestations of ophiolite magmatism, formation of volcanogenic-sedimentary complexes and radiolarites. In a number of areas, as a result of Late Cretaceous and Palaeogene orogeneses, the Lower Cretaceous rocks are strongly dislocated, included in nappes, in some places also strongly matemorphosed.

5. Some differences became apparent during the Early Cretaceous between the Eastern and Western Mediterranean Regions, which became more prominent during the subsequent Epoch of the Cretaceous Period.

During the Early Cretaceous the Tethys in the Western Mediterranean Region had two main straits: northern and southern, which surrounded the Iberian Plate and joined approximately in Sicily. The northern strait became gradually narrower as a result of several stages of subduction and intensive orogeneses, whereas the southern strait, starting from the Late Cretaceous, was gradually transformed into the present-day Mediterranean Sea.

6. The geological specificities of the Mediterranean Region are influenced not only by the relative movement in Africa and Europe, but also by a number of microplates within the Mediterranean space.

7. The data from JOIDES and the seismic studies indicate that the spreading and the ophiolite magmatism in the area are of Jurassic-Cretaceous age.

8. The geological evolution of the Mediterranean Region of the Tethys during the Early Cretaceous is connected with the opening of the Atlantic Ocean.

The spreading velocity of the ocean bottom in the Central Atlantic during the Early Cretaceous considerably increased compared with earlier periods. A number of mobile zones were activated in the Mediterranean Region, especially after the Barremian. It cannot be claimed that there was coincidence in the stages of the evolution of the two oceans, only that there was correlation of the activity and/or passivity in different parts of the plate-tectonic network. It is evident that the widening of the Atlantic led to gradual narrowing of the Mediterranean Region in the Tethys, which was clearly manifested at the end of the Early Cretaceous. It was accompanied by compression of the continental margins and shallowing of the basin.

9. The Early Cretaceous evolution in the Mediterranean Region gradually gained momentum, becoming activated in the main zones of the Region, and thus preparing and achieving the decisive Austrian transformations in the history of this dynamic area on the Earth.

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LE CRETACE INFERIEUR MESOGEEN

(R é s u m é)

La région mésogéenne fait partie de l'Océan de Téthys et englobe l'Afrique du Nord, l'Europe du Sud, le Caucase, l'Asie Mineure. Elle se caractérise par un développement spécifique du Crétacé inférieur, contrastant avec les autres régions et provinces avoisinantes (Volgienne, Boréale, Himalayenne, Malgache, Andienne). Des faciès — de mer profonde aux continentaux sont développés et de riches associations fossiles de différents groupes d'organismes sont établies dans cette région.

Cet ouvrage est fait à la base des résultats des recherches sur le Crétacé inférieur en Bulgarie, effectuées par l'auteur depuis 1957. De plus, de 1960 à 1982, il a eu la possibilité de faire des recherches et de collecter des matériaux dans certains pays de la région mésogéenne (Algérie, France, Suisse, Italie, Yougoslavie, Hongrie, Pologne, URSS, Roumanie, Tchécoslovaquie, Grèce).

Lors de l'examen du Crétacé inférieur dans une région si vaste, plusieurs difficultés sont apparues, particulièrement dans certains pays où il est faiblement étudié. D'autre part, les généralisations cachent toujours le danger d'un aperçu superficiel, aussi la tendance de l'auteur est-elle d'embrasser le plus pleinement possible les régularités générales du développement du Crétacé inférieur en présentant les données initiales de fait. On a tâché de faire un énoncé concis en évitant sa caractéristique détaillée dans les différents pays.

Première partie

INTRODUCTION

I. REMARQUES GENERALES SUR LE CRETACE INFERIEUR

Le chapitre traite la nomenclature du Crétacé inférieur, ses limites, les données radiométriques sur le Crétacé inférieur et le matériel ayant servi de base à cette recherche.

Le Crétacé inférieur comprend approximativement la moitié inférieure du Crétacé. Il contient des couches, formées lors du Crétacé inférieur où une chaîne de successions d'ammonites du Berriasien à la base (zone de *Pseudosubplanites grandis*) à l'Albien (zone de *Stoliczkaia dispar*) au sommet y compris est établie. Des sédiments marins, lacustro-marécageux et continentaux sont développés. D'après les données radiométriques le Crétacé inférieur englobe l'intervalle de 137±5mln d'années à 100±5 mln d'années.

II. ETAGES, SOUS-ETAGES ET ZONES BIOSTRATIGRAPHIQUES DU CRETACE INFERIEUR

Le Crétacé inférieur comprend les étages suivants: Berriasien, Valanginien, Hauterivien, Barrémien, Aptien et Albien subdivisés en sous-étages. Une brève carac-

téristique générale de chaque étage et de ses sous-étages est donnée et les zones biostratigraphiques d'ammonites, de calpionellides, de foraminifères, de nanoplancton et d'ostracodes sont examinées plus en détail.

Deuxième partie

STRATIGRAPHIE REGIONALE

II. CARACTERISTIQUE REGIONALE STRATIGRAPHIQUE DU CRETACE INFERIEUR

La caractéristique régionale stratigraphique du Crétacé inférieur commence par son examen sur le territoire bulgare, car il y possède des coupes particulièrement représentatives, étudiées en détail et qui sont à la base de cet ouvrage.

Ensuite, l'examen de la stratigraphie régionale est effectué par régions et zones paléogéographiques de l'Ouest à l'Est et du Sud au Nord.

1. Bulgarie

Le modèle de la classification stratigraphique du Crétacé inférieur en Bulgarie est fondé sur les régularités générales de son développement dans la région mésogéenne et sur les résultats des recherches antérieures des successions lithologiques et faunistiques dans les affleurements naturels et les sondages.

Grosso modo le panorama lithostratigraphique du Crétacé inférieur est constitué et y sont liées les formations de Gložene, de Slivnica, de Brestnica, de Kostel, de Hănevci, de Zlatarica, de Černi Osăm, de Tiča, de Salaš, de Kaspičan, de Kamčia, de Gorna Orjahovica, de Mramoren, de Hajredin, de Razgrad, de Trămbeš, de Sumer, de Svištov, de Kovačevec, de Ruse, de Elešnica, de Simeonovo, de Malo Peštene, de Roman et de Spasovo, des Groupes urgoniens de Vraca et de Loveč. Les relations entre les différentes unités lithostratigraphiques sont démontrées dans des coupes concrètes.

Les particularités régionales et stratigraphiques du Crétacé inférieur dans le Kraište, les Carpathes du Sud, les Balkanides, la Plate-forme moesienne et les Rhodopes de l'Est sont traitées en détail.

2. Afrique du Nord-Ouest

Dans l'Afrique du Nord-Ouest, c'est au Maroc que le Crétacé inférieur est le plus développé. Sa répartition est liée avec les bassins de Tarfaya-El Aaiun, Haut Atlas, Agadir-Essaouira, Meseta et le Rif marocain.

Dans le bassin de Tarfaya-El Aaiun le Crétacé inférieur débute par des grès et conglomérats continentaux d'une épaisseur d'environ 1100 m qui se rapportent conditionnellement au Barrémien (Wiedmann, Butt & Einsele, 1978). Ces formations reposent sur des roches triasiques ou jurassiques.

Les sédiments marins du Crétacé inférieur dans ce bassin sont d'âge aptien et albien.

Le bassin d'Agadir-Essaouira (Haha) comprend deux zones sédimentaires. Dans la zone sud d'Agadir le Crétacé inférieur affleure nettement sur la bande littorale entre Arhoud Tarhazoute et Aourir au Nord d'Agadir. Tous les étages du Crétacé inférieur y sont présentés.

Au Nord le Crétacé inférieur est développé dans la Meseta et le Rif marocain.

Dans la marge continentale de l'Afrique du Nord-Ouest le Crétacé inférieur est constaté sur l'île Maio (îles du Cap-Vert), autour des îles Canaries et le plateau de Mazagan où il est présenté par des faciès marins variés.

3. Afrique du Nord

Le Crétacé inférieur est développé en faciès marins en Algérie et en Tunisie, tandis qu'en Libye, Egypte et au Sahara, il est présenté par des formations continentales.

En Algérie le Crétacé inférieur est développé dans l'Atlas saharien, les Hauts Plateaux et l'Atlas tellien.

Dans la partie ouest de l'Atlas saharien le Crétacé inférieur est présenté par des grès et des argiles gréseuses („continental intercalaire") et à l'Est dans la même zone — par des grès et des évaporites (du type saharien).

Dans les Hauts Plateaux le Crétacé inférieur est du type terrigéno-carbonaté. Tous les étages y sont développés.

Les sédiments du Crétacé inférieur affluent largement dans l'Atlas tellien, où ils sont représentés par des faciès d'eaux profondes, qui contrastent avec les formations néritiques des Hauts Plateaux. La présence de tous les étages du Crétacé inférieur y est prouvée par des faunes riches.

Le Crétacé inférieur en Tunisie est lié avec trois zones tectoniques principales: le Sillon tunisien, le Complexe des bassins intracratoniques et des bassins néritiques instables en Tunisie centrale et au Sahara tunisien.

Dans la partie la plus méridionale (saharienne) de Tunisie, la base du Crétacé inférieur (Berriasien-Hauterivien) est constituée de sédiments continentaux terrigènes et d'évaporites. A l'Est et au Nord-Est les faciès terrigènes continentaux sont remplacés par des carbonates appartenant au Crétacé inférieur mésogéen typique. Leur limite méridionale à la fin de l'Albien marque le point de départ de la transgression transaharienne crétacée supérieure.

Le Crétacé inférieur est le plus largement développé en Tunisie du Nord où il est lié avec le Sillon tunisien. Tous les étages sont présentés — du Berriasien à l'Albien inclus (Burollet & Manderscheid, 1965; Stranik et al., 1974; Memmi, 1979, 1980, 1981). Dans cette région les sédiments du Crétacé inférieur sont développés dans deux environnements: néritique et pélagique.

Les faciès néritiques sont bien développés surtout dans le Massif de Zaghouan et sont présentés par des calcaires organogènes et biodétritiques et des marnes gréseuses.

Les faciès pélagiques sont largement développés dans la partie médiane du Sillon et dans l'Atlas tunisien oriental; ce sont des calcaires microgranulaires, des calcaires sublithographiques (du type vocontien-salašien) à intercalations de marnes. Ils contiennent beaucoup de calpionellides et d'ammonites.

En général, le Crétacé inférieur en Algérie et en Tunisie démontre des environnements paléosédimentaires très variés, de continentaux aux bathyaux, du type caractéristique mésogéen. A l'Est et au Sud-Est, en Libye et en Egypte, le Crétacé inférieur est présenté par des faciès continentaux.

4. Péninsule ibérique

Les sédiments du Crétacé inférieur dans la Péninsule ibérique sont liés avec quelques zones tectoniques. Des faciès littoraux à plusieurs hiatus intraformationnels sont développés autour du massif central hercynien de la Meseta ibérique. Dans les Chaînes Cantabriques, les Pyrénées, les montagnes ibériques et catalanes, le Crétacé inférieur est très varié, présenté par toute une gamme de faciès variés du type Weldien au flysch. Dans la dépression Sub-bétique (entre la Meseta et le

Massif Bétique, y inclus les Baléares, des faciès marins d'eau profonde sont développés. En général, la répartition du Crétacé inférieur représente un grand triangle autour de la Meseta, dans la partie occidentale de laquelle se trouve le Portugal, au Nord—Nord-Est — les chaînes Cantabriques et Ibériques et au Sud-Est — la zone Sub-bétique avec son prolongement vers les Baléares. Au Nord la Péninsule ibérique est bornée par les Pyrénées.

Dans les Pyrénées le Crétacé inférieur est présenté par des faciès extrêmement variés, d'une épaisseur variant rapidement et des relations spatiales compliquées entre les unités lithostratigraphiques (Rat, 1969; Peybernes, 1976; Jaffrezo, 1981). Les faciès du Crétacé inférieur sont principalement néritiques, avant tout du type carbonaté et dans des régions isolées sont aussi terrigènes. Les faciès urgoniens sont particulièrement développés et constituent des coupes épaisses du Valanginien à l'Albien inclus. Il existe beaucoup de lacunes stratigraphiques et d'érosions profondes de différents horizons, ayant conditionné la formation de gisements importants de bauxite.

Dans la partie centrale de la zone des Pyrénées septentrionales, lors du Crétacé inférieur, il s'est manifesté un magmatisme péridotique lié avec la formation des gisements de chrysotile-asbeste. Du point de vue de la paléontologie, le Crétacé inférieur se caractérise principalement par des foraminifères, algues, nanoplancton, etc., de même par des bivalves, gastropodes, brachiopodes, échinides. Les ammonites ne se rencontrent que rarement, surtout dans les roches argilo-calcaires de l'Aptien.

5. France

Le Crétacé inférieur en France est lié avec les régions suivantes: Alpes, inclus les chaînes subalpines avec la Fosse vocontienne, la Provence, le Jura, le Bassin de Paris et le Bassin d'Aquitaine. Ici il faut mentionner aussi le Crétacé inférieur dans les Pyrénées françaises.

Les Alpes françaises démontrent un Crétacé inférieur varié, développé en faciès d'eaux profondes. Dans cette région quelques zones se dessinent où le Crétacé inférieur démontre des particularités spécifiques.

La zone de la Savoie englobe une grande partie des Alpes occidentales — les massifs de Pelvoux/Belledonne et de Mont Blanc. Dans la partie nord-ouest de cette zone à l'Ouest du Mont Blanc (chaînes des Aravis), le Berriasien-Hauterivien est représenté par des calcaires micritiques et des calcaires argileux. Le Barrémien et l'Aptien — par des calcaires et des calcaires gréseux en faciès urgonien, superposés transgressivement par des grès glauconitiques de l'Albien. Au Sud-Ouest du Massif de Mont Blanc, dans la Zone ultrahelvétienne, les calcaires argileux barrémiens — une partie du charriage de Rosselette (Eltchaninoff-Lancelot et al., 1982), sont développés seulement.

La zone dauphinoise représente une dépression du Crétacé inférieur entre le Massif Central et les massifs de Mont Blanc, Belledonne et Mercantour. Au Sud la dépression s'élargit et passe dans la Fosse vocontienne. Dans sa partie nord la dépression est plus étroite et les sédiments possèdent des puissances plus grandes. En outre, dans la partie nord les sédiments sont aleurolitiques et/ou faiblement gréseux souvent avec un développement de turbidites, tandis qu'au Sud des sédiments argileux et calcaires sont développés exclusivement. Une bande de sédiments néritiques borne la dépression: au Nord-Ouest ce sont les hautes montagnes de la Savoie, les massifs de la Grande-Chartreuse et Vercors et les environs de Valence, au Sud, ce sont le Languedoc et la Provence.

Le Crétacé inférieur dans les Chaînes méridionales subalpines (Fosse vocontienne) est présenté par des sédiments pélagiques (du type alpin à la différence du type néritique dans le Jura). C'est la seule zone en France où du Berriasien à l'Albien une sédimentation de mer profonde passant aussi dans le Cénomanien a existé. En effet, la Fosse vocontienne représente un golfe énorme de la dépression subalpine du Crétacé inférieur. Des calcaires fins mircitiques, des calcaires argileux et des marnes riches en ammonites et en microfaune planctonique (calpionellides, radiolaires, foraminifères, nanoconus) y sont développés. C'est le même faciès dans lequel est développé le Crétacé inférieur dans le synclinal de Salaš en Bulgarie du Nord-Est.

Les Chaînes septentrionales subalpines où le Crétacé inférieur est développé en faciès mixtes commencent au Nord de Diois. Le haut mur des calcaires urgoniens qui constituent le bord sud du Vercors et représentent un élément typique de cette zone se détache au Nord de la région de la ville de Die. Le Crétacé inférieur est présenté par des faciès mixtes — une alternance multiple des calcaires biomorphes et des marnes. Ces sédiments réalisent la transition de faciès vocontiens aux faciès du Jura. Tous les étages du Crétacé inférieur sont développés et très nettement caractérisés du point de vue paléontologique. La coupe entre Grenoble et Chambéry est particulièrement représentative.

Le Crétacé inférieur dans la zone de Piémont est présenté par une épaisse série monotone de calcschistes qui, lors du chevauchement pendant l'Eocène supérieur et l'Oligocène sous l'influence du dynamométamorphisme, se sont transformés en schistes lustrés. Les calcschistes sont déterminés comme étant du Crétacé inférieur en comparaison avec une pareille suite non-métamorphisée dans les Apennins septentrionaux qui à l'aide de calpionellides est rapportée au Tithonique-Néocomien. Ils superposent les roches vertes — ophiolites (diabases et spilites) et gabbro et sont recouverts par des radiolarites, métamorphisés en quartzites à séricite et à chlorite, et affleurent bien à présent sur le Mont-Viso. Les calcschistes sont recouverts par un flysch du Crétacé supérieur à Helmenthoïdes.

En Provence le Crétacé inférieur est présenté par des sédiments marins d'eaux peu profondes--calcaires zoogènes, grès glauconitiques à phosphorites et marnes.

Dans le Bassin d'Aquitaine le Crétacé inférieur est connu dans la région d'Adour et de Parentis.

Les sédiments du Crétacé inférieur dans le Jura sont présentés par des faciès de plate-forme, principalement carbonatés. Le Crétacé inférieur débute par des sédiments lagunaires du Purbeckien, superposés par des marnes et des calcaires argileux à intercalations de lignites. Au-dessus suivent les calcaires rougeâtres et les marnes, connus de la région de Neuchâtel — Valangin — Hauterive du Jura suisse. Parmi les sédiments du Jura les marnes hauteriviennes à échinides sont formées dans des conditions des eaux les plus profondes. Leur formation coïncide avec l'époque quand la mer s'ouvre le plus largement au Nord-Ouest vers le Bassin de Paris.

Le Barrémien et l'Aptien sont développés uniquement dans les hautes parties du Jura et sont représentés principalement par des calcaires urgoniens. Des grès glauconieux albiens les superposent transgressivement.

Les sédiments du Crétacé inférieur affleurent comme une bande continue dans la partie sud-est du Bassin de Paris. Dans le reste du bassin partout le Crétacé inférieur est établi par des forages.

Lors du Crétacé inférieur le Bassin de Paris a représenté un détroit liant le bassin mésogéen à la Mer du Nord et cela conditionne la répartition et les particularités de différents étages. Les calcaires argileux lagunaires ou lacustres du Purbeckien sont superposés par des dépôts argileux et gréseux du Veldien, parmi lesquels sont découverts des iguanodons (près de Bernissart), des crocodiles, des tortues et des poissons.

Dans la partie centrale du détroit (Aube) la sédimentation marine commence par des calcaires zoogènes du Valanginien supérieur et se termine avec des argiles de l'Albien.

6. Alpes suisses

A part le Jura, le Crétacé inférieur est répandu dans les Alpes suisses. Il est établi une zonalité faciale, lors de laquelle sont observés des passages latéraux des faciès du type du Jura au Nord et du type vocontien au Sud à travers les faciès mixtes des chaînes septentrionales subalpines vers les faciès des Alpes suisses. Le Crétacé inférieur est lié avec la zone externe des Alpes, avec les Préalpes et avec les charriages helvétiens.

7. Alpes orientales

Le Crétacé inférieur possède une répartition limitée dans les Alpes orientales. Dans la zone de flysch s'établissent deux bandes du Crétacé inférieur. Dans la bande nord s'établissent: 1) marnes à *Duvalia lata* et à ammonites valanginiennes; 2) calcaires bréchoïdes (Valanginien); 3) calcaires à silex de l'Hauterivien; 4) calcaires urgoniens avec des marnes à orbitolines dans la partie supérieure (Barrémien-Aptien). Dans la bande sud les calcaires du Valanginien et de l'Urgonien se remplacent par des marnes. Un passage analogique des faciès néritiques vers des faciès bathyaux est observé de même dans les Alpes occidentales.

8. Hongrie

Le Crétacé inférieur dans le Massif Pannonien central est connu dans sa partie sud— Vilany et Meczek, et dans le Srednogorie hongrois — Bakony et Gerecse. Des faciès variés sont développés, ayant plusieurs lacunes stratigraphiques intraformationnelles. Dans la plupart des endroits les sédiments du Crétacé inférieur superposent la surface intensément érodée des calcaires du Tithonique.

Des coupes, où les dépôts berriasiens sont liés par une transition graduelle avec les roches tithoniques, sont établies à Meczek. Le Berriasien est présenté par des calcaires denses micritiques et des calcaires argileux à calpionellides, radiolaires et ammonites. Le Valanginien inférieur est lié aux formations volcano-sédimentaires (la formation tufogène trachydoléritique d'une épaisseur de 10—100 m) où *Kilianella roubaudiana* (d'O r b.) a été trouvée. Le Valanginien supérieur est présenté par des marnes et des grès.

Des calcaires urgoniens à plusieurs pachyodontes reposent sur une surface érodée.

Dans la montagne de Vilany les calcaires intensément érodés du Kimméridgien-Tithonique sont superposés par des volcanites à diabases (trachydolérites) qu'on admet d'être du même âge que la formation trachydoléritique tufogène valanginienne de Meczek. Dans le horst de Beremend et à Harsany lors du Valanginien et de l'Hauterivien se forment des bauxites. La sédimentation marine débute du Barrémien avec la formation des calcaires urgoniens à orbitolines et à pachyodontes qui atteignent la base de l'Albien.

La coupe de la série à Bakony est la plus complète. Les sédiments berriasiens sont liés par une transition lithologique avec les sédiments tithoniques (Sumeg, Lokut, Somhed). Là ils sont présentés: des calcaires clairs micritiques, calcaires argileux (faciès „Biancone") contenant des ammonites, beaucoup de calpionellides et de radiolaires. Dans la vallée de Alsomajor-Zirc et dans la partie est de Somhed le Berriasien est représenté par des calcaires rougeâtres à ammonites ou par des calcaires à rares crinoïdes (Istenesmal-Zirc), et au Nord de Zirc et près de Bakonycsernye — par des calcaires clairs à calpionellides. Plus haut sont établis le Valanginien et le Hauterivien (marnes), le Barrémien (calcaires jaunâtres), l'Aptien (calcaires), l'Albien (marnes glauconitiques).

Le Crétacé inférieur est développé dans la moitié nord de Gerecse, où il est lié à un complexe ininterrompu du Berriasien supérieur au Barrémien inclus.

9. Tchécoslovaquie

Le Crétacé inférieur est établi dans la zone des klippes (Carpathes occidentales), les Hauts Tatras et dans la zone de Silésie (Beskides). Des faciès variés sont développés — de néritiques aux bathyaux.

10. Pologne

Dans la région des Carpathes polonaises le Crétacé inférieur est développé dans trois zones: zone de flysch, zone des klippes pénines et dans les Tatras où il est présenté principalement par des sédiments de flysch.

11. Roumanie

Le Crétacé inférieur est largement répandu dans les Carpathes orientales, Monte Apuseni, la plaine de Valachie et la Dobroudja du Nord.

Les sédiments du Crétacé inférieur dans les Carpathes orientales sont de deux types: flysch et marnes, riches en ammonites. De leur côté, les dépôts de flysch sont extrêmement variés — de grossiers aux argilo-gréseux à pellosidérites. Des schistes siliceux, des schistes butumineux, des marnes à radiolaires sont développés par endroits. Des intercalations de tuffites y sont rencontrées.

Pour les Carpathes méridionales le changement rapide des faciès est très typique — des calcaires pélagiques argileux aux sédiments de flysch, terrigéno-carbonatés et carbonatés.

Dans les Monte Apuseni les sédiments du Crétacé inférieur sont principalement du type terrigène. Par endroits des formations volcano-sédimentaires sont développées.

Dans la plus grande partie de la plaine de Valachie (la partie nord de la Plate-forme moesienne) le Crétacé inférieur est présenté par les mêmes faciès qu'en Bulgarie centrale du Nord. Dans la partie du Berriasien-Valanginien de la coupe, des calcaires du type de Kaspičan sont développés.

Dans la partie centrale de la plaine du Nord un golfe s'avance où des calcaires de mer profonde à calpionellides sont développés.

Partout les calcaires de Kaspičan sont superposés par des sédiments argileux et carbonatés du type de Razgrad (Hauterivien-Aptien inférieur).

Les sédiments de l'Albien reposent transgressivement sur les étages plus anciens du Crétacé inférieur (Barrémien-Aptien), pareillement à la région septentrionale de la Bulgarie centrale du Nord (Brest — Gigen). Dans la Dobroudja du Nord des formations néritiques terrigènes et carbonatées à plusieurs lacunes stratigraphiques intraformationnelles sont développées.

12. Carpathes soviétiques

Le Crétacé inférieur affleure dans deux zones principales: de Staro-Samborsk et de Marmaroš.

Dans les Carpathes de Staro-Samborsk le Crétacé inférieur est lié avec le Groupe de Spask qui est présenté par trois formations terrigènes, développées dans la zone externe de flysch.

Dans la zone de Marmaroš le Crétacé inférieur est lié avec trois formations: de Kamenopotoksk (flysch), de Kamenolinsk (à deux faciès externes du type terrigène et carbonaté) et la formation de Soymoulsk (aleurolites et grès) qui passe dans le Cénomanien.

13. Crimée et Caucase

Le Crétacé inférieur dans la Crimée affleure comme une bande qui commence de la seconde chaîne des Montagnes de la Crimée dans la vallée de la rivière Tcherna et continue au Nord — Nord-Est vers Bahtchissaray — Symphéropol et de là à l'Est vers Théodossia. Dans la Crimée de steppe le Crétacé inférieur est prouvé dans des sondages profonds. Dans les synclinorii de Jaila et de la Crimée orientale le Crétacé inférieur est développé surtout dans des faciès marins d'eaux profondes et dans le reste de la Crimée des sédiments néritiques sont présentés.

Les sédiments du Crétacé inférieur démontrent des modifications importantes des faciès et des épaisseurs liées avec un nombre de lacunes stratigraphiques intraformationnelles. La plus grande épaisseur est comme dans la Crimée orientale (1500 m), tandis que dans la Crimée du Sud-Ouest elle atteint à peine par endroits 5 m.

Les sédiments du Crétacé inférieur sont liés par un passage graduel à ceux du Jurassique supérieur ou ils se disposent sur un fondement bigarré transgressivement et en discordance sur la série de Taurides (Trias — Jurassique moyen), ou ils remplissent en ingression les différentes dépressions dans le relief du Précrétacé inférieur. Les dépôts du Crétacé inférieur manquent par endroits.

Le Crétacé inférieur dans le Caucase est lié avec quelques zones tectoniques dont chacune se caractérise par différents faciès et épaisseurs. Les sédiments du Crétacé inférieur dans le Caucase du Nord-Ouest sont liés au versant nord de la crête principale du Caucase à l'Ouest de la rivière Belaya. Ils sont caractérisés par de grandes épaisseurs (4—5 km) et une prédominance des formations pélitiques — des argiles sidéritiques. Tous les étages du Crétacé inférieur sont développés, par endroits avec quelques lacunes dans les différentes parties des coupes.

A l'Est de la rivière Belaya jusqu'à la Mer Caspienne la coupe du Crétacé inférieur est constituée de deux grands complexes.

Le complexe inférieur est représenté par des sédiments terrigéno-carbonatés du Berriasien-Barrémien inférieur. Epaisseur — jusqu'à 850 m. Le complexe supérieur est terrigène (Barrémien supérieur — Albien inférieur). Des sédiments glauconieux gréseux et argileux, souvent à concrétions calcaires prédominent. Epaisseur — jusqu'à 700 m. L'Albien moyen et l'Albien supérieur sont ordinairement présentés par des argilites noires et dans leur partie supérieure apparaissent des intercalations de marnes à épaisseur de 40—80 m à 150 m au Nord du Précaucase.

Dans la région d'Abhasia-Ratcha de la zone géorgienne les sédiments du Crétacé inférieur se distinguent des dépôts de flysch dans le flanc sud du Grand Caucase et des formations néritiques du Caucase du Nord (Рентгартен, 1951). Dans cette région les calcaires, trop souvent pélitomorphes, et les marnes constituent les coupes du Berriasien, de l'Hauterivien et du Barrémien. Ils se caractérisent par des faunes riches en céphalopodes, connues de nombreuses publications. Des genres mésogéens prédominent, mais souvent des formes nordiques sont rencontrées. L'Aptien est présenté par des marnes et l'Albien — par des dépôts terrigènes.

Dans la région de Dziroulsk-Koutaissi les coupes du Crétacé inférieur sont constituées de sédiments terrigènes, souvent à Rudistes dans le Barrémien. L'Aptien est présenté par des marnes et dans l'Albien sont développés des aleurolites, des grès et des tuffites.

Le Crétacé inférieur est développé dans trois zones du Petit Caucase: zones de Mishano-Kafan, Sévano-Karabah et Somhito-Agdam. Tous les étages de la série y sont développés et leurs coupes ordinairement sont constituées par des sédiments terrigènes et carbonates, souvent avec des intercalations de grès tufacés.

14. Alpes méridionales, Apennins et Sardaigne

C'est la partie centrale de la région mésogéenne où le Crétacé inférieur est développé principalement dans des faciès marins d'eaux profondes, souvent associés avec des radiolarites. Dans le bord sud des Alpes vénitiennes, dans les Apennins méridionaux et en Sardaigne, des calcaires néritiques à Rudistes et à *Nerinea* sont présentés de même.

Des sédiments argileux et calcaires du type Maiolica et Biancone sont répandus dans la Lombardie et les Apennins septentrionaux.

15. Yougoslavie

En Yougoslavie le Crétacé inférieur est d'une vaste répartition et il est présenté par tous ses étages dans les zones paléogéographiques suivantes: la Dépression slovène, les Chaînes Dinariques, Kossovo, Choumadie et Serbie de l'Est.

Particulièrement typique pour la Dépression slovène est le large développement (du Trias tardif au Berriasien) des sédiments pélagiques carbonatés, des radiolarites schisteuses ou siliceuses qui contrastent avec les formations néritiques dans les régions avoisinantes.

Les calcaires berriasiens sont superposés transgressivement, mais en concordance, par des brèches calcaires avec des restes de Rudistes, orbitolines, algues, hydrozoaires, de rares Hedbergelles et des Talmanielles primitives qui prouvent l'âge Aptien-Albien.

Dans la Zone dalmatine des Chaînes Dinariques, dans la Zone du Haut-Karst et dans la Sous-zone prékarstique, le Crétacé inférieur est développé exclusivement dans des faciès carbonatés, et dans la zone Bosnienne — dans des faciès de flysch.

Les sédiments de flysch reposent sur une formation volcano-sédimentaire du Groupe ophiolitique à radiolarites du Jurassique supérieur dans la partie supérieure du Jurassique supérieur.

Des sédiments barrémiens, aptiens et albiens, développés dans la zone de Kukes, Metochie, la zone de Crnolevskidrenitchi à l'Ouest de Kossovska Mitrovica et dans la plaine de Kossovo sont connus seulement dans la région de Kossovo. Des sédiments terrigéno-carbonatés principalement dans des faciès néritiques et plus rarement dans des faciès bathyaux sont présentés là.

La zone de Choumadie englobe la marge sud du Banat, les environs de Belgrade, Choumadie, Kopaonik de l'Est et du Sud-Est, où des sédiments néritiques terrigéno-carbonatés sont développés principalement.

Le Crétacé inférieur est largement développé dans la Serbie orientale où il est présenté par des roches variées d'épaisseur importante. Il affleure de l'interfleuve de Morava et Timok au Nord à Souva planina et Stara planina au Sud-Est.

Dans les dépôts du Crétacé inférieur les géologues serbes distinguent quatre types principaux: 1) d'eaux peu profondes; 2) de flysch; 3) transitoire; 4) d'eaux profondes. Cependant, leur limitation spatiale n'est pas bien éclaircie et à cause de cela souvent des calcaires typiquement pélagiques à fossiles d'eaux profondes sont décrits dans des faciès néritiques.

Lors du Crétacé inférieur dans la Serbie orientale deux dépressions importantes se sont formées — dans l'une d'elles il s'est formé du flysch (la zone de Lužnica) et dans l'autre — des formations volcano-sédimentaires (zone de Krajna du graben du Danube).

14. Albanie

Les sédiments du Crétacé inférieur en Albanie sont un prolongement de ceux des Dinarides. Des calcaires pélagiques à silex, ainsi que des dépôts de flysch y sont développés.

17. Grèce

Dans la partie occidentale de la Grèce, dans la zone Préappulienne, le Crétacé inférieur englobe une partie des calcaires de Vigla (Tithonique — Sénonien inférieur). Ces calcaires sont développés aussi dans la Zone ionienne où ils sont déposés dans une mer très profonde, à radiolaires et à lentilles de jaspe. Ils contiennent des calpionellides, aptychus, *Mesohibolites* et *Orbitolina* qui permettent de déterminer l'intervalle du Berriasien à l'Albien inclus.

Dans la partie continentale de la zone de Gavrovo, le Crétacé inférieur est lié avec des calcaires à algues qui passent du Jurassique supérieur. Des calcaires plus variés avec des restes de foraminifères, coralliaires, algues qui caractérisent l'intervalle Jurassique supérieur et la base du Crétacé inférieur, sont développés dans le Péloponnèse.

Dans la zone du Pinde la base du Crétacé inférieur est liée avec des radiolarites, souvent imprégnées par des oxydes de manganèse. Elles alternent avec des calcaires pélagiques à radiolaires. Des intercalations de calcaires bréchoïdes, parfois gréseux et oolithiques sont rencontrées dans les marges. Ces sédiments sont recouverts d'un flysch gréso-marneux, associé avec des marnes rouges à radiolaires. Différents *Orbitolina* et *Dictyoconus* déterminent le Barrémien-Aptien.

Dans la zone du Parnasse le Crétacé inférieur englobe une partie de calcaires bréchoïdes à *Ellipsactinia ellipsoidea* Stein (Tithonique-Valanginien), des calcaires oolithiques et compacts sur lesquels le second niveau à bauxites du Parnasse est développé.

Dans la zone du Vardar, des sédiments aptiens-albiens à orbitolines et à nerinés sont développés. Ce sont des conglomérats à fragments calcaires, parfois ophiolitiques; de même des calcaires gréso-détritiques y sont présentés. Ils superposent transgressivement et en discordance les ophiolites du Jurassique supérieur.

Dans la Crète le Crétacé inférieur est présenté exclusivement par des calcaires, par endroits à radiolarites.

Dans les Rhodopes du Sud-Est le Crétacé inférieur est lié avec le complexe phyllithique du Macri, affleurant au Nord-Est d'Alexandropolis. Ce complexe est constitué de phyllithes, de grauwackes et d'ophiolites faiblement métamorphisés. Ils contiennent des intercalations de calcaires où des coralliaires du Jurassique supérieur et du Crétacé inférieur sont trouvés.

A Samothrace le Crétacé inférieur englobe une partie du complexe ophiolitique et il est présenté par des gabbro, diabases, calcaires coralliens, schistes et brèches polygènes. Les relations du gabbro et des diabases avec les sédiments démontrent que le volcanisme basique s'est manifesté à la limite du Crétacé inférieur — Crétacé supérieur (Braun, 1968).

A Trodos le Crétacé inférieur est présenté par des dolérites (130—120 mln d'années).

18. Turquie

Le Crétacé inférieur a une répartition limitée en Turquie. Il superpose souvent en transgression des terrains jurassiques ou paléozoïques.

Des roches du Crétacé inférieur sont connues sur le littoral sud de la Mer de Marmara, en Anatolie, dans la partie nord de la région de Beipazar-Nalihan, au Sud de Bolou, au Nord de Guoinouk et le lac Abant, dans la région de Zongouldak, au Nord de Ilgaz-Kourchounlou, autour de Baibourt, au nord de Tartouma et dans Taurus.

Sur le littoral de la Mer Noire le Crétacé inférieur débute avec des conglomérats, superposés par des calcaires (Valanginien-Aptien inférieur), des grès calcaires et des calcaires à *Nerinea* et *Requienia*. Des grès de Velebek (Aptien supérieur) et des grès et marnes de l'Albien, recouverts par des marnes et du flysch grossier (Albien supérieur — Cénomanien), sont observés plus haut.

Entre la Mer Noire et la région de Ilgaz-Kourchounlou, des calcaires blancs massifs à ammonites (Berriasien-Barrémien inférieur) sont développés.

Des sédiments du Crétacé inférieur dans un faciès marin d'eaux profondes sont développés entre les montagnes anatoliennes et les chaînes septentrionales montagneuses.

Dans l'Anatolie du Sud-Est, dans de profonds forages, des calcaires dolomitiques à orbitolines sont constatés.

19. Proche-Orient

Le Crétacé inférieur est connu dans tous les pays du Proche-Orient. Il est développé dans des faciès de mer peu profonde, principalement carbonatés et/ou dans des faciès terrigènes. Les sédiments aptiens et albiens sont les plus développés et presque partout sont du type marin. Des formations continentales sont répandues dans des territoires isolés.

Le volcanisme basique du Jurassique tardif continue encore lors du Crétacé inférieur avec un paroxysme bien manifesté lors de l'Aptien.

Troisième partie

SYNTHESE ET CONCLUSIONS

IV. APERÇU STRATIGRAPHIQUE

Le chapitre traite le développement des étages du Crétacé inférieur dans la région mésogéenne, en appuyant sur les traits spécifiques dans les différents pays, ainsi que sur les particularités générales de la répartition de chaque étage.

1. Berriasien

Le Berriasien est largement répandu dans la région mésogéenne. Il est présenté par des faciès marins variés et, par endroits, par des formations continentales du type Purbeckien ou saharien.

Dans la plupart des régions on observe une transition lithologique graduelle des sédiments tithoniques aux berriasiens. Cette continuité par endroits est perturbée par des phénomènes tectoniques et (ou) paléographiques locaux. L'absence des sédiments berriasiens dans certaines régions est conditionnée par des élévations stables d'une longue durée.

2. Valanginien

La répartition du Valanginien et le type de ses dépôts sont analogues à ceux du Berriasien. Cependant par endroits, la sédimentation du Crétacé inférieur commence dans le Valanginien. En outre, dans toutes les zones d'une sédimentation argilo-calcaire on observe un accroissement graduel du contenu argileux dans les coupes valanginiennes et un accroissement des marnes aux dépens des calcaires.

3. Hauterivien

Les sédiments hauteriviens sont de faciès variés et sont répandus largement. Dans la région de la Mediterranée occidentale les sédiments de flysch prédominent, tandis que dans le reste de la région mésogéenne l'Hauterivien est lié avec un tableau facial bigarré, dessiné par des sédiments de néritiques aux sédiments d'eaux profondes. Dans la partie occidentale de la Péninsule ibérique sont développés des dépôts continentaux hauteriviens du type Weldien.

4. Barrémien

Le Barrémien est caractérisé par faciès très variés parmi lesquels prédominent les faciès néritiques. Un large développement du faciès urgonien qui représente un phénomène mésogéen typique commence lors du Barrémien tardif. A part les faciès néritiques terrigènes, terrigéno-carbonatés et urgoniens, le plus largement développés, dans la partie centrale de la région mésogéenne ainsi que dans quelques zones de dépression, le Barrémien est lié avec des sédiments argileux d'eaux profondes et argilo-carbonatés et par endroits avec des sédiments de flysch.

5. Aptien

L'Aptien est connu dans toute la Mésogée — de l'Océan Atlantique au Proche-Orient. Il est développé dans des faciès variés dont les plus typiques sont les faciès urgoniens. A l'exception de quelques régions — par exemple la Provence, en partie les Hauts Plateaux en Algérie, ainsi que dans la Bulgarie du Nord-Est et la Dobroudja, où l'Urgonien est réprésenté par des calcaires très purs, dans les autres zones les calcaires urgoniens sont associés avec des dépôts terrigènes — marnes, aleurolites et grès. Partout les plates-formes urgoniennes sont contournées par la traîne terrigéno-carbonatée.

Dans un nombre de zones (Afrique du Nord, Alpes, Carpathes) l'Aptien est lié avec des sédiments de flysch et ailleurs (Dépression tunisienne, France du Sud-Est, Zone Sub-bétique) avec des dépôts argilo-carbonatés pélagiques.

Dans quelques régions (Pyrénées, Carpathes, Prébalkan, Caucase du Nord) les formations molassiques représentent une partie intégrante typique pour l'Aptien.

D'ordinaire les sédiments aptiens sont un produit final des grandes dépressions du Crétacé inférieur.

6. Albien

C'est le dernier étage du Crétacé inférieur. Par rapport aux autres étages il est d'une répartition la plus limitée, liée à la régression postaptienne ou à l'érosion postalbienne. A part les sédiments de flysch et les schistes noirs d'eaux profondes, les calcaires à radiolarites, connus dans certaines zones de la Mésogée occidentale, les sédiments les plus typiques de l'Albien sont les sédiments glauconieux gréseux et les molasses (conglomérats, grès glauconitiques, aleurolites et argiles).

V. EVOLUTION ET PALEOBIOGEOGRAPHIE DES ORGANISMES MARINS DU CRETACE INFERIEUR DANS LA REGION MESOGEENNE

1. Notes générales

Il est notoire que l'Echelle stratigraphique internationale de l'Erathème mésozoïque est établie sur la base de l'évolution des ammonites. Elles répondent aux exigences fondamentales pour des fossiles-guides: 1) un rythme rapide d'évolution; 2) une répartition horizontale importante; 3) une indépendance relative des faciès; 4) une bonne conservation.

En effet, un nombre d'autres organismes marins sont plus largement répandus que les ammonites mais leur rythme d'évolution est plus lent et à cause de cela à aide d'eux peuvent être individualisées des zones d'une durée plus grande que les zones d'ammonites.

La vaste pratique stratigraphique, particulièrement dans les vingt dernières années, démontre l'importance stratigraphique de quelques autres groupes d'organismes qui permettent une stratigraphie détaillée du Crétacé inférieur. Ce sont: foraminifères, radiolaires, calpionellides, dinoflagelles, algues, nanoconus, bivalves, échinides, brachiopodes, etc.

Ce chapitre traite l'évolution de quelques groupes d'organismes marins d'une répartition vaste lors du Crétacé inférieur, contribuant le plus au démembrement stratigraphique et à la corrélation du Crétacé inférieur, de ses différents étages et (ou) des types faciaux déterminés (par ex. du faciès urgonien largement répandu). En outre, sont éclaircis seulement tels aspects de l'évolution de ces groupes d'organismes, dont dépend le plus la formation des successions paléontologiques, et non pas les problèmes des corrélations phylogénétiques à l'intérieur de différents groupes.

Les régularités formant les successions d'organismes sont dans une dépendance étroite des facteurs écologiques de l'environnement. Avec ces facteurs sont liés plusieurs autres problèmes importants pour la stratigraphie. Ce sont: 1) les coactions entre les organismes; 2) la densité du peuplement de différents biotopes; 3) la dépendance de la morphologie des organismes du caractère du milieu; 4) les rythmes de la formation des espèces et leur relation avec les changements du milieu; 5) la migration des organismes — causes, vitesse et résultats.

2. Traits principaux de l'évolution des organismes marins du Crétacé inférieur

Indépendamment de la régression importante qui se manifeste sur de vastes surfaces dans la région mésogéenne vers la fin du Jurassique il existe un passage graduel du monde organique jurassique vers celui du Crétacé. Uniquement parmi les mollusques on observe une régénération considérable qui se caractérise par la disparition de plusieurs espèces et genres et l'apparition de nouveaux taxa.

Ce chapitre traite les traits principaux de l'évolution de la microflore (algues et nanoconus), Protozoa (radiolaires, foraminifères, calpionellides) et Métazoa invertébrés (octracodes, éponges et Coelenterata, échinides, brachiopodes, gastéropodes, bivalves, ammonites).

3. Paléobiogéographie du Crétacé inférieur

3.1. Principes initiaux

La répartition géographique des organismes dépend d'un nombre de facteurs, dont le plus important est le climat. Il existe une liaison étroite entre la répartition géographique et les facteurs écologiques: courants, caractère du fond, bathymétrie, particularité de la sédimentation, présence ou absence de barrières, coactions avec d'autres organismes, rapports trophiques, etc.

La subdivision paléozoogéographique du Crétacé inférieur proposée dans cet ouvrage est fondée sur les trois principes suivants: aréalo-génétique, écologique et statistique.

3.2. *Provincialisme d'ammonites lors du Crétacé inférieur*

Actuellement, tout le monde admet que les limites biogéographiques de différents groupes d'organismes ne coïncident pas. En outre, plus la catégorie paléobiogéographique est d'un rang inférieur, plus les différences dans les limites par groupes différents sont grandes.

Cet ouvrage traite uniquement la répartition des ammonites lors du Crétacé inférieur qui dessine les lignes principales de la paléobiogéographie du Crétacé inférieur. Ou peut y rajouter évidemment beaucoup de données intéressantes sur les bélemnites, les foraminifères et les rudistes qui inscrivent des traits importants dans le panorama de la vie du Crétacé inférieur dans la région mésogéenne.

La répartition des ammonites au début du Crétacé inférieur possède les traits fondamentaux du provincialisme ammonitique du Tithonique. En outre, de nouveaux traits s'imposent qui modifient les configurations des régions et surtout des provinces.

Le tableau paléobiogéographique du Crétacé inférieur continue de se développer et sur la base de la répartition des ammonites peuvent être déterminées deux étapes berriasienne-barrémienne et aptienne-albienne avec quelques fluctuations intérieures.

3.2.1. Horologie des ammonites berriasiennes-barrémiennes dans la région mésogéenne

Le début du Crétacé inférieur démontre une bipolarité dans la répartition des ammonites dessinée lors du Jurassique tardif. L'Océan de Téthys occupe une position médiane dans l'hydrosphère terrestre en évoluant en direction subéquatoriale entre deux masses continentales principales. Le Bassin Boréal s'étend au Nord et au Sud — le Bassin périgondwanien.

La Mésogée se dessine comme une région relativement homogène du Berriasien au Barrémien incluse avec les provinces suivantes:

1. Province alpine. C'est la province centrale de la région mésogéenne qui grosso modo englobe les deux branches de la bande orogène alpine de l'Océan Atlantique à l'Ouest comprenant l'Afrique du Nord-Ouest et du Nord, la Péninsule ibérique, les Pyrénées, la partie la plus méridionale de Drance, les Alpes, le Massif Pannonien, les Dinarides, les Hélénides, les Rhodopes du Sud-Est, la Turquie et l'Iran à l'Est.

Dans cette province les faunes des ammonites sont très homogènes, principalement d'eaux profondes accompagnées par un large développement des foraminifères planctoniques, calpionellides et radiolaires.

La province alpine a englobé les zones les plus profondes de la région mésogéenne.

C'est dans la partie est de la province alpine que se forme la Subprovince (ou région) arabe se caractérisant par le développement prédominant des sédiments continentaux lors du Berriasien-Barrémien et par des formations néritiques avec plusieurs espèces endémiques lors de l'Aptien et l'Albien. Elle comprend les pays du Proche-Orient au Golfe Persan.

2. La Province euro-caucasienne s'étend au Nord de la Province alpine. Elle est nommée par Uhlig (1911) comme „une zone néritique marginale", mais cette nomination n'est pas exacte. Elle contient des faunes mésogéennes, mais avec des émigrants boréaux isolés. On les rencontre plus souvent dans le Bassin de Paris, le Jura, la partie nord-est de la France, la partie sud de la RFA, la Crimée et le Caucase. La région de la Choumadie, la Serbie de l'Est, les Carpathes et les Balkanides sont dans la zone de passage entre la Province apline et la Province euro-caucasienne et quoi qu'elles soient caractérisées par des faunes typiquement mésogéennes, elles contiennent de rares émigrants boréaux. A cause de cela ces pays doivent être considérés comme la partie la plus méridionale de la Province euro-caucasienne.

Le trait commun des deux provinces c'est le développement des sédiments urgoniens qui représentent un biofaciès typique mésogéen à rudistes, coralliaires et grands foraminifères.

3.2.2. Horologie des ammonites aptiennes-albiennes dans la région mésogéenne

Dès le début de l'Aptien la répartition des ammonites démontre une homogénéité beaucoup plus grande, sans une nette différenciation intra-provinciale dans la région jusqu'à l'Albien moyen. Dans cet intervalle (Aptien-Albien inférieur) la région mésogéenne est bien distinguée principalement par le développement des faciès récifaux à coralliaires rudistes et foraminifères benthoniques. Cependant, par rapport aux ammonites, il manque de limite, même en tant qu'une zone vaste transitoire entre la partie sud de la zone boréale et la région mésogéenne.

Le modèle aptien dans l'horologie des ammonites est conservé grosso modo dans l'Albien inférieur aussi.

L'Albien moyen marque le commencement d'une nouvelle, essentiellement autre, différenciation des ammonites qui continue aussi lors du Crétacé supérieur. La limite entre le Téthys et le Boréal est très cadencée et beaucoup d'espèces boréales pénètrent vers le Sud. Ce brusque changement de l'image paléobiogéographique est un résultat des plissements autrichiens dans la Mésogée et de la grande transgression du Crétacé moyen (Albienne-Cénomanienne) les ayant suivis. Les faunes d'ammonites se dispersent largement et à cause de cela les provinces et les régions paléobiogéographiques perdent leur caractère de bandes, orientées subéquatorialement. Cela importe surtout pour la vaste province européenne (Hoplitinid faunel province; Owen, 1973) qui est déterminée par le développement prédominant de Hoplitinae. Cette province englobe le bassin anglo-parisien et toute la Province euro-caucasienne du Berriasien-Barrémien. C'est au Sud de la Province européenne que s'étend la Province atlaso-apenninienne, qui se caractérise par la présence de plusieurs espèces du Gondwana. Cette province englobe de même le Proche-Orient (Subprovince arabe).

La fin du chapitre traite les facteurs principaux de l'écologie des ammonites et quelques biotopes typiques du Crétacé inférieur.

VI. TRAITS PRINCIPAUX DU DEVELOPPEMENT GEOLOGIQUE DE LA REGION MESOGEENNE LORS DU CRETACE INFERIEUR

1. Caractéristique générale de la paléogéographie

Sur le plan commun de l'histoire géologique le Crétacé inférieur dans la région mésogéenne semble un temps relativement calme. Parmi les cycles marins mésozoïques globaux il est inclus entre la régerssion du Jurassique supérieur et la transgression cénomanienne (A g e r, 1981).

Lors du Crétacé inférieur la région mésogéenne paraît reprendre „haleine" après l'activation cimmérienne tardive. Ce tableau général, répandu largement dans des monographies générales sur le développement phanérozoïque de la Zone alpo-himalayenne, cache des traits essentiels de ce développement.

1. 1. Evolution des continents et des marges continentales

Les bassins marins du Crétacé inférieur dans la région mésogéenne sont dans le domaine de l'Océan de Téthys. Il a une forme linéaire d'une orientation subéquatoriale, mais à tournants complexes arqués et un nombre de massifs médians (des fragments continentaux). Deux supercontinents — Gondwana et Laurasia déterminent la configuration spatiale du Tethys. La région mésogéenne se développe dans la superficie entre la Plaque afro-arabe et la Plaque euroasiatique.

Les parties marginales des continents sont entraînées dans le champ du Géosynclinal mésogéen et quelques fragments s'en dégagent et constituent les plaques apulienne, ibérique, carno-pannonienne et égéenne.

La riftogenèse, commencée lors du Jurassique dans l'Atlantique central, s'accélère lors du Crétacé inférieur en s'élargissant vers le Nord et vers le Sud.

Dans la Mésogée même il existe des phénomènes analogiques dans les Alpes et dans la Péninsule balkanique linéamentée d'une manière complexe, où il existe des relations de confrontation entre le Massif des Rhodopes, les Kraištides, les Balkanides, les Carpathes et les Dinarides (B o n č e v, 1977; L a u b s c h e r, B e r n o u l l i, 1977; У н к с о в, 1981).

Le début du Crétacé inférieur est marqué par la transgression épicontinentale considérablement plus vaste que celle du Jurassique. Elle laisse seulement des terres fermes insulaires isolées.

Les marges continentales sous-marines dans la région mésogéenne lors du Crétacé inférieur sont du type atlantique (passives). Entre le littoral et le flanc continental presque partout il y a une terrasse d'eau peu profonde. Les sédiments néritiques de la zone du shelf sont le plus largement développés. Dans un nombre de régions (Afrique du Nord, Cordillères bétiques, Pyrénées, Alpes, Carpathes, Balkanides, Caucase, Dinarides), de puissants complexes se forment dans les limites du flanc continental.

Ce chapitre traite en détail les particularités régionales de l'évolution géologique du Crétacé inférieur des marges continentales ainsi que les complexes les plus typiques du Crétacé inférieur: flysch, molasses et plates-formes carbonatées.

1.2. Zones mobiles

Le développement du Crétacé inférieur dans la Mesogée dessine les zones médianes de l'Océan qui ordinairement représentent des zones mobiles héritées du Jurassique.

Aux zones mobiles je rapporte les parties centrales de la région mésogéenne où il existe un magmatisme ophiolitique, ainsi que les zones de dépressions intenses, chargées par de puissants sédiments de flysch. Souvent les zones de formation de flysch sont liées avec des marges continentales relativement actives.

Ce chapitre traite la répartition des ophiolites, des complexes volcano-sédimentaires, des radiolarites et les manifestations orogènes lors du Crétacé inférieur.

2. Certaines particularités du développement géologique de la Mésogée et l'ouverture de l'Océan Atlantique lors du Crétacé inférieur

Il existe des raisons pour supposer que l'évolution de la Mésogée lors du Crétacé inférieur est prédestinée à un grand degré par la tectonique des plaques. De toute évidence, le conflit entre les deux grands cratons — afro-arabe et euroasiatique joue un rôle considérable. Probablement la configuration complexe et les particularités des bassins du Crétacé inférieur sont un reflet de la mosaïque de microplaques et du réseau de failles entre elles.

En outre, la formation de l'Océan Atlantique sud est d'une grande importance géologique. Son ouverture est la plus intense lors du Crétacé inférieur et un nombre de particularités géodynamiques dans la région mésogéenne y sont liées.

3. Conclusions

Dans l'évolution du Crétacé inférieur des différentes zones de la région mésogéenne se dessinent quelques régularités générales.

1. La région se caractérise par un climat chaud et un large développement de différents groupes d'organismes. Une certaine zonalité, déterminée principalement par les particularités climatiques et de même par quelques autres paramètres paléogéographiques, est établie dans leur répartition. Les ammonites, les rudistes et les foraminifères démontrent une zonalité provinciale particulièrement nette.

Pendant le Crétacé inférieur on découvre un panorama paléobiogéographique en train de développement, qui commence par des provinces subéquatoriales nettement marquées au Berriasien et se termine à l'Albien par des régions intensément dispersées.

2. Des associations typiques de roches, liées avec les particularités tectoniques de la zone sont développées dans les différentes zones de la Mésogée. Elles sont parallèles aux lignes tectoniques principales. Cela est nettement souligné dans le développement des ophiolites et du flysch.

Des zones internes avec des complexes marins d'eaux profondes, fortement déformées, parfois faiblement métamorphisées, des zones externes d'un large développement de sédiments de flysch et (ou) des plates-formes carbonatées et un avant-pays, où sont développés des dépôts néritiques ou continentaux, s'y détachent.

En principe, les complexes de flysch sont développés dans les marges continentales qui se caractérisent par une dépression intense compensée. L'épaisseur du flysch dans les différentes zones est de 2000 à 4000 m.

Les plates-formes carbonatées sont d'une large étendue et sont constituées par des rudistes, d'autres bivalves pachyodontes, des coralliaires, de grands foraminifères, des échinides, des gastropodes, des algues, des bryozoaires.

3. Le développement du Crétacé inférieur en Bulgarie représente un intérêt particulier à cause de la présence de coupes complètes, l'abondance des restes fossiles et les faciès variés.

L'analyse des lithofaciès et de l'évolution des environnements sédimentaires lors du Crétacé inférieur en Bulgarie démontre une grande variété, conditionnée par une dynamique importante dans le temps et dans l'espace. En même temps avec les traits spécifiques dans l'évolution des environnements sédimentaires dans le bassin lors du Crétacé inférieur, quelques régularités générales, dont une partie est héritée du Tithonique, se détachent.

Lors du Crétacé inférieur le bassin est disposé entre deux terres émergées: méridionale — de Thrace, qui représente un microcontinent singulier dans l'Océan de Téthys septentrional — et de Dobroudja, qui représente un reste d'un massif plus ancien. Dans la partie méridionale du bassin se détache une grande dépression continuelle, au Nord de laquelle se trouve la vaste zone du shelf. Par rapport au Jurassique tardif l'évolution géologique du Prébalkan s'accélère, ce qui est marqué par une activation de la fosse de flysch.

La formation des roches du Crétacé inférieur dans les Rhodopes du Sud-Est s'est effectuée dans une ramification de la partie sud du bassin mésogéen.

Le bassin du Crétacé inférieur commence à se rétrécir vers la fin du Hauterivien et cette tendance s'accélère graduellement. Les parties est et sud deviennent des terres émergées. A l'Est se découpe une élévation méridionale — l'Elévation euxinienne, qui s'élargit à l'Ouest et à la fin de l'Aptien le bassin ne recouvre que la Bulgarie du Nord-Ouest et la Bulgarie centrale du Nord et une petite bande sur les bords du Danube de la Bulgarie du Nord-Est aux environs de la ville de Ruse.

A la fin de l'Aptien, dans le Prébalkan central et oriental, un plissement assez fort se manifeste. Par la suite, ainsi qu'à cause des tendances générales de l'évolution géotectonique, un changement considérable de la structure régionale et de la paléogéographie y liée s'effectue à la fin du Crétacé inférieur.

4. Dans plusieurs endroits des zones internes de la région mésogéenne il y a des manifestations de magmatisme ophiolitique, des formations de complexes volcano-sédimentaires et des radiolarites. Dans plusieurs secteurs par suite des orogenèses du Crétacé supérieur et du Paléogène, les roches du Crétacé inférieur sont fortement disloquées, englobées dans des charriages par endroits faiblement métamorphisés.

5. Quelques différences entre la Mésogée occidentale et la Mésogée orientale se dessinent lors du Crétacé inférieur, qui se découpent fortement dans l'époque suivante du Crétacé.

Pendant le Crétacé inférieur le Téthys dans la Mésogée occidentale a deux détroits principaux — septentrional et méridional, qui contournent la Plaque ibérique et se joignent vers la Sicile. Le détroit septentrional se rétrécit graduellement par suite de quelques étapes de subduction et d'orogenèses intenses, tandis que celui du Sud, débutant lors du Crétacé supérieur, se transforme progressivement dans la Méditerranée actuelle.

6. Les particularités géologiques de la région mésogéenne ont été influencées non seulement par le mouvement relatif de l'Afrique et de l'Europe, mais aussi par un nombre de microplaques à l'intérieur de l'espace mésogéen.

7. Les données de JOIDES et les recherches séismiques démontrent que le spreading et le magmatisme ophiolitique de la région sont du Jurassique-Crétacé.

8. L'évolution géologique de la région mésogéenne du Téthys lors du Crétacé inférieur est liée avec l'ouverture de l'Océan Atlantique sud.

La vitesse du spreading du fond de l'Océan dans l'Atlantique central lors du Crétacé inférieur s'accélère considérablement par rapport aux époques antérieures. Un nombre de zones mobiles, particulièrement après le Barrémien, s'activent dans la Mésogée. On ne peut pas affirmer qu'il y a une coïncidence des étapes d'évolution des deux océans. Il n'y a qu'une corrélation d'activité et (ou) de passivité dans les différentes parties du réseau tectonique des plaques. Il est évident que l'élargissement de l'Atlantique a amené un rétrécissement graduel de la région mésogéenne du Téthys manifesté nettement à la fin du Crétacé inférieur. Il est accompagné par une compensation des marges continentales et le bassin devient moins profond.

9. L'évolution du Crétacé inférieur s'accélère progressivement, s'active dans les zones principales de la région et par là prépare et réalise les transformations autrichiennes, décisives dans l'histoire de cette zone dynamique de la Terre.

СРЕДИЗЕМНОМОРСКИЙ НИЖНИЙ МЕЛ

(Резюме)

Средиземноморская область является частью Тетисского океана. Она охватывает Северную Африку, Южную Европу, Кавказ и Малую Азию. Она характеризуется специфическим развитием нижнемеловой серии (= нижнемелового отдела), что контрастирует с другими соседними областями и провинциями (Волжской, Бореальной, Гималайской, Мальгашской, Андской). В этой области развиты разнообразные фации — от глубоководных морских до континентальных. Установлены богатые комплексы фоссилий различных групп организмов.

Основой этой работы являются результаты исследований нижнемеловой серии в Болгарии, которые автор проводит с 1957 г. Кроме того, с 1960 г. по 1982 г. он имел возможность проводить исследования и собирать материал в ряде стран Средиземноморской области (в Алжире, Франции, Швейцарии Италии, Югославии, Венгрии, Польше, СССР, Румынии и Чехословакии).

При рассмотрении нижнего мела в такой обширной области возникло и много затруднений, особенно в некоторых странах, где серия слабо изучена. С другой стороны, обобщения всегда таят опасность поверхностного обзора. Вот почему стремление автора охватить, по возможности, наиболее полно общие закономерности развития нижнемеловой серии, представляя исходные фактические данные. В желании сделать изложение более сжатым избегнута подробная характеристика серии в отдельных странах.

Часть первая

ВВЕДЕНИЕ

I. ОБЩИЕ СВЕДЕНИЯ О НИЖНЕМ МЕЛЕ

В этой главе рассмотрены номенклатура нижнего мела, его границы, радиометрические данные о нижнемеловой эпохе и материал, послуживший основвой для исследования.

Нижний охватывает приблизительно нижнюю половину меловой системы. Она включает пласты, образованные в раннемеловую эпоху, в которых устанавливается цепь последовательностей аммонитов от берриасского яруса в основании (зона *Pseudosubplanites grandis*) до альбского яруса (зона *Stoliczkaia dispar*), включительно в верхней части разреза. Развиты морские, озерно-болотные и континентальные осадочные породы.

По радиометрическим данным раннемеловая эпоха охватывает интервал от 137±5 млн. лет до 100±5 млн. лет.

II. ЯРУСЫ, ПОДЪЯРУСЫ И БИОСТРАТИГРАФИЧЕСКИЕ ЗОНЫ НИЖНЕГО МЕЛА

Нижнемеловая серия охватывает следующие ярусы: берриасский, валанжинский, готеривский, барремский, аптский и альбский, которые подразделяются на подъярусы. Дана краткая общая характеристика каждого яруса и его подъярусов и более подробно рассмотрены биостратиграфические зоны аммонитов, кальпионеллид, фораминифер, наноконусов и остракод.

Часть вторая

РЕГИОНАЛЬНАЯ СТРАТИГРАФИЯ

III. РЕГИОНАЛЬНО-СТРАТИГРАФИЧЕСКАЯ ХАРАКТЕРИСТИКА НИЖНЕГО МЕЛА

Регионально-стратиграфическая характеристика нижнемеловой серии начинается с рассмотрения нижнемеловых отложений Болгарии, так как они имеют особенно представительные и детально изученные разрезы, которые составляют основу этого труда.

Дальше рассмотрение региональной стратиграфии проведено по областям и палеогеографическим зонам с запада на восток и с юга на север.

1. Болгария

Модель стратиграфической классификации нижнемеловой серии в Болгарии основывается на общих закономерностях развития этой серии в Средиземноморской области и на результатах проведенных до настоящего времени исследований литологических и фаунистических последовательностей в естественных обнажениях и в разрезах скважин.

Составлена в общих чертах литостратиграфическая панорама нижнемеловой серии в Болгарии, которая связана со следующими единицами: Гложенской, Сливницкой, Брестникской, Костелской, Хыневской, Златарицкой, Черниосымской, Тичанской, Салашской, Каспичанской, Камчийской, Горнооряховской, Мраморенской, Хайрединской, Разградской, Трымбешской, Сумерской, Свиштовской, Ковачевской, Русенской, Елешницкой, Симеоновской, Малопештенской, Романской и Спасовской свитами, Врачанской и Ловечской ургонской группой. Взаимоотношения между отдельными литостратиграфическими единицами показаны на конкретных разрезах.

Подробно рассмотрены регионально-стратиграфические особенности нижнемеловой серии в Краиште, Южных Карпатах, Балканидах, Мизийской платформе, Страндже и в Восточных Родопах.

2. Северо-Западная Африка

В Северо-Западной Африке нижнемеловая серия наиболее широко развита в Марокко. Ее распространение связано с бессейнами Тарфайя-Эль Ааиун, Высокого Атласа, Агадир-Есауира, Месеты и Марокканского рифа.

В бассейне Тарфаяй-Эль Ааиун нижнемеловые отложения начинаются континентальными песчаниками и конгломератами мощностью около 1100 m, которые условно относятся к барремскому ярусу (W i e d m a n n, B u t t, E i n s e l e, 1978). Эти образования залегают на триасовых и юрских породах.

Морские нижнемеловые осадки в этом бассейне аптского и альбского возраста.

Бассейн Агадир-Есауира (Хаха) охватывает две седиментационные зоны. В южной, Агадирской зоне нижнемеловая серия очень хорошо обнажается вдоль береговой полосы между Arhoud, Tarhazoute и Aourir, севернее Агадира. Представлены все ярусы серии.

На севере нижнемеловая серия развита в Месете и в Марокканском рифе.

В континентальной окраине СЗ Африки нижнемеловая серия установлена на острове Майо (острова Зеленого Мыса), около Канарских островов и в Маганском плато, где она представлена разнообразными морскими фациями.

3. Северная Африка

Нижнемеловая серия развита в морских фациях в Алжире и Тунисе, в то время как в Ливии, Египте и Сахаре она представлена континентальными образованиями.

В Алжире нижнемеловые отложения развиты в Сахарском Атласе, в Высоких плато и в Тельском Атласе.

В западной части Сахарского Атласа серия представлена песчаниками и песчаными глинами (continental intercalaire), а на востоке этой же зоны — песчаниками и эвапоритами (сахарского типа).

В Высоких плато нижнемеловая серия терригенно-карбонатного типа. Развиты все ярусы.

Осадочные породы нижнемеловой серии обнажаются на обширных площадях в Тельском Атласе, где они представлены глубоководными морскими фациями, которые контрастируют с неритическими образованиями Высоких плато. Богатой фауной доказано присутствие всех нижнемеловых ярусов.

Нижнемеловая серия в Тунисе связана с тремя основными тектоническими зонами: Тунисской депрессией, комплексом интракратонных бассейнов и с нестабильными неритическими бассейнами в Центральном Тунисе и Тунисской Сахаре.

В самой южной (Сахарской) части Туниса основание нижнего мела (берриас — готерив) сложено континентальными терригенными породами и эвапоритами. К востоку и северо-востоку континентальные терригенные фации сменяются карбонатными, относящимися к типичной средиземноморской нижнемеловой серии. Их южная граница в конце альбского века отмечает отправную точку транссахарской позднемеловой трансгрессии.

Наиболее широко серия развита в Северном Тунисе, где она связана с Тунисской депрессией (Sillon Tunisien). Представлены вся ярусы от берриасского до альбского включительно (Burollet, Manderscheid, 1965; Stranik et al., 1974; Memmi, 1979, 1980, 1981). В этой области нижнемеловые осадочные породы развиты в двух основных фациальных обстановках: неритической и пелагической.

Неритические фации хорошо развиты преимущественно в массиве Загуан (Zaghouan). Они представлены органогенными и биодетритовыми известняками и песчаными мергелями.

Пелагические фации широко развиты в средней части депрессии и в Восточно-Тунисском Атласе — микрозернистые известняки, сублитографические известняки (вокontско-салашского типа) с прослоями мергелей. Они содержат большое количество кальпионеллид и аммонитов.

В общем, нижнемеловые отложения в Алжире и Тунисе показывают значительно разнообразные палеоседиментационные обстановки от континентальных до батиальных типичного средиземноморского типа. На востоке и юго-востоке — в Ливии и Египте, нижний мел представлен континентальными фациями.

4. Иберийский полуостров

Нижнемеловые осадочные породы на Иберийском (Пиренейском) полуострове связаны с несколькими тектоническими зонами. Около центрального герцинского массива Иберийской Месеты развиты прибрежные фации со многими внутриформационными перерывами. В Кантабрийских горах, в Пиренеях, Иберийских и Каталонских горах нижнемеловая серия очень разнообразна, представлена целой гаммой различных фаций — от вельдского до флишевого типа. В Суббетской депрессии (между Месетой и Бетским массивом), включая и Балеарские острова, развиты глубоководные морские фации. Общее распространение нижнемеловой серии очерчивает большой треугольник вокруг Месеты, в западной части которой находится Португалия , на северо-востоке — Кантабрийские и Иберийские горы и на юго-востоке — Суббетская зона с ее продолжением на Балеарских островах. На севере Иберийский полуостров отгорожен Пиренеями.

В Пиренеях нижнемеловая серия представлена исключительно разнообразными фациями с быстро варьирующими мощностями и сложными пространственными соотношениями между литостратиграфическими единицами (Rat, 1969; Peybernes, 1976; Jaffrezo, 1981). Нижнемеловые фации преимущественно неритические, главным образом карбонатного типа, а в отдельных областях и терригенные. Особенно широко развиты ургонские фации, слагающие мощные разрезы от валанжина до альба включительно. Налицо множество перерывов и глубоких размывов отдельных горизонтов, что обусловило образование значительных бокситовых месторождений. В центральной части Северопиренейской зоны в раннемеловую эпоху проявлен перидотитовый магматизм, с которым связано образование хризотил-асбестовых месторождений. В палеонтологическом отношении серия характеризуется преимущественно фораминиферами, водорослями, нанопланктоном и др., а также бивальвиями, гастроподами, брахиоподами, эхиноидеями. Аммониты встречаются редко, главным образом среди аптских глинисто-известковых пород.

5. Франция

Нижнемеловая серия во Франции связана со следующими областями: Альпами (включая Подальпийские цепи с Воконтским прогибом), Провансом, Юрскими горами, Парижским и Аквитанским бассейнами. Здесь следует упомянуть и нижнемеловые отложения во Французских Пиринеях.

Французские Альпы показывают разнообразие нижнемеловых отложений, развитых в глубоководных морских фациях. В этой области намечаются несколько зон, в которых серия показывает специфические особенности.

Савойская зона охватывает значительную часть Западных Альп с массивами Пельвэ, Бельдон и Монблан. В северо-западной части этой зоны, западнее Монблан (chaînes des Aravis), отложения берриас-готерива представлены микритовыми и глинистыми известняками. Баррем и апт — известняками и песчаными известняками ургонской фации, на которых трансгрессивно залегают альбские глауконитовые песчаники. К юго-западу от Монбланского массива в Ультрагельветской зоне развиты только барремские глинистые известняки — часть надвига Рослет (Eltchaninoff—Lancelot et al., 1982).

Дофинейская зона представляет раннемеловое понижение между Центральным массивом и массивами Монблан, Бельдон и Меркантур. В южном направлении понижение расширяется и переходит в Воконтский прогиб. В северной части оно более узкое, а для осадочных пород характерны бо́льшие мощности. Кроме того, в северной части осадки алевритовые и/или слабопесчаные, часто с развитием турбидитов, в то время как на юге развиты исключительно глинисто-известковые породы. Полоса неритических отложений ограждает понижение: на севере это — высокие известковые горы Савойи, массивы Гранд-Шартрёз и Веркор и окрестности Валанса; на юге — Лангедок и Прованс.

Нижнемеловые отложения в *Южных Подальпийских отрогах (Воконтский прогиб)* представлены пелагическими осадками (альпийского типа в отличие от неритического типа в Юрских горах). Это единственная зона во Франции, где от берриасского до альбского века существовало глубоководное морское осадконакопление, переходящее и в сеноман. По существу, Воконтский прогиб представляет громадный залив Подальпийского раннемелового понижения. Развиты микритовые известняки, глинистые известняки и мергели, богатые аммонитами и планктонной микрофауной (кальпионеллиды, радиолярии, фораминиферы и нанокопусы). Это та же фация, в которой развита нижнемеловая серия в Салашской синклинали в СЗ Болгарии.

К северу от Диуа начинаются *Северные Подальпийские отроги*, в которых нижнемеловая серия развита в смешанных фациях. Севернее района г. Ди (Die) выделяется высокая стена ургонских известняков, слагающих южную окраину массива Веркор и представляющих характерный элемент этой зоны. Нижнемеловые отложения представлены смешанными фациями — многократным чередованием биоморфных известняков и мергелей. Эти породы осуществляют переход от воконтских к юрским фациям нижнего мела. Развиты все ярусы серии, которые очень хорошо охарактеризованы палеонтологически. Особенно представителен разрез между Греноблем и Шамбери.

Нижнемеловые отложения в Пьемонтской зоне представлены мощной монотонной серией известковых сланцев (calcshistes), которые во время верхнеэоценового и олигоценового надвигового этапа в результате динамометоморфизма превращены в блестящие сланцы (schistes lustrés). Эти известковые сланцы определены как нижнемеловые по аналогии с подобной неметаморфизованной толщей Северных Апеннин, которая по наличию кальпионеллид отнесена к титон-неокому. Они залегают на зеленокаменных породах — офиолитах (диабазах и спилитах) и габбро и перекрываются радиоляритами, метаморфизованными в кварциты с серицитом и хлоритом и имеющими хорошие современные обнажения на Мон-Визо (Mont-Viso). Известковые сланцы перекрываются верхнемеловым флишем с гельминтоидами.

В Провансе нижнемеловая серия представлена мелководными морскими осадками — зоогенными известняками, глауконитовыми песчаниками с фосфоритами и мергелями.

В Аквитанском бассейне нижнемеловые отложения известны в районе Адур и Парантис.

Нижнемеловые осадки в Юрских горах представлены платформенными, преимущественно карбонатными фациями. Серия начинается пурбекскими лагунными отложениями, над которыми залегают мергели и глинистые известняки с прослойками лигнитов. Вверх по разрезу следуют красноватые известняки и мергели, известные из района г. Невшатель — Валанжин — Отрив в Швейцарских Юрских горах. Относительно наиболее глубоководными среди нижнемеловых осадков в Юрских горах являются готеривские мергели с эхиноидеями. Их образование совпадает со временем, когда море наиболее широко открывается на северо-запад к Парижскому бассейну.

Барремские и аптские отложения развиты только в высоких частях Юрских гор и представлены главным образом ургонскими известняками. На них трансгрессивно залегают альбские глауконитовые песчаники.

Нижнемеловые осадочные породы обнажаются в виде непрерывной полосы в юго-восточной части Парижского бассейна. В остальной части бассейна серия повсюду установлена с помощью скважин.

В раннемеловую эпоху Парижский бассейн представлял пролив, который связывал Средиземноморский бассейн с Северным морем, и это определяет распространение и особенности отдельных ярусов. Над лагунными или озерными глинистыми известняками пурбекского „яруса" следуют вельдские песчано-глинистые толщи, в которых найдены игуанодоны (около Бернисарта), крокодилы, черепахи, рыбы.

В центральной части пролива (р. Об) морское осадконакопление начинается с верхневаланжинских зоогенных известняков и завершается альбскими глинами.

6. Швейцарские Альпы

Кроме Юрских гор, нижнемеловые отложения распространены и в Швейцарских Альпах. Устанавливается фациальная зональность, при которой наблюдаются латеральные переходы фаций от юрского типа на севере и воконтского типа на юге через смешанные фации Северных Подальпийских отрогов к фациям в Швейцарских Альпах. Нижнемеловая серия связана с внешней зоной Альп, с Предальпами и с Гельветскими надвигами.

7. Восточные Альпы

Нижнемеловая серия имеет ограниченное распространение в Восточных Альпах. Во флишевой зоне устанавливаются две нижнемеловые полосы. В северной полосе устанавливаются: 1) мергели с *Duvalia lata* и валанжинские аммониты; 2) брекчиевидные известняки (валанжин); 3) кремнистые готеривские известняки; 4) ургонские известняки с орбитолинными мергелями в верхней части (баррем — апт). В южной полосе валанжинские известняки и ургонские отложения замещаются мергелями. Подобный переход от неритических к батиальным фациям наблюдается и в Западных Альпах.

8. Венгрия

Нижнемеловая серия в Паннонском срединном массиве известна в его южной части — на возвышенности Виллань и в горах Мечек и в Венгерском Средногорье — в Бакони и в Герече. Развиты разнообразные фации с большим количеством внутриформационных перерывов. В большинстве мест нижнемеловые породы залегают на сильно размытой поверхности титонских известняков.

В горах Мечек устанавливаются разрезы, в которых берриасские отложения связаны постепенным переходом с титонскими породами. Берриас представлен плотными микритовыми известняками и глинистыми известняками с кальпионеллидами, радиоляриями и аммонитами. Нижний валанжин связан с вулканогенно-осадочными образованиями (трахидолеритовой туфогенной свитой мощностью 10—100 m), в которых найдена *Kilianella roubaudiana* (d'O r b.). Верхний валанжин представлен мергелями и песчаниками.

На размытой поверхности залегают ургонские известняки с большим количеством пахиодонтов.

В Виланских горах на глубокоразмытых кимеридж-титонских известняках залегают диабазовые вулканиты (трахидолериты), которые принимаются за одновозрастные с валанжинской трахидолеритовой туфогенной свитой в горах Мечек. В Беремендском горсте и в Харшани во время валанжина и готерива образуются бокситы. Морская седиментация начинается в барреме образованием ургонских известняков с орбитолинами и пахиодонтами, которые достигают основания альба.

Наиболее полным является разрез серии в Бакони. Берриасские отложения связаны литологическим переходом с титонскими (Шумег, Локут, Шомхед). Представлены светлые микритовые известняки, глинистые известняки (фация „бьянконе"), содержащие аммониты, большое количество кальпионеллид и радиолярий. В долине Алшомайор-Зирц и в восточной части Шомхед берриас представлен красноватыми известняками с аммонитами или известняками с редкими криноидеями (Иштенешмал-Зирц), а севернее Зирц и вблизи Баконичёрнье — светлыми известняками с кальпионеллидами. Вверх по разрезу устанавливаются валанжин и готерив (мергели), баррем (желтоватые известняки), апт (известняки), альб (глауконитовые мергели).

Нижний мел развит и в северной половине Герече, где он связан с непрерывным комплексом от верхнего берриаса до баррема включительно

9. Чехословакия

Нижний мел установлен в зоне клиппов (Зап. Карпаты), в Высоких Татрах и в Силезской зоне (Бескиды). Развиты разнообразные фации от неритических до глубоководных морских.

10. Польша

В области Польских Карпат нижний мел развит в трех зонах: флишевой зоне, в зоне Пеннинских клиппов и в Татрах, где представлены преимущественно флишевые отложения.

11. Румыния

Нижнемеловая серия широко распространена в Восточных Карпатах, в Апусенах, во Влахской низменности и в Северной Добрудже.

Нижнемеловые осадки в Восточных Карпатах двух типов: флиш и мергели, богатые аммонитами. Флишевые отложения, в свою очередь, исключительно разнообразны — от грубых до песчано-глинистых с келитовыми сидеритами. Местами развиты кремнистые сланцы, битуминозные сланцы, мергели с радиоляриями. Встречаются прослойки туффитов.

Особенно характерна для нижнего мела в Южных Карпатах быстрая смена фаций — от пелагических глинистых известняков к флишевым, терригенно-карбонатным и карбонатным породам.

В Апусенах нижнемеловые отложения преимущественно терригенного типа. В некоторых местах развиты и вулканогенно-осадочные толщи.

В большей части Влахской низменности (северная часть Мизийской платформы) нижний мел представлен теми же фациями, как и в Центральной Северной Болгарии. В берриас-валанжинской части разреза развиты известняки каспичанского типа.

В центральной части низменности с севера вдается залив, в котором развиты более глубоководные морские известняки с кальпионеллидами.

Над каспичанскими известняками повсюду залегают глинисто-известковые породы разградского типа (готерив — нижний апт).

Альбские отложения залегают трансгрессивно на породах более древних нижнемеловых ярусов (баррема — апта), подобно северной полосе Центральной Северной Болгарии (Брест — Гиген). В Северной Добрудже развиты неритические терригенные и карбонатные толщи с множеством внутриформационных перерывов.

12. Советские Карпаты

Нижний мел обнажается в двух основных зонах: Старо-Самборской и Мармарошской.

В Старо-Самборских Карпатах серия связана со Спасской группой, которая представлена тремя терригенными свитами, развитыми во внешней флишевой зоне.

В Мармарошской зоне нижний мел связан с тремя свитами: Каменепотокской (флиш), Каменелинской (с двумя краевыми фациями — терригенного и карбонатного типа) и Соймульской свитой (алевролиты и песчаники), которая переходит и в сеноман.

13. Крым и Кавказ

Нижний мел в Крыму обнажается в виде полосы, начинающейся со второго отрога Крымских гор в долине р. Черная и продолжающейся на северо-северо-восток к Бахчисараю — Симферополю и оттуда на восток к Феодосии. В Степном Крыму серия установлена в глубоких скважинах. В Яйлинском и Восточно-Крымском синклинории нижний мел развит преимущественно в глубоководных морских фациях, а в остальной части Крыма представлены неритические отложения.

Нижнемеловые отложения показывают значительные изменения фаций и мощностей в ряде внутриформационных перерывов. Наиболее значительную мощность серия имеет в Восточном Крыму (1500 m), в то время как в Юго-Западном Крыму она местами едва достигает 5 m.

Нижнемеловые породы связаны постепенными переходами с верхнеюрскими или залегают на пестром основании — трансгрессивно и несогласно на породах Таврической серии (триас — средняя юра), или ингрессивно заполняют различные понижения в донижнемеловом рельефе. Местами нижнемеловые отложения отсутствуют.

Нижний мел на Кавказе связан с несколькими тектоническими зонами, каждая из которых характеризуется различными фациями и мощностью.

Нижнемеловые породы в Северо-Западном Кавказе приурочены к северному склону Главного Кавказского хребета к западу от р. Белая. Они характеризуются большими мощностями (4—5 km) и преобладанием пелитовых образований — т. наз. сидеритовых глин. Развиты все ярусы серии; местами в отдельных частях разреза отмечается некоторая неполнота.

К востоку от р. Белая до Каспийского моря разрез нижнего мела слагается двумя большими комплексами.

Нижний комплекс представлен терригенно-карбонатными породами берриас-нижнебарремского возраста. Мощность до 850 m. Верхний комплекс терригенный (верхний баррем — нижний альб). Преобладают песчано-глинистые, глауконитовые породы, часто с известковыми конкрециями. Мощность до 700 m. Средний и верхний альб обычно представлены черными аргиллитами, в верхней части которых появляются прослои мергелей. Мощность от 40—80 m до 150 m на севере в Предкавзазье.

В Абхазско-Рачинском районе Грузинской зоны нижнемеловые осадочные породы отличаются от флишевых отложений южного склона Большого Кавказа и от неритических образований Северного Кавказа (Рентгартен, 1951). Широкое развитие в районе имеют известняки, довольно часто пелитоморфные, и мергели, которые слагают разрезы берриаса, готерива и баррема. Они характеризуются богатой фауной цефалопод, известной из многочисленных публикаций. Преобладают средиземноморские виды, но встречаются и северные формы. Апт представлен мергелями, а альб — терригенными осадками.

В Дзирульско-Кутаисском районе нижнемеловые разрезы слагаются известняками, часто с рудистами в барреме. Апт представлен мергелями, а в альбе развиты алевролиты, песчаники и туффиты.

Нижний мел развит в трех зонах Малого Кавказа: Мисхано-Кафанской, Севано-Карабахской и Сомхито-Агдамской. Развиты все ярусы серии, разрезы которых обычно сложены терригенными и карбонатными породами, часто с прослоями туфопесчаников.

14. Южные Альпы, Апеннины и Сардиния

Это центральная часть Средиземноморской области, в которой нижний мел развит преимущественно в глубоководных морских фациях, часто в ассоциации с радиоляритами. В южной части Венецианских Альп, в Южных Апеннинах и в Сардинии представлены и неритические известняки с рудистами и неринеями.

В Ломбардии и Северных Апеннинах распространены глубоководные морские глинисто-известковые отложения типа Майолика и Бьянконе.

15. Югославия

Нижний мел в Югославии имеет широкое распространение и представлен всеми своими ярусами. Серия распространена в следующих палеогеографических зонах: в Словенской депрессии, в Динаридах, Косово, в Шумадии и Восточной Сербии.

Особенно характерно для Словенской депрессии широкое развитие (от позднего триаса до берриаса) пелагических карбонатных осадков, сланцеватых и окремнелых радиоляритов, которые контрастируют с неритическими образованиями в соседних районах.

На бериасских известняках трансгрессивно, но согласно залегают известковые брекчии с остатками рудист, орбитолин, водорослей, гидрозоа, редких гербергелей и примитивных тальманиэлей „которые определяют апт-альбский возраст.

В Далматинской зоне Динарских гор, в зоне Высокого карста и в Предкарстовой подзоне развиты исключительно карбонатные фации нижнемеловых отложений, а в Босненской зоне — флишевая фация.

Флишевые отложения залегают на вулканогенно-осадочной толще офиолитовой группы с верхнеюрскими радиоляритами в самой верхней части, а берриасские отложения связаны переходом с верхнеюрскими карбонатами.

В Косово известны только барремские, аптские и альбские отложения, развитые в Кукесской зоне, в Метохии, в Црнслевскидреницкой зоне, западнее Косовска Митровица и в Косово Поле. Представлены терригенно-карбонатные осадки преимущественно неритической и реже батиальной фаций.

Шумадийская зона охватывает южную окраину Баната, окрестности Белграда, Шумадию, Восточный и Юго-Восточный Копаоник, где развиты преимущественно неритические терригенно-карбонатные отложения.

Нижнемеловая серия имеет широкое развитие и в Восточной Сербии, где представлена разнообразными породами значительной мощности. Она хорошо обнажается от междуречья Моравы и Тимока на севере до Сува-Реки и Стара-Планины на юго-востоке.

Сербские геологи выделяют четыре основных типа нижнемеловых отложений: 1) мелководные морские; 2) флишевые; 3) переходного типа; 4) глубоководные морские. Однако их пространственное разграничение недостаточно выяснено. В связи с этим часто типичные пелагические известняки с глубоководными морскими фоссилиями описываются как неритические фации.

Во время раннего мела Восточной Сербии оформляются два значительных понижения, в одном из которых образуется флиш (Лужникская зона), а в другом — вулканогенно-осадочные толщи (Краиненская зона Дунайского трога).

16. Албания

Нижнемеловые отложения в Албании являются продолжением Динарских. Преобладают неритические карбонатные фации. Развиты также пелагические известняки с кремнем и флишевые осадки.

16. Греция

В западной части Греции, в Предапулийской зоне нижний мел охватывает часть известняков Вигла (титон — нижний сенон). Эти известняки развиты и в Ионийской зоне, где они представлены более глубоководной морской фацией с радиоляриями и яшмовыми линзами. Известняки содержат кальпионеллиды, аптихи, *Mesohibolites* и *Orbitolina*, которые позволяют определить интервал от берриаса до альба включительно.

В континентальной части зоны Гаврово нижний мел связан с водорослевыми известняками, которые переходят в верхнюю юру. На полуострове Пелопоннес развиты более разнообразные неритические известняки с остатками фораминифер, кораллов, водорослей, которые характеризуют интервал от верхней юры до основания нижнего мела.

В зоне гор Пинд основание серии связано с радиоляритами, часто импрегнированными марганцевыми окислами. Радиоляриты чередуются с пелагическими известняками с радиоляриями. В краевых частях встречаются прослои брекчиевидных известняков, иногда песчаных и оолитовых. Над этими отложениями залегает песчано-мергелевый флиш, ассоциирующий с красными мергелями с радиоляриями. Различные *Orbitolina* и *Dictyoconus* определяют баррем-аптский возраст.

В зоне горы Парнас нижний мел охватывает часть брекчиевидных известняков с *Ellipsactinia ellipsoidea* Stein (титон — валанжин), оолитовые и плотные известняки, над которыми развит второй бокситовый горизонт Парнаса.

В Вардарской зоне развиты апт-альбские отложения с орбитолинами и нринеями. Это конгломераты с известняковой, иногда с офиолитовой галькой; представлены также песчано-детритовые известняки. Они залегают трансгрессивно и несогласно на верхнеюрских офиолитах.

На Крите нижний мел представлен исключительно известняками, местами с радиоляритами.

В Юго-Восточных Родопах нижний мел связан с филлитовым комплексом Макри, обнаженным северо-западнее Александрополиса. Этот комплекс сложен филлитами, граувакками и слабо метаморфизованными офиолитами. Они содержат прослои известняков, среди которых найдены верхнеюрские и нижнемеловые кораллы.

На о. Самотраки нижний мел охватывает часть офиолитового комплекса. Серия представлена габбро, диабазами, коралловыми известняками, сланцами и полигенными брекчиями. Взаимоотношения габбро и диабазов с осадочными породами показывают, что базитовый вулканизм проявлен на границе нижнего мела (Braun, 1968).

В Тродос нижний мел представлен долеритами (130—120 млн. лет).

18. Турция

Нижний мел имеет ограниченное распространение в Турции. Отложения серии часто залегают трансгрессивно на юрских или палеозойских породах.

Нижнемеловые породы известны вдоль южного побережья Мраморного моря, в Анатолии, в северной части района Бейпазары — Наллыхан, к югу от Болу, к северу от Гёйнюк и оз. Абант, в районе Зонгулдак, к северу от Илгаз — Куршунлу, вблизи Байбурт, к северу от Тартума и в Таурус.

Вдоль Черноморского побережья серия начинается конгломератами, над которыми следуют известняки (валанжин — нижний апт), известковые песчаники и известняки с *Nerinea* и *Requienia*. Вверх по разрезу наблюдаются песчаники Велебек (верхний апт) и альбские песчаники и мергели, перекрытые мергелями и грубым флишем (верхний альб — сеноман).

Между Черным морем и районом Илгаз — Куршунлу развиты белые массивные известняки с аммонитами (берриас — нижний баррем).

Нижнемеловые осадки глубоководной морской фации развиты между Анатолийскими горами и северными горными цепями.

В Юго-Восточной Анатолии в кернах глубоких скважин установлены доломитовые известняки с орбитолинами.

19. Ближний Восток

Нижний мел известен во всех странах Ближнего Востока. Серия развита в мелководных морских, преимущественно карбонатных и/или терригенных фациях. Наиболее широкое развитие имеют аптские и альбские осадочные породы, которые почти повсеместно относятся к морскому типу. На отдельных территориях распространены континентальные образования.

Базальтовый вулканизм позднеюрской эпохи продолжается в раннемеловой эпохе с ясно выраженным пароксизмом в аптском веке.

Часть третья

ОБОБЩЕНИЯ И ВЫВОДЫ

IV. СТРАТИГРАФИЧЕСКИЙ ОЧЕРК

В этой главе рассмотрено развитие нижнемеловых ярусов в Средиземноморской области, причем обращено внимание как на специфические черты в отдельных странах, так и на общие особенности в распространении каждого яруса.

1. Берриасский ярус

Берриасский ярус имеет широкое распространение в Средиземноморье. Он представлен разнообразными морскими фациями, а местами и континентальными образованиями пурбекского или сахарского типа.

В большинстве районов наблюдается постепенный литологический переход от титонских к берриасским отложениям. Эта непрерывность нарушается в отдельных местах локальными тектоническими и/или палеогеографическими явлениями. Отсутствие берриасских осадков в некоторых районах обусловлено устойчивыми поднятиями значительной продолжительности.

2. Валанжинский ярус

Распространение валажина и тип его осадков сходны с распространением и типом берриасских отложений. Однако местами раннемеловое осадконакопление начинается в валанжинском веке. Кроме того, во всех зонах с глинисто-известковой седиментацией наблюдается постепенное увеличение содержания глинистой составляющей в валанжинских разрезах и увеличение мергелей за счет известняков.

3. Готеривский ярус

Готеривские отложения имеют значительное распространение и очень разнообразные фации. В Западном Средиземноморье преобладают флишевые отложения, в то время как в остальной части Средиземноморской области для готеривского яруса характерна пестрая фациальная картина, очерченная неритическими глубоководными морскими осадочными породами. В западной части Иберийского полуострова развиты континентальные готеривские толщи вальдского типа.

4. Барремский ярус

Баррем характеризуется очень разнообразными фациями, среди которых преобладают неритические. Во время позднебарремского века начинается широкое развитие ургонской фации, что представляет типично средиземноморское явление. Кроме неритических терригенных, терригенно-карбонатных и ургонских фаций, которые наиболее широко распространены в центральной части Средиземноморской области, как и в некоторых депрессионных зонах, барремский ярус связан с глубоководными морскими глинистыми и глинисто-карбонатными, а местами и флишевыми породами.

5. Аптский ярус

Аптский ярус известен во всем Средиземноморье — от Атлантического океана до Ближнего Востока. Развиты разнообразные фации, среди которых особенно характерны ургонские. За исключением некоторых районов, например, Прованса, отчасти Высоких плато в Алжире, а также в Северо-Восточной Болгарии и Добрудже, где ургон представлен довольно чистыми известняками, в остальных зонах ургонские известняки ассоциируют с терригенными осадками — мергелями, алевролитами и песчаниками. Повсюду ургонские платформы оконтуриваются терригенно-карбонатным шлейфом.

В ряде зон (Северная Африка, Альпы, Карпаты) аптский ярус связан с флишевыми отложениями, а в других местах (Тунисская депрессия, Юго-Восточная Франция, Суббетская зона) — с пелагическими глинисто-карбонатными породами.

Характерным компонентом аптского яруса в некоторых районах (Пиренеи, Карпаты, Предбалканье, Северный Кавказ) являются молассовые образования.

Обычно аптские отложения представляют конечный продукт больших раннемеловых депрессий.

6. Альбский ярус

Это последний ярус нижнего мела. В сравнение с другими ярусами он имеет самое ограниченное распространение, связанное с постаптской регрессией или с размывом после альбского века. Кроме флишевых отложений и глубоководных морских черных сланцев и известняков с радиоляритами, известных в некоторых зонах Западного Средиземноморья, наиболее характерными отложениями для альбского яруса являются песчано-глауконитовые и молассы (конгломераты, глауконитовые песчаники, алевролиты и глины).

V. ЭВОЛЮЦИЯ И ПАЛЕОБИОГЕОГРАФИЯ РАННЕМЕЛОВЫХ МОРСКИХ ОРГАНИЗМОВ В СРЕДИЗЕМНОМОРСКОЙ ОБЛАСТИ

1. Общие заметки

Известно, что Международная стратиграфическая шкала Мезозойской эратемы создана на основе эволюции аммонитов. Они отвечают основным требованиям к руководящим окаменелостям: 1) быстрые темпы эволюции; 2) значительное горизонтальное распространение; 3) относительная независимость от фаций; 4) хорошая сохранность.

Действительно, ряд других морских организмов имеют более широкое распространение в сравнении с аммонитами, но они показывают более медленные темпы эволюции и в связи с этим с их помощью могут быть выделены зоны со значительно большей продолжительностью, чем аммонитовые.

Широкая стратиграфическая практика, особенно за последние 20 лет, показывает большое стратиграфическое значение некоторых других групп организмов, которые позволяют провести детальное расчленение нижнемеловой системы: фораминифер, радиолярий, кальпинеллид, динофлягеллят, водорослей, наноконусов, бивальвий, эхиноидей, брахиопод и др.

В этой главе рассмотрена эволюция только нескольких групп морских организмов, которые имеют широкое распространение в нижнем мелу и в наибольшей степени способствуют стратиграфическому расчленению и корреляции серии, ее отдельных ярусов и/или определенных типов фаций (например, широко распространенной ургонской фации). При этом освещены только те аспекты эволюции этих групп организмов, от которых больше всего зависит формирование палеонтологических последовательностей, а не проблем филогенетических взаимоотношений внутри отдельных групп.

Закономерности, в соответствии с которыми формируются последовательности организмов, находятся в тесной зависимости от экологических факторов среды обитания. С этими факторами связано много других вопросов, имеющих особое значение для стратиграфии: 1) взаимоотношения организмов; 2) густота населенности отдельных биотопов; 3) зависимость морфологии организмов от характера среды; 4) темпы видообразования и их связь с изменениями среды; 5) расселение организмов — причины, скорость и результаты.

2. Основные черты эволюции раннемеловых морских организмов

Независимо от значительной регрессии, которая проявляется на обширных площадях в Средиземноморской области в конце юрского периода, существует плавный переход от юрского к меловому миру организмов. Единственно среди моллюсков отмечается существенное обновление, которое характеризуются изчезновением многих юрских видов и родов и появлением новых таксонов.

В этом разделе рассмотрены основные черты эволюции микрофлоры (водорослей, наноконусов), низших одноклеточных организмов (радиолярий, фораминифер, кальпионеллид) и беспозвоночных метазоа (остракод, губок и мшанок, иглокожих, брахипод, гастропод, бивальвий, аммонитов).

3. Палеобиогеография раннемеловой эпохи

3.1. Исходные принципы

Географическое распространение организмов зависит от ряда факторов, основное значение среди которых имеет климат. Существует тесная связь между географическим распространением и экологическими факторами: течениями, характером дна, батиметрией, особенностями седиментации, наличием или отсутствием преград, взаимоотношениями с другими организмами, трофическими связями и др.

Палеозоогеографическое районирование раннемеловой эпохи, предложенное в этом труде, основано на следующих трех принципах: ареало-генетическом, экологическом и статистическом.

3.2. Аммонитовые провинции в раннемеловой эпохе

В настоящее время считается общепринятым, что биогеогеографические границы отдельных групп организмов не совпадают. При этом, чем ниже ранг палеобиогеографической категории, тем больше различия в границах различных групп.

В работе рассмотрено только распределение аммонитов в течение раннего мела, что намечает основные линии раннемеловой палеобиогеографии. К этому, конечно, можно добавить много интересных данных о белемнитах, фораминиферах и рудистах, которые вносят примечательные штрихи в панораму раннемеловой жизни в Средиземноморской области.

Распределение аммонитов в начале раннемеловой эпохи выявляет особенности титонской аммонитовой провинции. Вместе с тем накладываются новые черты, которые изменяют конфигурации областей и особенно провинций.

Палеобиогеографическая картина в раннемеловую эпоху развивается и на основе распределения аммонитов, при этом могут быть выделены два этапа: берриас-барремский и аптальбийский с некоторыми флуктуациями внутри этих этапов.

3.2.1. Берриас-барремская хорология аммонитов в Средиземноморской области

Начало раннемеловой эпохи показывает биполярность в распределении аммонитов, имеющем место в поздней юре. Тетисский океан занимает срединное положение в земной гидросфере, развиваясь в субэкваториальном направлении между двумя основными континентальными массами. На северс простирается Бореальный, а на юге — Перигондванский бассейн.

Средиземноморье очерчивается как относительно гомогенная палеобиогеографическая область от берриасского до барремского века включительно со следующими провинциями:

1. Альпийская провинция. Это центральная провинция Средиземноморской области, которая в общих чертах охватывает две ветви Альпийского орогенного пояса от Атлантического океана на западе, включая Северо-Западную и Северную Африку, Иберийский полуостров, Пиренеи, самую южную часть Франции, Альпы, Панонский массив, Динариды, Хелениды, Юго-Восточные Родопы, Турцию, до Ирана на востоке.

В этой провинции аммонитовая фауна очень гомогенна; она преимущественно глубоководная морская, сопровождаемая широким развитием планктонных фораминифер, кальпионеллид, радиолярий.

Альпийская провинция охватывает самые глубокие зоны Средиземноморской области.

В восточной части Альпийской провинции обособляется Арабская субпровинция (или район), характеризующаяся преобладающим развитием континентальных осадков в берриас-барремское время и неритических образований с большим числом эндемических видов во время аптского и альбского веков. Она охватывает страны Ближнего Востока до Персидского залива.

2. Европейско-Кавказская провинция простирается к северу от Альпийской. Она обозначена Улигом как „краевая неритическая зона", но это наименование неточно. Провинция имеет средиземноморскую фауну, но с отдельными бореальными иммигрантами. Они встречаются большей частью в Парижском бассейне, в Юрских горах, в северо-восточной части Юго-Восточной Франции; южная часть ФРГ, Крым, Кавказ. Шумадийский район, Восточная Сербия, Карпаты и Балканиды находятся в буферной зоне между Альпийской и Европейско-Кавказской провинциями,и хотя они характеризуются типично средиземноморской фауной, содержат редкие бореальные иммигранты. В связи с этим эти страны следует рассматривать как самую южную част Европейско-Кавказской провинции.

Общей чертой обеих провинций области является развитие ургонских осадочных пород, которые представляют типичную средиземноморскую биофацию с рудистами, кораллами и крупными фораминиферами.

3.2.2. Апт-альбская хорология аммонитов в Средиземноморской области

С начала аптского века распространение аммонитов показывает значительно большую гомогенность, без ясной внутрипровинциальной дифференциации в области до среднеальбского подвека. В этом интервале (апт-ранний альб) Средиземноморская область хорошо очерчена главным образом благодаря развитию рифовых фаций с кораллами, рудистами и бентосными фораминиферами. Для аммонитов, однако, отсутствует граница, даже и в виде широкой переходной зоны между южной частью Бореального пояса и Средиземноморской областью.

Аптская модель хорологии аммонитов сохраняется в общих чертах и в раннеальбском подвеке.

Среднеальбский подвек отмечает начало новой и существенно различной дифференциации аммонитов, которая продолжается и в позднемеловой эпохе. Граница между Тетисом и Бореалем очень плавная, и ряд бореальных видов проникает на юг. Эта резкая перемена в палеобиогеографической картине является следствием австрийской складчатости в Средиземноморье и последовавшей большой среднемеловой (альб-сеноманской) трансгрессии. Амонитовая фауна широко диспергирует, и в связи с этим палеобиогеографические провинции и области теряют свой характер субэкваториально ориентированных поясов. Это особенно важно для широкой Европейской провинции (Hoplitinid faunal province; Owen, 1973), которая определяется преобладающим развитием Hoplitinae. Эта провинция охватывает Англо-Парижский бассейн и всю Европейско-Кавказскую провинцию берриас-барремского этапа.

К югу от Европейской провинции простирается Атласско-Апеннинская провинция, которая характеризуется наличием большого количества гондванских видов. Эта провинция охватывает и Ближний Восток (Арабская субпровинция).

В конце этой главы рассмотрены основные факторы экологии аммонитов и некоторые характерные раннемеловые биотопы.

VI. ОСНОВНЫЕ ЧЕРТЫ ГЕОЛОГИЧЕСКОГО РАЗВИТИЯ СРЕДИЗЕМНОМОРСКОЙ ОБЛАСТИ В РАННЕМЕЛОВУЮ ЭПОХУ

1. Общая характеристика палеогеографической обстановки

В общем историко-геологическом плане раннемеловая эпоха в Средиземноморской области кажется относительно спокойной. Среди глобальных мезозойских морских циклов она включается между позднеюрской регрессией и сеноманской трансгрессией (Ager, 1981).

В раннемеловую эпоху Средиземноморье как будто „перевело дух" после позднекиммерийской активизации. Эта общая картина, широко распространенная в обобщающих монографиях о фанерозойском развитии Альпийско-Гималайского пояса, скрывает существенные черты этого развития.

1.1. Эволюция континентов и континентальных окраин

Раннемеловые морские бассейны в Средиземноморской области находятся в пределах Тетисского океана. Он имеет линейную форму субэкваториального простирания, но со сложными дугообразными изгибами и рядом промежуточных массивов (континентальных фрагментов).

Два суперконтинента — Гондвана и Лавразия определяют пространственную конфигурацию Тетиса. Средиземноморская область развивается в пространстве между Афро-Арабской и Евразиатской плитами.

Краевые части континентов увлекаются в пределы Средиземноморской геосинклинали, и от них отделяются несколько фрагментов, которые образуют Апулийскую, Иберийскую, Карнийско-Паннонскую и Эгейскую плиты.

Рифтогенез, начавшийся в Центральной Атлантике во время юрского периода, усиливается в раннемеловую эпоху, расширяясь на север и на юг.

В самом Средиземноморье существуют аналогичные явления в Альпах и в сложно линеаментированном Балканском полуострове, где осуществяются конфликтные взаимодействия Родопского массива, Краиштид, Балканид, Карпат и Динарид (Bončev, 1977; Laubscher, Bernoulli, 1977; Унксов, 1981).

Начало раннемеловой эпохи ознаменовывается эпиконтинентальной трансгрессией, которая значительно обширнее юрской. После нее остаются только отдельные островные суши.

Подводные континентальные окраины в Средиземноморской области в раннем мелу атлантического типа (пассивные). Между берегом и континентальным склоном почти повсюду присутствует мелководная терраса. Наиболее широко развиты неритические отложения шельфовой зоны. В ряде областей (Северная Африка, Бетские Кордильеры, Пиренеи, Альпы, Карпаты, Балканиды, Кавказ, Динариды) образуются мощные осадочные комплексы в пределах континентального склона.

В этой главе подробно рассматриваются региональные особенности раннемеловой геологической эволюции континентальных окраин, как и наиболее характерные нижнемеловые комплексы: флиш, молассы и карбонатные платформы.

1.2. Мобильные пояса

Развитие нижнего мела в Средиземноморье очерчивает срединные зоны океана, которые обычно представляют собой мобильные зоны, унаследженные от юрского периода.

К мобильным поясам автор относит центральные части Средиземноморской области, в которых существует офиолитовый магматизм, как и зоны интенсивных понижений, которые нагружены мощными флишевыми отложениями. Часто зоны флишеобразования приурочены к относительно активным континентальным окраинам.

В этом разделе рассмотрены распространение раннемеловых офиолитов, вулканогенно-осадочных комплексов и радиоляритов, как и орогенные проявления.

2. Некоторые особенности геологического развития Средиземноморья и открытие Атлантического океана в раннемеловую эпоху

Существует основание предполагать, что раннемеловая эволюция Средиземноморья в значительной степени предопределяется тектоникой плит. Очевидно, конфликт между двумя большими кратонами — Афро-Арабским и Евразиатским играет определяющую роль. Вероятно сложная конфигурация и особенности раннемеловых бассейнов являются отражением мозаики микроплит и сети разломов между ними.

Кроме того, важное геологическое значение имеет образование Атлантического океана, открытие которого наиболее интенсивно в раннемеловую эпоху. С ним связан ряд геодинамических особенностей Средиземноморской области.

3. Выводы

В раннемеловой эволюции отдельных зон Средиземноморской области выделяются некоторые общие закономерности.

1. Область характеризуется теплым климатом и широким развитием различных групп организмов. В их распространении устанавливается определенная зональность, обусловленная главным образом климатическими особенностями, а также некоторыми другими специфическими палеогеографическими параметрами. Особенно ясную провинциальную зональность показывают аммониты, рудисты и фораминиферы.

В течение раннемеловой эпохи открывается развивающаяся палеобиогеографическая панорама, начинающаяся с четко очерченных субэкваториальных провинций в берриасском веке и завершающаяся сильно диспергированными областями в альбском веке.

2. В отдельных поясах Средиземноморья развиты характерные ассоциации пород, связанные с тектоническими особенностями пояса. Они параллельны главным тектоническим линиям (направлениям). Это особенно подчеркнуто в развитии офиолитов и флиша.

Определяются внутренние зоны с глубоководными морскими и сильно деформированными, иногда слабометаморфизованными комплексами, внешние зоны с широким развитием флишевых отложений и/или карбонатных платформ и форланда, на котором развиты неритические или континентальные толщи.

Флишевые комплексы, как правило, развиты в континентальных окраинах, характеризующихся интенсивным компенсированным понижением. Мощность флиша в отдельных зонах 2000—4000 m.

Карбонатные платформы широко распространены и слагаются рудистами, другими толстораковинными бивальвиями, кораллами, крупными фораминиферами, эхиноидеями, гастроподами, водорослями, мшанками.

3. Развитие нижнемеловой серии в Болгарии представляет особый интерес в связи с полнотой разрезов, богатством фоссилий и разнообразием фаций.

Анализ литофаций и эволюции седиментационных обстановок в течение раннемеловой эпохи в Болгарии показывает большое разнообразие, обусловленное значительной динамикой во времени и пространстве. Вместе со специфическими чертами развития осадочных обстановок в раннемеловом бассейне намечаются и некоторые общие закономерности, часть которых унаслеживается из титонского века.

В раннемеловую эпоху бассейн располагается между двумя сушами: южной — Фракийской, которая представляет собой своеобразный микроконтинент в Тетисском океане, и северной — Добруджанской, которая является реликтом более старого массива. В южной части бассейна очерчивается большая и продолжительная депрессия, севернее которой находится обширная шельфовая зона. В сравнении с позднеюрской эпохой геологическая эволюция Предбалканья ускоряется, что отмечается активизацией флишевого трога.

Образование нижнемеловых пород в Юго-Восточных Родопах произошло в разветвлении южной части Средиземноморского бассейна.

Раннемеловой бассейн начинает сужаться с конца готеривского века, причем эта тенденция постепенно усиливается. Осушаются восточные и южные части. На востоке проявляется меридиональное поднятие — Эвксинское, которое расширяется к западу, и уже в конце аптского века бассейн покрывает только Северо-Западную и Центральную Северную Болгарию, а также небольшую полосу придунайской части Северо-Восточной Болгарии в Русенском районе.

В конце аптского века в Центральном и Восточном Предбалканье проявляется довольно сильное складчатое движение. В результате этого, как и в результате общих тенденций геотектонической эволюции, в конце раннемеловой эпохи происходит существенное изменение региональной структуры и связанной с ней палеогеографической обстановки.

4. Во многих местах внутренних зон Средиземноморской области существуют проявления офиолитового магматизма, образование вулканогенно-осадочных комплексов и радиоляритов. В ряде участков вследствие позднемеловых и палеогеновых тектонических орогенических движений нижнемеловые породы сильно дислоцированы, включены в надвиги и чешуи, а местами и слабо метаморфизованы.

5. В раннемеловую эпоху устанавливаются некоторые различия между Западным и Восточным Средиземноморьем, которые сильно выявляются в следующую эпоху мелового периода.

В раннем мелу Тетис в Западном Средиземноморье имеет два основных протока — северный и южный, которые огибают Иберийскую плиту и сливаются у Сицилии. Северный проток постепенно сужается в результате нескольких этапов субдукции и интенсивных орогенезов, в то время как южный, начиная в нижнемеловой эпохе, постепенно превращается в современное Средиземное море.

6. Геологические особенности Средиземноморской области испытывают влияние относительного движения не только Африки и Европы, но также ряда микроплит в средиземноморском пространстве.

7. Данные ДЖОИДЕС и сейсмические исследования показывают, что спрединг и офиолитовый магматизм в области имеют юрско-меловой возраст.

8. Геологическая эволюция Средиземноморской области в Тетисе в раннемеловую эпоху связана с открытием Атлантического океана.

Скорость спрединга океанического дна в Центральной Атлантике в течение раннего мела значительно нарастает в сравнении с предшествующими эпохами. В Средиземноморье активизируется ряд мобильных зон, особенно после барремского века. Нельзя утверждать, что существует совпадение этапов эволюции двух океанов. Речь может идти только о корреляции активности и/или пассивности в различных частях плейттектонической сети. Очевидно, что расширение Атлантики приводит к постепенному сужению Средиземноморской области Тетиса, ясно выраженному в конце раннемеловой эпохи. Оно сопровождается компенсацией континентальных окраин и обмелением бассейна.

9. Раннемеловая эволюция Средиземноморья постепенно набирает скорость, активизируется в главных зонах области, и этим подготавливает и осуществляет решительные австрийские преобразования в истории этой динамичной области Земли.

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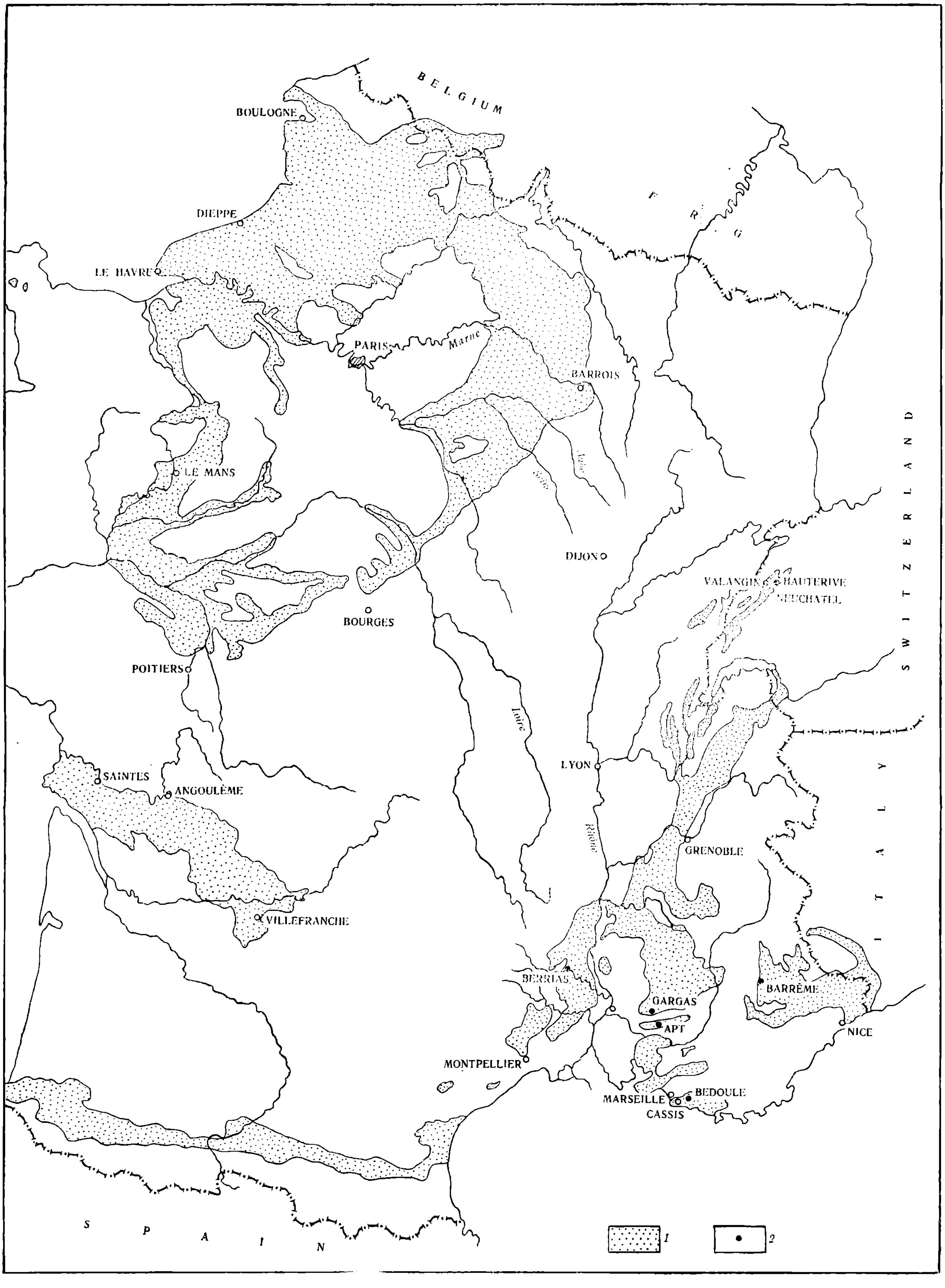

Fig. 2. Map of the distribution of the Lower Cretaceous in France and Switzerland

1 — outcrops; *2* — stratotypes

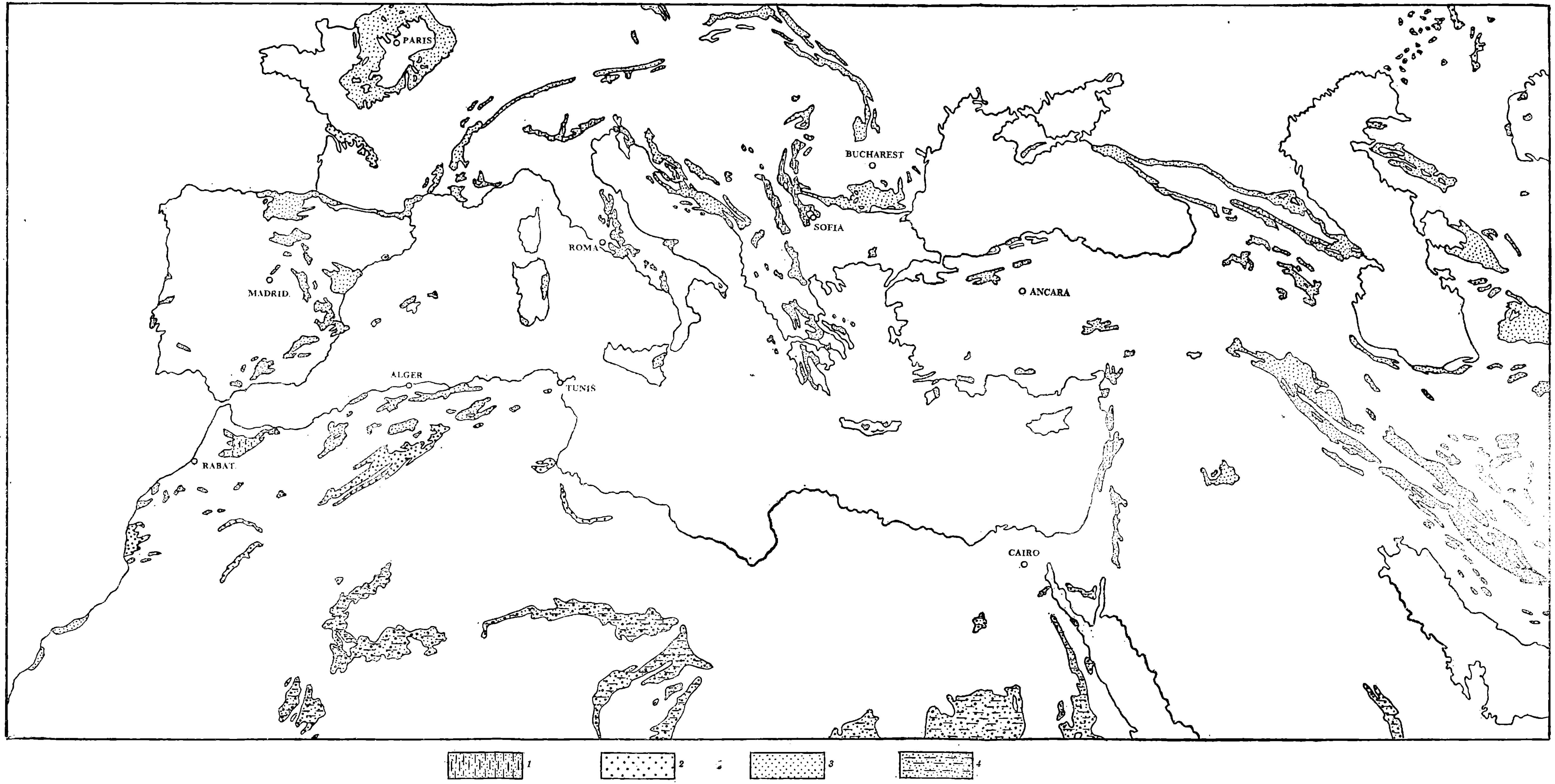

Fig. 1. Simplified map of the distribution of the Lower Cretaceous in the Mediterranean Region
1 — Upper Jurassic-Lower Cretaceous; *2* — Lower Cretaceous (continental facies in Africa), Purbeckian-Wealdian (sediment in Europe) *3* — Lower Cretaceons (marine sediments); *4* — Lower Cretaceous (Nubian Sandstones