

On the extension and lithological-facial composition of the Upper Cretaceous phosphatic horizon in the Ionian Zone

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А. Серьяни — О распространении и литолого-фациальном составе верхнемелового фосфатного горизонта в Ионической зоне. Верхнемеловой карбонатно-фосфатнокремнистый горизонт прослеживается через всю ионическую зону на территории Албании и Греции. Он обнажается преимущественно в антиклинальных складках. Можно выделить два фосфорогенических пояса. Формирование горизонта, очевидно, имело место в открытом морском бассейне. Предполагается, что выделение фосфора происходило в результате осаждения в стадии седиментации или диагенетическим путем: в результате фосфоритизации микрофауны и карбонатов.

Abstract. An Upper Cretaceous carbonaceous-phosphatic-chert horizon is traced throughout the Ionian Zone on the territories of Albania and Greece. It crops out predominantly within anticlinal belts. Two phosphogenic belts can be distinguished. The formation of the horizon has apparently taken place in an open-sea basin. Separation of phosphorus is supposed to have occurred as a result of precipitation during the sedimentation and in a diagenetic way, by phosphorization of microfauna and carbonates.

Introduction

The first efforts of Albanian young geologists were materialized with the discovering of poor phosphate limestones at the Kurvelesh plateau in 1956. Since 1960, in an attempt to secure raw materials for phosphate fertilizers for the country, geological research and mapping work has intensified. Likewise, stratigraphical, paleontological, mineralogical, technological, etc., detailed studies have been carried out.

In the 70's researches for phosphorites were done in Greece in the Upper Cretaceous deposits of the Ionian zone by A. E. H., E. P. L. and I. G. M. E. (Skurnaqis, 1979; Mechainos et al., 1979) as well as radiometric studies of the Epirus and Ionian islands (Stayropolis & Basjakos, 1981).

The article presents general data on this problem. It gives a picture of the geographic and geological-structural extent of the horizon in the Ionian zone, defines the stratigraphic position through its faunistic data and describes briefly the lithological-facial features of the horizon. A concept about the formation conditions has been proposed finally.

In writing this article, alongside with his own factual material, the author has also used previous publications by other researchers, chiefly Albanian and Greek ones. The further geological study of the Upper Cretaceous phosphatic horizon throughout the Ionian zone in searching for high strata constitutes a continuous task for the future.

Geographical extent of the horizon

The Upper Cretaceous horizon consists of limestone, phosphatic and chert strata. It is a stratified lithologo-facial, sedimentary horizon of large extension, localized between the Upper Cretaceous carbonaceous-chert deposits. The wide spreading and characteristic fau-

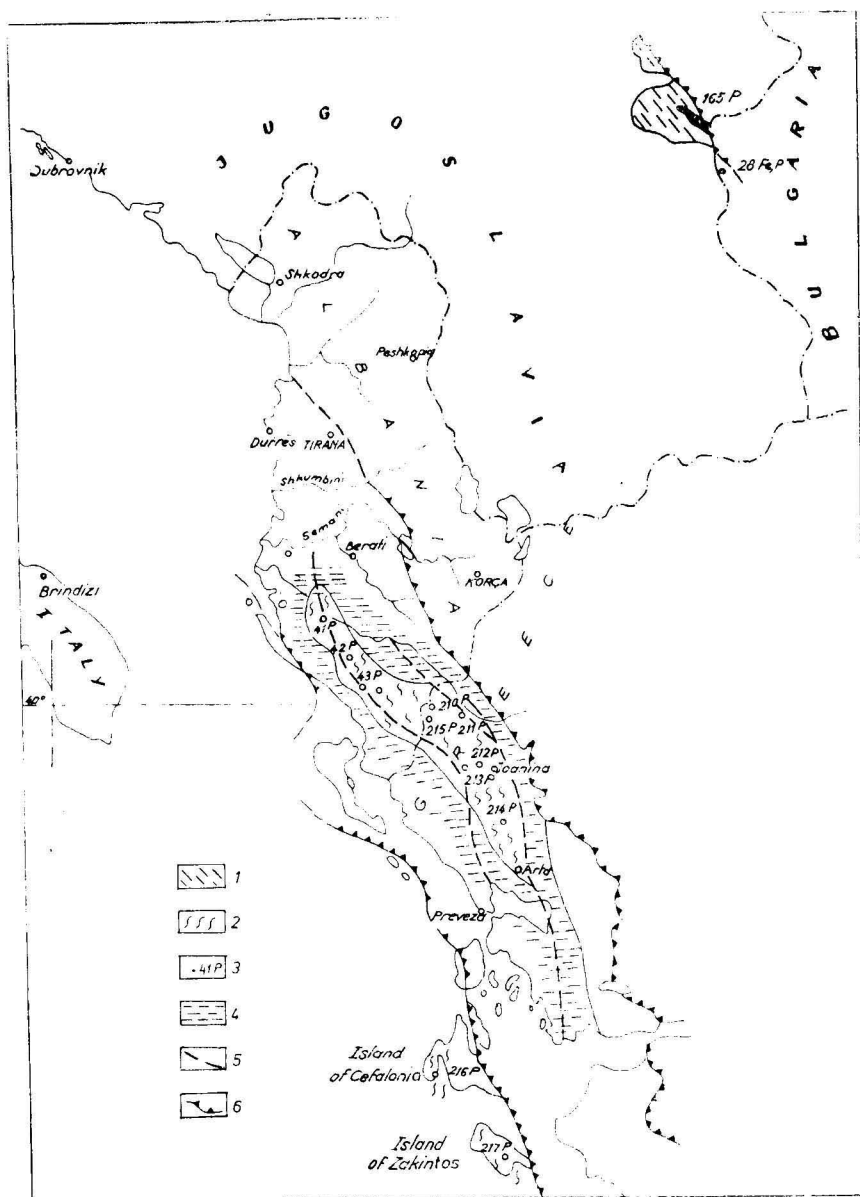


Fig. 1. Extension of Upper Cretaceous phosphatic facies in the Ionian zone

1 — metamorphic phosphatic rock fields (Yugoslavia, Bulgaria); 2 — sedimentary phosphorite field according to the *Metallogenic Map of Europe* (1983); 3 — ore deposits respective numbers; 4 — metallogenic province of extension of Upper Cretaceous phosphatic facies; 5 — axes of perspective structural belts; 6 — overthrusts outlining the phosphatic facies (Fig. 2)

Phosphorite deposits (according to the *Metallogenic map of Europe*): 165 — Bosilegrad; 28 — Češljanci; 41 — Ploče; 42 — Nivice; 43 — Fush-Bardhë; 210 — Delvinaki; 211 — Micikeli; 212 — Yoannina; 213 — Korenta; 214 — Xerovounia Arta; 215 — Ktismata; 216 — Cefalonia; 217 — Zante

nistic association make this carbonate-phosphate-chert-globotruncanic series a marked horizon. It has a vast regional extension. The geographical extent of phosphatic facies shows that its boundaries are linked with the extension of the Ionian zone itself.

In order to get a more accurate idea of the extent of the phosphatic facies in Albania and the neighbouring countries based on the data of the *Metallogenic Map of Europe* (Paris, 1983) and on other sources (Machairas et al., 1979; Skurnakis, 1979; Stayropodis & Basjakos, 1981; *Geological Map of Greece*, 1983; *Geological Map of PSR of Albania*, 1982; Shehu et al., 1982; Serjani, 1986), we have compiled the schematic map shown in Fig. 1. The facies of sedimentary phosphatic rocks are widespread in the Ionian tectonic zone in Albania and Greece. In the islands of Cephalonikos and Zakintos, belonging to the tectonic zone of Paksos (Sazan-Karaburun), the encountered phosphatic facies (216 P; 217 P) are of a terrigenous nature (Anastasopoulos & Koukoulas, 1977), while the phosphatic facies at the Bulgarian-Yugoslavian boundary (28 Fe, P; 165 P) belong to metamorphic ones with gneisses, micas, schists, etc.

Two stratigraphic levels of the phosphatic facies are known in the Mesozoic deposits of the Ionian zone (Fig. 2):

- Middle Jurassic phosphatic level linked with a break in sedimentation, and
- Upper Cretaceous (Coniacian) phosphatic level (the most important one).

To the north of the Ionian zone, the Upper Cretaceous phosphatic horizon is exposed on the surface in the shape of marly limestones with rare and weak phosphatic bands (to the south of the Semani river: Shpirag, Kremanarë) and follows in the southern continuation, on the territory of PSR or Albania in all structures (about 100 km long) (Serjani, 1986). Further to the south, on the territory of Greece, the horizon continues at about another 200 km up to the beach of Astakios (according to the *Geological Map of Greece*, 1983).

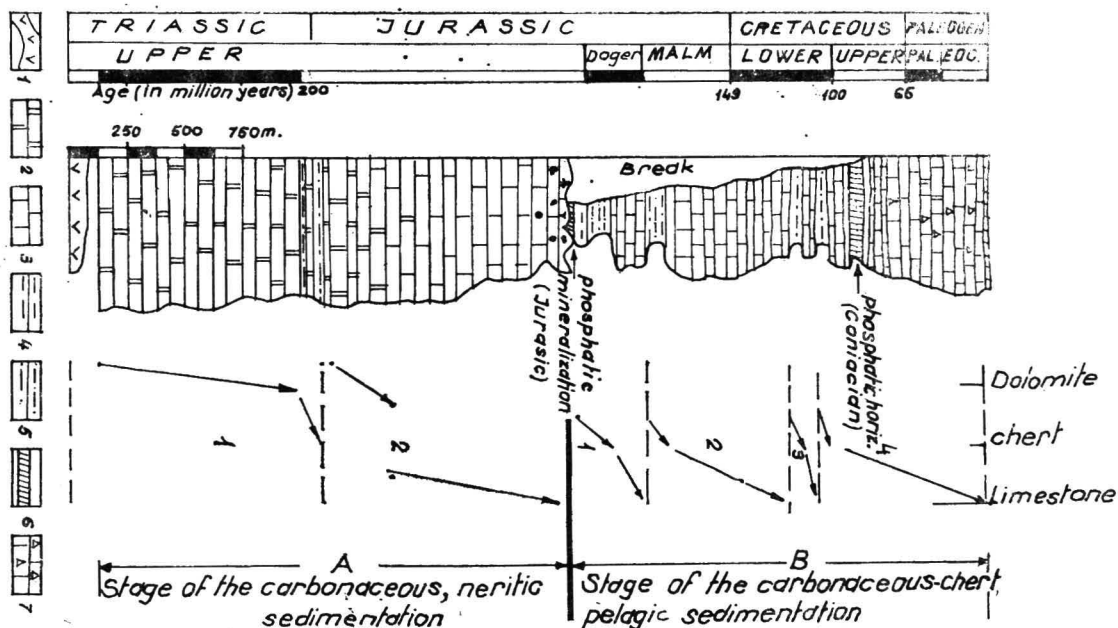


Fig. 2. Lithostratigraphic column of Mesozoic deposits of the Ionian zone with the levels of the phosphatic facies

1 — evaporites; 2 — dolomites; 3 — limestones; 4 — Toarcian marls; 5 — siliceous-argilic pack; 6 — phosphatic strata; 7 — clastic limestones

Just as the Ionian zone, the horizon extends from west to east, to some tens of km.

With the recent discovery of the horizon of phosphatic limestones in the Melesini mountain (Leskovik), the width of the horizon from the seaside to Melesini reaches about 70 km, occupying all the Ionian zone.

Geological structural spreading

The phosphatic horizon is better evidenced on the surface in the anticline belts of the Ionian zone, more affected by erosion (Fig. 3).

In the northern part of the Ionian zone the horizon has a vast extension in the anticline belts of Kurveleshi, Lunxhëri-Bureto and Nemërcka, while the Cika one has a limited extension and is weakly expressed. In this belt the horizon occurs from Tragjas in the north (Kondo et al., 1968) to the south of Himara, where it dips into the sea. In the southern continuation of this anticline belt, to the south of Saranda, the horizon is marly or is totally missing due to the hard ground.

The outcrops of the phosphatic horizon in the southern continuation of the Ionian zone in Greece occur in the anticline belts of Micikeli, Prevesa, Morgana, Ravena, etc.

The horizon is mainly evidenced in the eastern structures. No outcrops of this horizon have been encountered in the western littoral ones (Marchairas et al., 1979).

In spite of the vast facial extension of the phosphatic horizon throughout the Ionian zone, better concentrations and the main ore deposits are limited and located in the central subzone of the Ionian zone (anticline belt of Kurveleshi); while in the southern continuation, in Greece, the main ore deposits are situated in the most eastern anticline belts (Micikeli), or in the most eastern part of the central subzone of the Ionian zone.

We are of the opinion that the western phosphorogenic belt of Kurveleshi continues to the south and the eastern phosphorogenic belt of Micikeli — to the north. Thus contrary to previous concepts of other authors, we think that here we have to do with two almost parallel perspective phosphorogenic axes (Fig. 1). One of them is linked with the central subzone of the Ionian zone and is better expressed in its northern part, while the other is linked with the eastern belt of the central subzone of the Ionian zone and has a greater extension in the southern continuation, from Micikeli close to the Patra seaside.

Stratigraphical position of the horizon

The horizon has an immediate contact at the bottom, which is distinguished by the presence of thin green clay layers intercalated with limestone strata, while its top has a gradual passage to the limestones with rare phosphatic bands and to the limestones above (Fig. 4). The Upper Turonian—Lower Senonian age of the phosphatic horizon has been determined in 1968 (Kondo et al., 1968). The age given by Greek authors belongs to the Upper Cretaceous (Surnaqis, 1979) or the Middle-Upper Cretaceous (Mecharios et al., 1979).

Only two works are doubtful about the Coniacian-Santonian age (Aubouin & Ndojaj, 1965; Patzelt, 1971).

Several detailed sections through various structures of the Ionian zone have been carried out for determining the exact age and stratigraphical position of this horizon. The performed sections are continual from bottom to top. No break has been observed throughout the section. The faunistic assemblage is almost the same for all the sections. Almost in all of them, with some rare exceptions, immediately on the clay strata is observed a bloom of rich microfaunistic association with predominance of the planktic forms (globotruncanas mainly). The following globotruncanas have been found: *Globotruncana renzi*, *G. schneegansi*, *G. coronata*, *G. lapparenti*, *G. sigali*, *G. concavata*, *G. fornicata*, Heterohelicidae, Radiolaria, Ostracoda, *Pithonella*, Globigerinidae, etc. This association occurs mainly in the

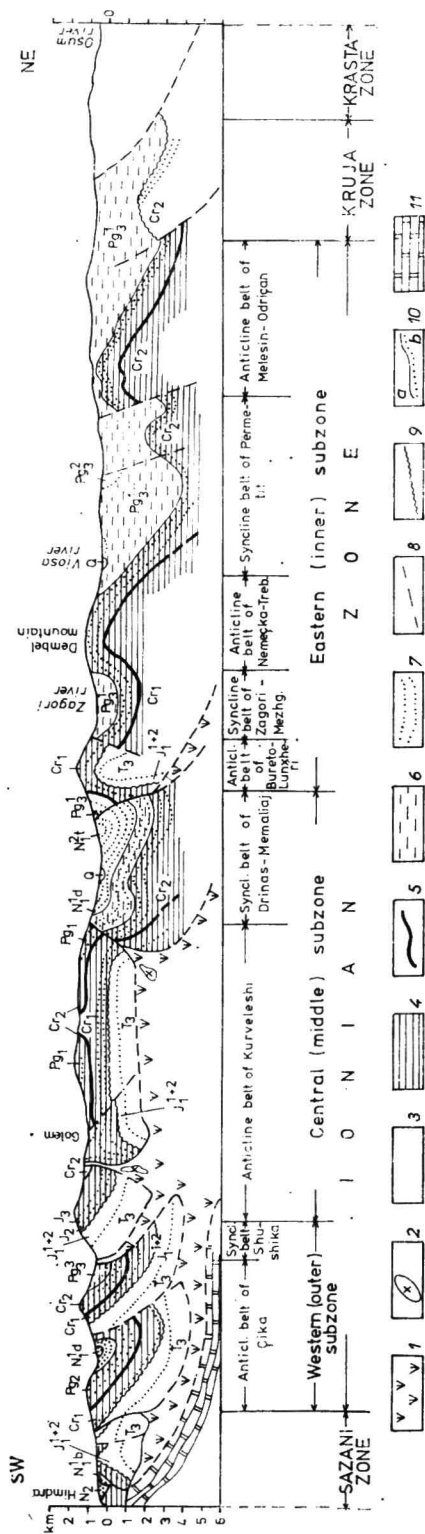


Fig. 3. Geological section of the Ionian zone across the structural belts and the lithological-facial types of the Upper Cretaceous phosphatic horizon (scale 1:200 000)

1 — depositions of the evaporitic sedimentation stage; 2 — bodies of magmatic and metamorphic rocks; 3 — depositions of the carbonate platform sedimentation stage ($T_3 - J_1^{1+2}$); 4 — carbonate-chert deep deposits of the pre-flyschoidal stage ($J_1^3 - Pg_2$); 5 — phosphatic limestones and Upper Cretaceous phosphorite horizon; 6 — depositions of the flyschoidal sedimentation stage ($Pg_3 - Pg_3^1$); 7 — deposits of the "schlieren" flyschoidal ($N_1 - N_1^{2+}$) and molasse ($N_1^{2+} - N_2$) sedimentation stage; 8 — fault; 9 — Juarsic sedimentation break, separating carbonate neritic stage of sedimentation from carbonate chert pelagic one; 10 — contacts; a — between sedimentation stages; b — between different ages; 11 — Sazan-Karaburun (Adria) tectonic zone

limestone and phosphorite strata some meters above the top of the horizon. Traces of ammonites and *Baculites cf. vertebralis* (Patzelt, 1971) have also been found in this horizon.

Based on the above mentioned faunistic assemblage, the Coniacian age of the horizon has been determined (Serjani & Ylli, 1984). The microfaunistic assemblage is such one that the horizon can be named as a carbonate-phosphate-chert-globotruncanic complex. In general, the globotruncanas are oriented according to the stratification. Their phosphatization is often seen, mainly in the rich phosphatic strata, whereas in poor strata and in phosphatic limestones the globotruncanas are very well preserved.

The strata under the floor of the horizon are poor in microfauna. On top, almost close to the phosphatic horizon an evident impoverishment of microfauna, mainly of planktic forms has been noted.

The faunistic assemblage of the phosphatic horizon shows that component elements belong to the deep sea facies. This distinguishes this horizon from the known ore deposits in the world geological literature belonging to shallow sea, terrigenous facies.

Lithological-facial features of the horizon

Various authors (Diamanti, 1966; Bajo, 1971; Liko, 1972; Nika, 1976; Meçe, 1977; Husi, 1982; Serjani & Koçi, 1983; Koçi, 1985), have written about the lithological-facial construction of the phosphatic horizon.

The horizon consists of limestones, phosphorites and cherts. They form individual strata intercalated with each other (Fig. 4). The thickness of the horizon varies from some meters to 40-50 m (Fig. 5). The thickness 8-10-15 m predominates in general. The limestone strata thickness varies from 0.2 to 0.4 m, rarely 0.8-1 m. The chert layers are 0.05 to 0.2 m thick. Depending on the relations of the above mentioned lithological components, the horizon forms different lithological facial types in different structures (Fig. 3). Depending on the above mentioned lithological-facial components change also the average content of P_2O_5 and the meter percentage indicator of the horizon (the product of the thickness and the content) (Fig. 5). The horizon has an evident phosphatic character in the central parts of the Ionian zone, where the overwhelming majority of phosphorus has been deposited. The phosphate-carbonaceous and the phosphorus facies have been encountered here. At both flanks, in west and east, we have replacing of the phosphatic facies by the carbonaceous ones. To the west, close to the seaside mountainous chains occurs also the reduction of thickness of the phosphatic marly limestones horizon, while the contrary occurs to the east. The lithological-facial changes occur also within the same structure. The content of the phosphatic layers varies from 7-15% P_2O_5 and rarely more.

A successive intercalation of the limestone, phosphorite and chert strata, having a rhythmic construction from bottom to top has been observed in the horizon. From sedimentological analysis it results that in the vast majority we have a normal facial recurrent carbonate-phosphate-chert evolution (Serjani, 1986). The intercalation of the limestone, phosphorite and chert strata and the mutual facial transition through the extension shows a close connection and co-genesis of these facies and their deposition in the same sea regimen. The thickness of the carbonaceous strata increases gradually from bottom to top. The contrary occurs with the phosphatic strata.

The limestone strata between the phosphatic horizon consist of micritic, often marly sorts with laminated texture, fine plankton and phosphate grains. Biopelmicritic, biomicropelletal and marly limestones also with very fine plankton are encountered in the strata of the limestones on top of the horizon in several sections.

The strata and the phosphatic bands consist of massive micritic, biomicritic with laminated structures and globotruncanic phosphorites. Many phosphatic pellets and fine abundant coprolites occur in the phosphatic strata (Plate 1). In the cases when phosphatic facies consist of limestones with phosphatic bands laminated structures are observed,

Lithol. Column	Nr of sample	Lithology	Microfauna
Carbonaceous phosphate-chert-globotruncan horizon	221	Less phosphatic biomicritic limestones, globotruncanic limestones	Radiolaria
	220		Globotruncana cf. lapparenti
	219		Globotruncana sigali
	217	Biomicritic limestones with globotruncanas	
	216	Phosphatic limestones, limestones	Globotruncana concavata; G. sigali, G. Coronata, G. schnee gansi
	215	Radiolaritic, argillic limestones	G. sp.
	214	Marly, phosphatic limestones	
	213	Phosphatic limestones with diagenetic cherts	Radiolaria
	212		
	211		
	210	Phosphatic globotruncanic biomicritic limestones	Globotruncana coronata G. cf. lapparenti, G. cf. sigali
	209	" " "	
	208	Microturbiditic phosphorites (Radiolaria - Globotruncanas)	Globotruncana sp., Heterohelix
	207	Biomicritic limestones (radiolaritic and globotruncanic)	Radiolaria
	206	Alevritic marly schists with organic matter	
	205	Biomicritic limestones with globotruncanas	Radiolaria
	204	Laminated phosphatic globotruncanic limestones	Globotruncana sigali; G. cf. helvetica; G. cf. imbricata; Praeglobotruncana sp. Heterohelix.
	203	Silicized biomicritic limestones	
	202	Less phosphatic biomicritic limestones with globotruncanas	Radiolaria
	201	Phosphatic globotruncanic limestones	Globotruncana coronata G. schnee gansi; G. primitiva G. sigali G. cf. bulloides Heterohelix
	200	Biomicritic globotruncanic less phosphatic limestones with laminated textures	
	199	Phosphorites of peletal texture with graded bedding, silicized	
	198	Less phosphatic limestones with the peletal fragments	
	196	" "	
	195	" "	
	194	Slightly phosphatic globotruncanic limestones	G. schnee gansi; G. Coronata; G. sigali; G. primitiva, G. sp.
	193	Phosphatic globotruncanic limestones	
	192	Massive phosphorites	G. sigali G. coronata
	191	" with diagenetic sil.	
	189	Marls with the manganese detritus	Globigerinidae, Radiolaria
	185	Slightly phosphatic marly limestones	
	184	" " " "	
	182	" " " "	
	181	" " " "	
	180	" " " "	
	179	" " " "	
	178	Biomicrocalcarenitic limestones	Praeglobotruncana cf. Rotulipora
	177	Petal recrystallized limestones	
	176	Planctonic marls with pyrite	
	175	" " "	
	173	" " " with detritus with Mn and pyrite	Globigerinidae

Fig. 4. Lithological-stratigraphical column of the phosphatic horizon

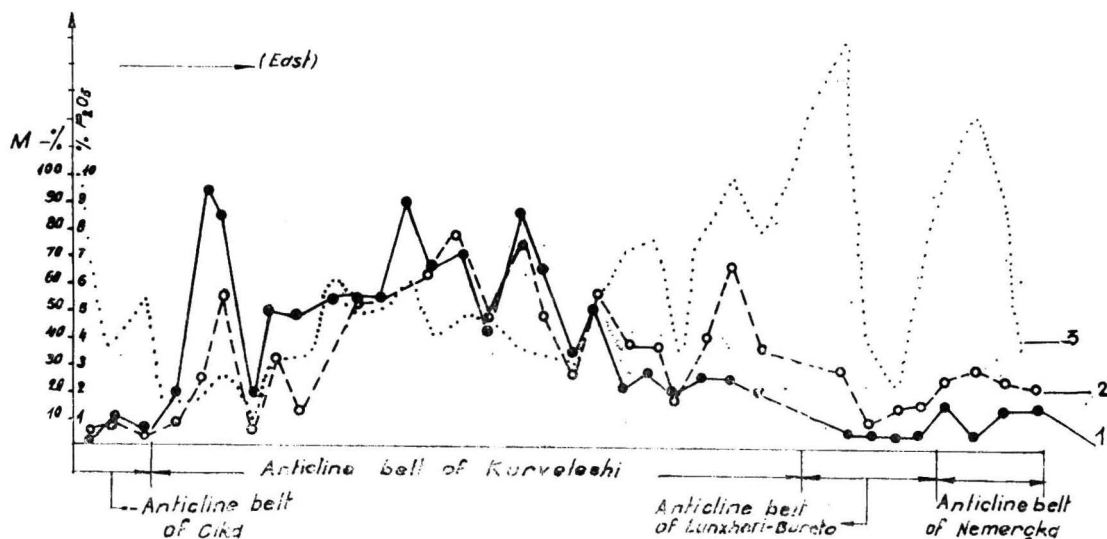


Fig. 5. Distribution of thickness, average content and metre percentage indicators
1 — concentrated average content; 2 — metre percentage indicator; 3 — average thickness of the horizon

consisting of biomicritic phosphatic laminations with globotruncanides, phosphatic pelets, globotruncanas' laminations, pelets and teeth of fishes, etc., in the overwhelming majority of cases. The phosphatic laminations are 0.1-1 mm thick, while the carbonaceous, globotruncanic, marly and marly-phosphatic ones are thicker: 3-5 mm. The cases of gradual mutual replacement of the phosphatic laminations by marly globotruncanic ones have been observed.

The lower contact of the phosphatic laminations is acute, while the upper one — the transition to the carbonaceous lamination is gradual. Often iron-manganese detritus occurs in the phosphatic limestones of the floor and top of the horizon. Iron hydroxides formed by pyrite oxidization are also frequent. The phenomenon of phosphatization and, in most cases, silicification, calcitization and pyritization of microfauna occurs.

Chert strata consist of radiolaritic microcrystalline sorts, often low phosphatic ones with laminated structure. The phenomenon of diagenetic silicification — opal-quartz-chalcedony is observed. Weathering is an important phenomenon for the phosphatic horizon. In some places the carbonaceous-phosphate-chert complex is subjected to the physico-chemical activity of the atmospheric agents, mainly water, and is much weathered. As a result of weathering the horizon underwent evident changes. Now it is transformed to a brown argillic-phosphate-chert complex. Only traces of the phosphatic bands occur, whereas the phosphatic mass has an argillic view. The chert strata remain untransformed. In the cases when the horizon is weathered it is characterized by the changes in the structure and in the mineral and chemical contents. The weathered strata are rich in P_2O_5 .

Opinions on the conditions of formation

The Coniacian phosphatic horizon has been formed under deep sea conditions of the Ionian basin. The carbonaceous, phosphatic and chert strata of the horizon are biomicritic formations formed by mud of small grain sizes — 15-30 microns. Sedimentation has occurred under a relatively calm tectonic regime. The phenomenon of hard grounds of unlitified strata, which proves the activity of the underground currents often occurs. Sedimentation took place in the depth of the basin, where the clastic, terrigenous matter is

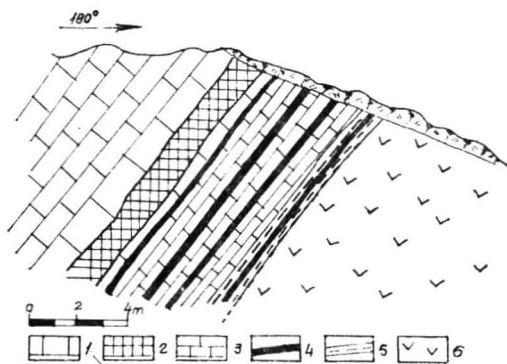


Fig. 6. Outcropping of the horizon in the carrier of Gusmari
1 — massive limestones of the top; 2 — massive phosphatic layers; 3 — stratified limestones of the floor; 4 — thin chert layers; 5 — thin argillic layers; 6 — weathered diabase

totally missing. In rich phosphatic strata the argillic matter is also missing. The presence of phosphatic strata as well as pyrite disseminations, organic matter and traces of elements such as Pb, Zn, etc., testify to the formation in a paleogic, reduced environment, at levels of depth with minimum oxygen (Slansky, 1980).

The chemical, mineralogical, petrographical and paleontological investigations of the horizon such as the recent works on the formation of phosphorites into the floor of the ocean (Baturin, 1982) allow to suppose that with respect to the formation of the microgranular francolites in a biochemical way at a greater depth than the shelf ones, diagenetic processes of phosphatization of microfauna and carbonate have played an important role.

The deep faults contributed especially to the formation of the favourable sea floor bathymetry, mainly for the central subzone of the Ionian zone. They have caused the formation of the most raised parts in the form of horsts at the floor of the sea. The magmatic rocks (diabases) came from the depth to the sea floor through deep faults (Fig. 6). An alkaline environment favourable for the formation of phosphate has been formed from their submarine alterations.

The microorganisms have played a major role in the accumulation and separation of phosphorus. It is supported by the presence of strontium, organic matter and the association with the strata of radiolaritic cherts, numerous globotruncanas, etc. The separation and accumulation of phosphorus proceeds as a result of the precipitation of phosphates at the beginning and in a diagenetic way, from the phosphatization of the microfauna and carbonates. Thus we consider the formation of phosphatic strata as a sedimentary-biogene-diagenetic process.

Conclusion

1. The Upper Cretaceous phosphatic horizon represents a carbonaceous-phosphate-chert-globotruncanic complex. It serves as a marked lithological-stratigraphical horizon in all the Ionian zone. It is better expressed through the anticline structures.

2. The horizon has facial spreading throughout the Ionian tectonic zone, but the industrial accumulations and main ore deposits are limited and spread along two main phosphorogenic belts: one linked with the middle subzone of the Ionian zone, known from its northern part (anticline belt of Kurveleshi) and the other linked with the eastern belt of the middle subzone of the Ionian zone known from its southern part (anticline belt of Micikeli) and its southern continuation close to the gulf of Astakias.

3. The Coniacian age of the horizon has been determined on the basis of the microfaunistic assemblage, mainly on the presence of *Globotruncana concavata*. The microfaunistic assemblage proves pelagic facies.

4. The horizon has the facial phosphatic character mainly in the central subzone of the Ionian zone, where the facial type with the massive phosphorite has been observed, while in the western and eastern subzones occurs the replacement of the phosphatic facies by the carbonate ones, which become predominant. The horizon has a rhythmic construction with normal facial evolution: carbonate-phosphate-chert.

5. The horizon has been on a relatively calm regimen, under the reducing conditions of a deep sea basin. The separation and accumulation of phosphorites has been made as a result of both the precipitation of phosphate at the beginning and in the diagenetic way: the phosphatization of microfauna and carbonates. The formation of the phosphatic strata is made in the biogene-sedimentary-diagenetic way.

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PLATE I

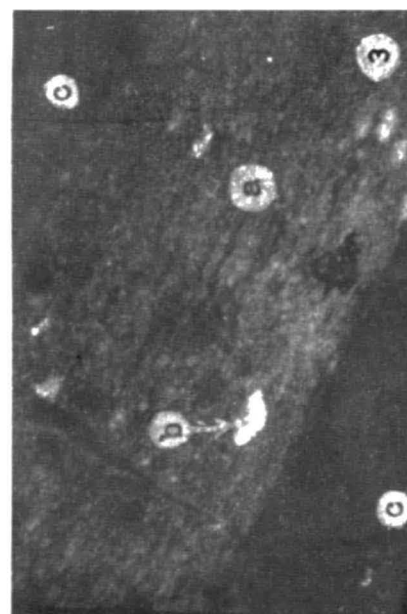
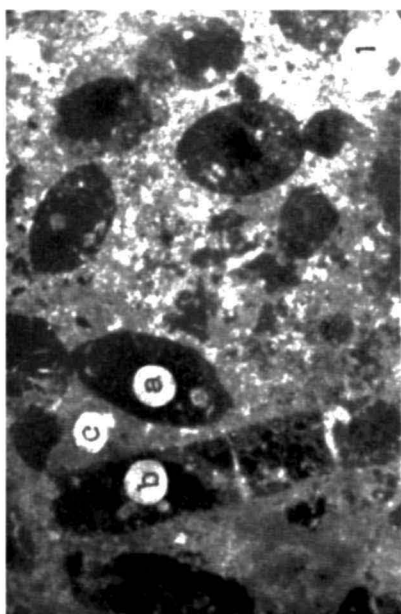
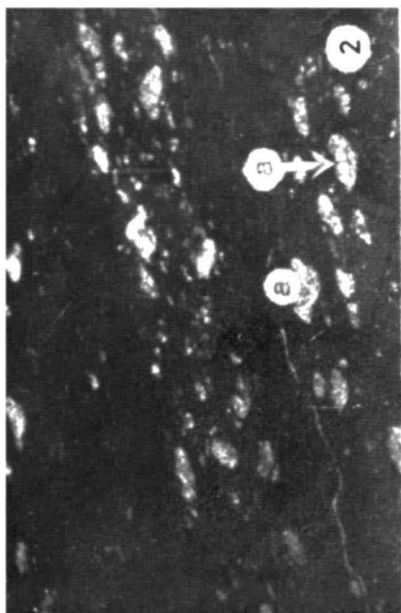


PLATE I

1. Phosphatic pelets (a) and coprolites (b) distributed in the carbonate-phosphatic micritic mass (c) $\times 5$
2. Globotruncanas (a) oriented according to stratification $\times 25$
3. Carbonaceous-phosphatic lamination (a) with rare globotruncanas (b) within the massive phosphatic laminations $\times 25$
4. Globotruncanas (a), slightly phosphatized at periphery $\times 50$