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THE CARBONATE/FLYSCH TRANSITION AND THE BASAL UNITS OF THE FLYSCH SEQUENCE, IN THE OSIOS LOUKAS AREA, PARNASSUS-GHIONA ZONE, CENTRAL GREECE

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ABSTRACT

As a result of the Late Cretaceous horst and graben tectonism in the Loukas area there was a change from shallow-water carbonate sedimentation to pelagic during the Maastrichtian, and an intraplatform depression surrounded by extensive shallower submarine plains formed during the Late Maastrichtian.

Sedimentation was, however, interrupted all over the area during the latest Maastrichtian-earliest Paleocene, owing to the fall in sea-level. During the Early Paleocene-Middle Paleocene a hardground-stromatolitic unit on the plains and a phosphatic calcarenitic / calcilutite unit in the depression developed as a result of the Paleocene transgression. Reactivation of tectonism during the Late Paleocene caused first a sudden shallowing, followed by the gradual subsidence of the sea floor that was now almost flat, during the deposition of the lower shaly parts of the sequence, viz. the yellow-green and grey-green mudshales (units 1-2).

They consist of a mixture of terrigenous supply and reworked Parnassian material, thus representing a "pre-flysch" stage deposited under shallow-water conditions. Open marine conditions prevailed only during the Eocene, when sediments forming the upper shaly parts of the sequence, the shaly flysch, viz. the red calcareous mudshales and the intercalations of the red calcareous mudshales and grey laminated siltstones (units 3-4), were deposited.

ΠΕΡΙΛΗΨΗ

Ο 'Ανω Κρητικιδκός τεκτονισμός τύπου "horst και graben" στην περιοχή του 'Οσιου Λουκά όχι μόνο άλλαξε τις συνθήκες ρηχής ανθρακικής ιζηματογένεσης σε πελαγικές κατά το Μαιστρίχτιο, αλλά επιπλέον δημιούργησε μία ενδο-πλατφορμική κοιλότητα πειστοιχιζόμενη από εκτεταμένες υποθαλάσσιες πεδιάδες κατά το 'Ανω Μαιστρίχτιο. Παρ' όλα αυτά, η ιζηματογένεση διεκόπει σε όλη την περιοχή κατά τη διάρκεια του ανώτατου Μαιστρίχτιου - κατώτατου Παλαιόκαινου, εξαιτίας της πτώσης της στάθμης της θάλασσας. Κατά τη διάρκεια Κάτω Παλαιοκαίνου - Μέσου Παλαιοκαίνου αναπτύχθηκαν ενότητες hard - ground - στρωματολίθων στις υποθαλάσσιες πεδιάδες και μία ενότητα φωσφορικού ασβεστο- αρενίτη / ασβεστο - λουτίτη στην ενδο - πλατφορμική κοιλότητα, σαν αποτέλεσμα της Παλαιοκαινικής ανύψωσης της στάθμης της θάλασσας. Επαναενεργοποίηση του τεκτονισμού κατά το τέλος του Παλαιοκαίνου προκάλεσε αρχικά ένα φαινόμενο ταχείας ρήχευσης και στη συνέχεια τη σταδιακή βύθυνση του επιπέδου πια θαλάσσιου πυθμένα, κατά τη διάκεια της απόθεσης των κατώτερων μαργαϊκών τμημάτων της ενότητας (ενότητες

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1 - 2). Οι ενότητες αυτές αποτελούν ένα μείγμα αλλόχθονου κλαστικού υλικού και αυτόχθονου Παρνασσιακού υλικού και γι' αυτό αντιπροσωπεύουν ένα προ-φλυσχικό στάδιο, που αποτέθηκε υπό συνθήκες ρηχής θάλασσας. Συνθήκες ανοιχτής θάλασσας τελικά επικράτησαν μόνο κατά το Ηώκαινο, όταν αποτέθηκαν τα ανώτερα μαργαϊκά τμήματα, ο μαργαϊκός φλύσχης (ενότητες 3-4).

INTRODUCTION

The flysch deposition in the Parnassus-Ghiona Zone, which took place during the Late Paleocene-Eocene (e.g. Prossilion, Solakius & Pomoni-Papaioannou, in press), is of significance since it marks the final stage of the depositional history of the zone, characterized by the collapse and subsidence of history of the zone, characterized by the collapse and subsidence of the collapce of the Parnassus carbonate platform and the erosion and subsequent deposition of terrigenous material from the inner zones (Gregou et al., in press). The fragmentation of the platform began, however, during the Late Cretaceous as a result of horst and graben tectonism (Richter & Mariolakos, 1974, 1975), which brought about a change in stable shallow-water carbonate conditions that had prevailed since the Cenomanian. Pelagic carbonate deposition prevailed in the deeper parts, while in the ridges shallow marine conditions persisted.

The transition from the carbonate to the flysch facies took place in the zone at the latest Maastrichtian-Middle Paleocene interval and was not continuous. In central Parnassus (e.g. Prossilion, Sernikaki, Stene Pigadhia, Distomo) the interruption in deposition during the latest Maastrichtian-earliest Paleocene led to the development of an extensive hardground pavement, with the subsequent development of stromatolites during the Middle Paleocene, when a shallow water tidal setting prevailed (Solakius et al., 1989; Pomoni & Solakius, 1991; Solakius et al., 1992). In the eastern margins, such as at Arachoal., 1992). In the eastern margins, such as Arachova, on the other hand, the transition can be seen in the form of argillaceous limestone beds with flaser structures deposited during the latest Maastrichtian-Middle Paleocene, with a short interruption in deposition across the K-T boundary, which gave rise to a brecciated carbonate horizon (Gregou et al.,in press). The deposition of the flysch began, however, all over Parnassus in the Late Paleocene (Solakius, in this volume).

Although several authors, such as Papastamatiou (1960), Celet (1962), Richter & Mariolakos (1974, 1975), Richter (1976) and Richter & Risch (1980) have described the general characteristics of the Parnassus-Ghiona flysch, there is no detailed sedimentological study of the flysch sequences. The subdivision of the flysch by Cellet (1960) into the red marly flysch (flysch rouge), the sandy-marly and marly-sandy flysch (rythmique pélitique and gréso-marneux flysch) and the conglomerates (flysch conglomÄratique) is the only lithological subdivisionthat has existed and has been used extensively over the years.

My aim is to present sedimentological and geochemical analyses of one of the most characteristic flysch sequences of central Parnassus, the Osios Loukas flysch sequence, which occurs close to the village of Distomo **(Fig. 1)**. Its has been preserved since is due to the fact that appearIts has been preserved since it lies in the centre of the Distomo - Stirion - Osios Loukas syncline, which has a general NW-SE direction (Tselepidis, personal communication).

Apart from a general description of this flysch sequence, emphasis will be placed on the basal parts, viz. the shaly flysch and the carbonate / clastic transition in the area. Two transitions are observed, the most extensive being

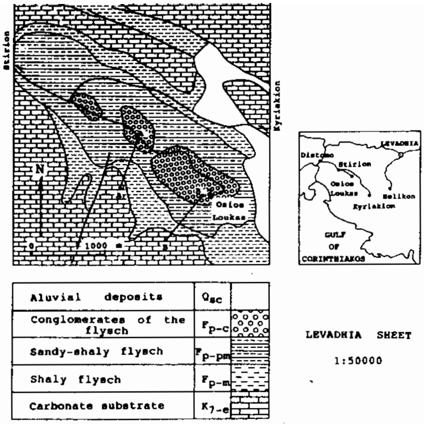

Fig. 1: Simplified geological map of the studied area, based on Levadhia sheet 1:50000.

Σχ. 1: Απλοποιημένος γεωλογικός χάρτης της υπό μελέτη περιοχής, βασισμένος στο φύλλο Λειβαδιά 1:50000.

that characterized by the formation of a hardground - stromatolitic unit overlying pelagic limestone beds of Late Maastrichtian age (Richter & Mariolakos, 1974; Kalpakis, 1979). However, another transition is found reported here for the first time, through the development of a phosphatic calcarenite / calcilutite unit, resembling that mentioned by Keup (1976) in the Delphi - Arachova area of Maastrichtian sandstone / sandy shales beds, and by Kalpakis (1979) in the Kyriakion area of phosphatic sandstone bedsc sandstone beds. These two transitions are described below, on the basis of petrological, geochemical and sedimentological studies, and the depositional environments they represent are correlated.

The basal units of the Osios Loukas flysch sequence have also been investigated using mineralogical, geochemical and sedimentological analyses, in order to reconstruct the environment of their deposition and to differentiate the contribution of autocthonous Parnassian material from the allochtonous clastic influx.

GEOLOGICAL SETTING AND LITHOLOGY OF THE OSIOS LOUKAS SEQUENCE

The Osios Loukas flysch sequence is exposed in the valleys surrounding the Osios Loukas monastery, about 2km past the Distomo-Osios Loukas and Distomo-Kiriakion crossroads (Fig. 1), covering an area of about $2km^2$.

The Parnassus-Ghiona Zone, which is restricted to Parnassus, and the Ghiona and Helicon mountains and some parts of Mt Oete, is geotectonically assigned to the external Hellenides and it overthrusts the Olonos-Pindos Zone from the north-west, while it is in turn overthrusted by the Beotian and Subpelagonian Zones from the east (Papanikolaou, 1986).

During the Triassic and Early Cretaceous, a shallow carbonate platform deposition prevailed in the Parnassus - Ghiona Zone, interrupted by three main short periods of subaerial exposure. Karstification took place, followed by bauxite accumulation in the karsts.

During the Late Cretaceous the Parnassus platform was affected by horst and graben tectonism (Richter) & Mariolakos, 1974; 1975), with resulting pelagic sedimentation in some areas. During the K/T boundary interval and the earliest Paleocene there was a marked interruption in deposition in most parts of Parnassus, leading to the development of a hardground horizon, while during the Middle Paleocene stromatolites were superimposed (Solakius et al., 1989; Pomoni - Papaioannou & Solakius, 1991; Solakius et al., 1992). As a result of the total collapse of the platform the flysch was deposited during the Late Paleocene - Eocene (Solakius & Pomoni - Papaioannou, in press).

The Osios Loukas carbonate-flysch sequence comprises the following lithologies (Figs 1, 2, 3): The lower units consist of rudist-bearing limestone beds of Upper Cretaceous age (K_{7-8}) gradually passinsing upwards into Maastrichtian pelagic limestone beds (K_{8-e}) with Globotrucanidae. The transition from the rudist - bearing to the pelagic limestone beds takes place through the presence of limestone beds with rudist fragments and the appearance of the first

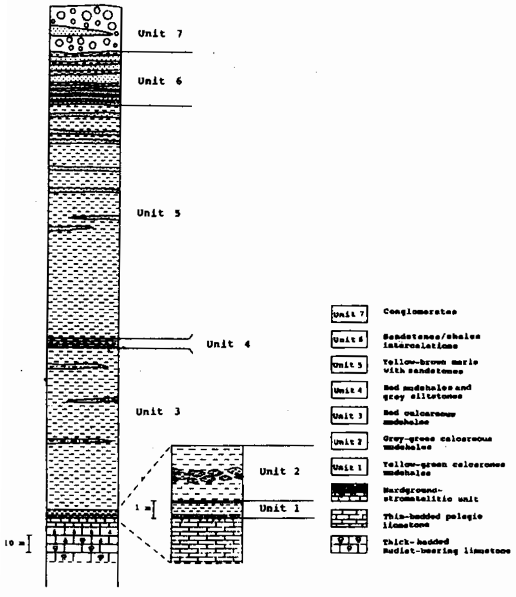

Fig. 2: The Osios Loukas carbonate/flysch sequence and a new sub-division of the flysch.

Σχ. 2: Η ακολουθία ανθρακικών/φλύσχη του Οσίου Λουκά, καθώς και μία νέα υποδιαίρεση του φλύσχη.

Globotrucanidae. The rudist - bearing limestone are generally around 100 m thick, but in the Osios Loukas area only the upper 20 m appear, due to tectonic events. In the Osios Loukas area the overlying pelagic limestone does not exceed 5 - 10 m. Above the pelagic limestones a hardground - stromatolitic bed develops (c. 25 cm thick) (Richter & Mariolakos, 1974; Kalpakis, 1979), followed by the shaly units of the flysch (F_{p-m}). In succession, sandstones - shales intercalations and compact sandstone banks middle - to thin - bedded (F_{p-pm}) are observed and finally the flysch sequence closes with the conglomerates (F_{p-c}).

THE AGE OF THE SEQUENCE

The pelagic limestone beds include the planktonic foraminifera *Globotruncana linneiana* (d' Orbigny), *Globotruncana arca* (Cushman), *Racemiguembelina textulariformis* (White), *Rosita contusa* (Cushman), *Globotruncanita stuarti* (De Lapparent) and *Abathomphalus mayaroensis* (Bolli), which indicates that the carbonate substratum of the sequence was deposited during the Maastrichtian. In the overlying hardground - stromatolitic unit and in the posphatic calcarenite, *Morozovella pseudobulloides* (Plummer), *Globigerina trinoculinoides* Plummer, *Planorotalites compressa* (Plummer), as well as *Morozovella angulata* (White) and *Morozovella aequa* (Cushman & Renz) occur indicating a late Early and Middle Paleocene age. Finally, the presence of *Globigerina velascoensis* (White), *Morozovella subbotina* (Morozova) *Morozovella aragonensis* (Nuttalli) *and Morozovella caucasica* (Glaessner) in the shaly part of the flysch sequence points to an Upper Paleocene-Eocene age. A complete analysis of the foraminiferal assemblages will be presented in a forthcoming paper.

ANALYTICAL METHODS

Titrimetric analysis of the calcium-carbonate content and major element analysis, by plasma atomic emission spectrometry, were performed on whole-rock samples. In addition the <2μm fraction of the samles was analysed, air-dried, treated with ethylene glycol (EG) and after heating at 550° C, with XRD. Point-counting (250 points) was performed on thin-sections from selected samples.

THE CARBONATE SUSTRATUM

The lower carbonate substratum in the Osios Loukas area, the Upper Cretaceous grey, bitumenous, rudist-bearing limestone passes upwards to the grey-white Maastrichtian pelagic limestone **(Plate I, 1)**, through transitional limestone beds with rudist fragments. There appears to be a variation in the degree of phosphatization in the Maastrichtian pelagic limestone, depending on the overlying beds transitional to the clastic facies.

The grey-white pelagic limestone of Maastrichtian age, which is overlain by the hardground-stromatolitic bed, is a phosphatized foraminiferal wackestone-packstone (type 1); is c. 10 m thick and is characterized by a decreasing degree of phosphatization with increasing depth (83-98% $CaCO_3$). The phosphate takes the form of amorphous phosphatic compounds, peloids composed of collophanite, sub-rounded phosphatized limestone fragments and phosphatized foraminifera tests. Fragments of brachiopods, echinoderms, ostracodes and calcispheres are also present. Rounded glauconite grains, a few subrounded quartz grains and amorphous iron oxides appear in the micritic matrix or preferentially concentrated, as insoluble residue, along microstylolites and stylolitic seams.

The pelagic limestone, which appears below the phosphatic calcarenite, is a whitish foraminiferal wackstone (87% $CaCO_3$) of Maastrichtian age, with no sign of intense phosphatization processes (type 2). Amorphous phosphatic and iron compounds occur along pressure-solution microstylolitic surfaces. The most abundant fossils are planktonic foraminifera, Globotrucanidae species, but there are also benthonic types and echinoderms. The small amount of clay minerals comprises illite and vermiculitic mixed-layers.

THE TRANSITIONAL BEDS FROM CARBONATE TO CLASTIC FACIES

a. THE HARDGROUND-STROMATOLITIC UNIT

In the upper layers of the phosphatized pelagic limestone of Late Maastrichtian age with abundant impregnations of amorphous iron oxides, a hardground-stromatolithic bed (15-25 cm) occurs extensively. It is underlain by a strongly Fe-P mineralized burrowed discontinuity surface, which is the result of a latest Maastrichtian-earliest Paleocene interruption in sedimentation subsequently filled with iron oxides, phosphatic compounds and pelmicritic material.

According to Kalpakis (1979) the hardground-stromatolitic unit **(Fig. 2)** consists of the following sub-units: the discontinuity surface, the stromatolitic crust (Stromatolites of SH -type in the lower parts and LLH-type in the upper) and finally the "nodules", which have a complex nucleus consisting of limestone particles from the substrate, volcanic, metamorphic rock fragments, particles of the stomatolitic crust, phosphatic compounds, glauconite grains, encrusted by parallel lamination of iron oxides and hydroxides.

This investigation revealed the presence of a reworked breccia (c. 5 cm) below the nodules, consisting of limestone particles and stomatolitic fragments **(Plate I, 2),** packed together in a micritic matrix of Middle Paleocene age.

This horizon, characterized by its packed framework and Fe-P mineralized preomission trace fossils (burrows) filled with Middle Paleocene micritic material **(Plate II, 3),** could represent a further discontinuity surface above the stromatolites and below the nodules. In addition the nodules might represent algal oncolites with complex intra- and extraclasts nucleus and a rim of algal laminae. The encrustations show similarities with stromatolitic development, such as interlayering of sediment and organic-rich laminae **(Plate II, 1,2)** and the entrapping of pelagic planktonic foraminifera between the layers.

A primary synsedimentary lithification of the unit is suggested because of the presence of early marine cement of fibrous-radial type **(Plate I, 3)** and the development of phosphatic/glauconitic grains, replacing calcitic foraminifera tests. This glauconitization process occurs at the sediment/water interface implying lengthy contact of the sediment with sea water. On the other hand, the appearance of a network of thin, slightly sinous sheaths filled with blocky calcite **(Plate I, 2)**, resembling rhizolitic structures (calcified filaments), such as those described by Pomoni-Papaioannou & Solakius (1991) in the Prossilion hardground-stromatolitic unit, require further attention. The presented sedimentological evidence is not sufficient for an adequate paleoenvironmental evaluation of this particular hardground-stromatolitic bed, which will be treated separately in a forthcoming paper. Nevertheless, there is a marked interruption in sedimentation during the latest Maastrichtian - earliest Paleocene, resulting in the mineralization of the uppermost layers of the Late Maastrichtian pelagic limestone. Subsequently a shallow water tidal setting prevailed probably interrupted during short emersions when the stromatolites developed. In conclusion the hardground-stromatolitic unit developed during the latest Maastrichtian-Middle Paleocene in a shallow submergent to probably periodically emergent setting.

A 10 cm layer of yellow-orange semi-consolidated non - laminated mudstone (19.7% $CaCO_3$) immediately overlies the hardground - stromatolitic unit, consisting of quartz, feldspars, micas, phosphatic peloids, phospatized limestone (foraminiferal wackestone - packstone) particles, glauconitic grains and amorphous iron compounds in a micritic matrix (Plate V, 1). The layer is generally poor in fossils, except for some agglutinated benthonic foraminifera and a few transported and phosphatized planktonic species. The quartz grains are subangular to subrounded, monocrystalline, with slightly undulose extinction implying a detrital origin. The phosphatic peloids resemble those in the carbonate substrates and the calcarenite, so a primary faecal origin is attributed to them, even if reworking and later redeposition took place. The glauconite develops mainly as replacements of primary calcitic foraminifera tests and faecal pellets. The phosphatized limestone particles are reworked and redeposited from adjacent areas, without significant transportation. The lack of stratification implies continuous rapid sedimentation from suspension or its destruction by bioturbation. This thin mudstone layer is probably the result of a Late Paleocene "shallowing up". It consists of the first clastic material which affected the platform in a shallow environment, and Parnassian material supplied with synchronous reworking and redeposition of the immediate sustrate or/and adjacent areas.

b. THE PHOSPHATIC CALCARENITE UNIT

The phosphatic calcarenitic bed **(Fig. 2)**, 0,7 m thick, appears along the Xeropotamos river which runs across the Osios Loukas valleys with a general E - W direction, in an outcrop 88m long and more than 100m wide. This limited development appears adjacent to hardground - stromatolitic transitional beds directly to the east, but only after a 370 m covered interval to the west.

The upper parts of the underlying pelagic limestone show a microrelief and borings a few cm deep. The transition to the phosphatic calcarenite occurs through an intermediate mixed - zone, c. 5 cm thick, consisting of angular to subrounded particles of the underlying limestone in a phosphatic calcarenite matrix. Before or during the influx of the first phosphatic supply the upper parts of the carbonate substratum were reworked and redeposited in situ, in the form of an intraformational carbonate conglomerate, probably as a result of the eaustatic fall of sea - level in the Late Maastrichtian (Vail et al., 1991) in combination or not with local tectonic effects. A submarine formation of this intraformational conglomerate is suggested since there is no sedimentological evidence for subaerial exposure during its development.

The dark brownish - black phosphatic calcarenite (38% $CaCO_3$), 0.7 m thick, appears to be strongly bioturbated and in the upper 20 cm, there are abudant trace fossils with mainly horizontal development. It is composed of subrounded micritic phosphatic peloids, subrounded phosphatic limestone particles of Maastrichtian and Paleocene age, glauconite grains, a few quartz and flesdspar grains, packed together by Paleiocene foraminifera tests and micritic calcite matrix. In addition to foraminifera are found echinoderms, brachiopods and ostracodes fragments, calcitic or partly phosphatized. The phosphate phase is francolite, carbonate F-apatite.

The phosphatic compounds, giving rise to a 18.3% P_2O_5 content, appear in the following forms:

1. Phosphatic peloids, ovoidal, composed of microcrystalline apatite (collophanite) with no apparent internal structure and 0.1 - 0.6 mm in diameter, either pure or with contaminants consisting of iron oxides, clay, calcite, organic matter and foraminifera tests **(Plate IV, 1)**. These peloids acted as a nucleation site for apatite, as shown by the secondary rim of pure collophanite outlining some of the primary phosphate concentrations. The peloids which contain foraminifera tests/ fragments and scattered pieces of organic matter, could possibly represent faecal pellets **(Plate III, 1)**, resembling those described by Kidder (1985). The entrapped foraminifera in the peloids show they were formed during the Paleocene. Two generations of peloid formations can sometimes be distinguished, a younger peloid enclosing an older one. The preservation of faecal pellets requires early intragranular cementation in a low - energy shallow - water environment. I consider that most of the faecal pellets are were deposited in situ, while reworking and redeposition of pre - existing pellets cannot be excluded.

2. Phosphatized fossils, mainly planktonic foraminifera and echinoderms, brachiopods and ostracodes, with a few phosphatic fossils such as fragments of fish teeth.

3. Phosphatized rock fragments, mainly foraminiferal packstone particles, but also claystone/mudstone, varying in degree of phosphatization. These subrounded rock fragg rock fragments are characterized by a thin lining of pure secondary apatite.

The transported particles, phosphatized rock fragments, have a thin lining of primary marine calcitic cement (fibrous/radial type) secondarily cemented by micritic calcite with a varying contribution of collophanite and clay minerals. Microcrystalline quartz is present as cement in isolated primary pores. The shape and colour of the glauconite shows that it mainly replaces calcite from foraminiferal tests or faecal pellets, which is consistent with the suggestion that glauconite formation requires a semi-confined diagenetic environment, such as can develop within the tests of microfossils or in decomposing organic matter (Odin & Matter, 1981). The clay mineral content consists of illite and ved vef microfossils or in decomposing organic matt ter (Odin & Matter, 1981). The clay mineral content consists of illite and vermiculitic mixed-layers (Illite-vermiculite and chlorite-vermiculite).

The presence of particles composed of structured interlayers of iron oxides and organic matter, apparently derived from the hardground-stromatolitic bed, shows that reworking and transportation from the adjacent hardground-stromatolitic bed, shows that reworking and transportation from the adjacent hardground - stromatolitic unit took place during the deposition of the calcarenite.

Above the calcarenite is a 15 cm thick layer of yellowish-brown phosphatic calcilutite (30.5% CaCO3) where the content of detrital minerals such as quartz, feldspars and micas, as well as micritic matrix, increases dramatically in contrast to planktonic foraminifera which have almost disappeared **(Plate IV, 2)**. The phosphatic peloids and the phosphatized rock fragments make up 10.3% P_2O_5. The clay minerals comprise illite and vermiculitic mixed - layers (illite - vermiculite and chlorite - vermiculite). Glauconite grains are more abundant than in the underlying calcarenite beds.

The calcilutite is overlain by a 20 cm thick layer of red calcareous, organic - rich mudshales (29.5% $CaCO_3$), poor in planktonic foraminifera. The amount of micritic matrix and detrital minerals increases while the phosphatic compounds form an almost insignificant component and the P_2O_5 content drops to 0.9% **(Plate IV, 3)**. The clay minerals are illite and vermiculitic mixed - layers.

Overlying this are found green calcareous shales (34.5% $CaCO_3$) with large benthonic foraminifera, probably equivalent to the first units of the flysch sequence. The clay minerals are illite, chlorite and illite - vermiculite mixed - layers. It was not possible to determine the exact thickness of the unit of the upwards continuation of the sequence, since it is not exposed.

The content of major - element oxides **(Table 1)** in the posphatic calcarenite and its overlying units, in combination different conditions during their deposition.

Table 1: Geochemical analyses of the phosphatic calcarenite and its overlying beds (phosphatic calcilutite, red calcareous mudshales and green c alcareous mudshales) and their calcium-carbonate content.

Πίνακας 1: Γεωχημικές αναλύσεις του φωσφορικού ασβεσταρενίτη και της υπερκείμενης ακολουθίας, καθώς και το περιεχόμενό τους σε ανθρακικό ασβέστιο.

Samples-Lithology	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	K_2O %	MgO %	MnO %	Na_2O %	P_2O_5 %	TiO_2 %	$CaCO_3$ %
OS4B/calcarenite	4,9	1,3	1,2	0,1	0,6	0,03	0,4	18,3	0,08	38,0
Eb/calcilutite	28,2	5,9	3,1	0,9	1,1	0,04	1,1	10,3	0,34	30,5
Ec/r.mudshales	41,3	10,2	4,9	1,7	1,8	0,05	0,9	0,9	0,54	29,5
Ed/g.mudshales	26,8	7,4	3,2	1,2	1,9	0,12	0,6	0,2	0,36	34,5

The MnO/TiO_2 ratio of a sediment can be used as an indicator of the sedimentation rate for the clastic supply (Sugisaki, 1984), as the ratio of an authigenic element (Mn) to a terrigenous element (Ti). The MnO/TiO_2 ratio of the phosphatic calcarenite is 0.4, suggesting a slow sedimentation rate for the clastic supply. On the other hand, the MnO/TiO_2 ratio of the phosphatic calcilutite and its overlying red calcareous mudshales beds is only 0.12 and 0.09 respectively, suggesting fairly rapid sedimentation for the clastic influx, which agrees with the mineralogical data. This taken in combination with the fact that the planktonic foraminifera were abundant in the phosphatic calcarenite but almost disappear in the phosphatic calcilutite and the red calcareous mudshales, implies increased proximity to land during their deposition, probably the effect of rather sudden Late Paleocene shallowing up. Finally, the MnO/TiO_2 ratio of the overlying green calcareous mudshales is once agian high with a value of 0.33, pointing the a slow sedimentation rate for the clastic supply. During the deposition of these beds the area probably gradually began to subside, allowing the first benthonic foraminifera species to appear.

CORRELATION OF THE TRANSITIONS

The transitions from the carbonate to the clastic facies described have as a common characteristic the presence of iron - phosphate - rich accumulations, which occur both in the hardground - stromatolitic unit (first transition) and in the posphatic calcarenite / calcilutite unit (second transition), deposited during the latest Maastrichtian - Middle Paleocene **(Fig. 3)**. However, the Late Maastrichtian limestone beds underlying the hardground - stromatolitic unit are strongly phosphatized, while the immediate carbonate substrate of the phosphatic calcarenite / calcilutite unit is not.

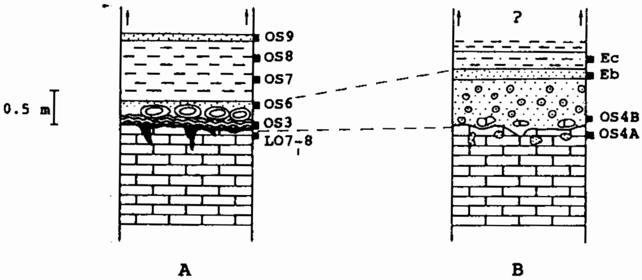

Fig. 3: The two carbonate to clastic facies transitions, (A) The hardground - stromatolitic unit, (B) The phosphatic calcarenite unit, in the Osios Loukas area.

Σχ. 3: Οι δύο μεταβάσεις από τα ανθρακικά προς το φλύσχη (A) Η ενότητα λιθοποιημένου υποβάθρου (hardground) - στρωματολίθων, και (B) Η ενότητα φωσφορικού ασβεστο-αρενίτη, στην περιοχή του Οσίου Λουκά.

Nevertheless, in both transitions there was a marked interruption during the latest Maastrichtian - earliest Paleocene, as a result of the world - wide Late Maastrichtian eustatic fall of sea - level (Vail et al., 1991). Due to this interruption a hardground developed in the uppermost layers of the Late Maastrichtian phosphatized pelagic limestone, in the form of a strongly burrowed iron - phosphate - mineralized discontinuity surface (first transition), while an intraformational carbonate conglomerate appears in the uppermost layers of the Late Maastrichtian pelagic limestone (second transition). During the late Early Paleocene - Middle Paleocene above the hardground a shallow water tidal setting probably interrupted by short periodic emersions prevailed, where stromatolites developed, while a deeper setting prevailed where the phosphatic calcarenite developed. The thin layer of the phosphatic mudstone directly overlying the hardground - stromatolitic unit is regarded as being equivalent in composition to the phosphatic calcilutite beds overlying the phosphatic calcarenite. They represent a mixture of the first clastic material supplied in the Osios Loukas area, together with reworked material from the substrate and eroded autocthonous Parnassian material prsumably transported from neighbouring areas. The deposition of the phosphatic calcilutite together with the red calcareous shales probably reflect sudden Late Paleocene shallowing up, before the gradual subsidence indicated by the deposition of the green calcareous mudshales.

The presence of the stromatolitic crust fragments and laminated Fe-P compounds inside the phosphatic calcarenite indicates that reworked material from the hardground - stromatolitic pavement was supplied, implying paleotopographical proximity. The reason suggested for the formation of the hardground - stromatolitic unit and for the phosphatic calcarenite / calcilutite unit is the existing paleotopography of the Osios Loukas area at the time of their development. During the Late Maastrichtian the paleorelief of the sea - floor was characterized by the presence of an interplatform depression, which extended for at least 100m with a general N-S direction, adjacent to paleiotopographical submarine plains. During the lates Maastrichtian - Middle Paleocene, the hardground - stromatolitic unit developed in the plains in a shallow submergent to periodically emergent setting, while the calcarenite unit was formed in this depression. Since the deposition of the upper parts of the phoshpatic calcarenite unit, viz. the phosphatic calculutite and the red calcareous mudshales took place in a shallowing setting, it can therefore be assumed that by that time the depression was nearly full and the paleorelief gradually became smoother. Taking this into account, the depth of the depression was probably only a few metres, despite its considerable latteral extension (hundeds of metres). Although the uppermost parts of the phosphatic calcarenite unit, viz. the green calcareous mudshales, cannot be directly correlated to the basal units of the flysch (units 1-2), they nevertheless represent the first sediments deposited in a gradually subsiding environment.

The presence of phosphatic compounds in the Late Maastrichtian pelagic limestone beds and in the transitions from the carbonate to the flysch facies during the latest Maastrichtian - Middle Paleocene in the Osios Loukas area, corresponds with the world - wide Late Maastrichtian - Early Paleocene development of extensive phosphatic formations (Valeton, 1988), which is believed to be the result of the Late Maastrichtian global regression (Vail et al., 1991). The Late Maastrichtian fall of sea - level provided conditions favourable for phosphorite development, by changing the pre-existing depositional environment into conditions of condense sedimentation and subsequent reworking. The phosphate is believed to be precipitated within the uppermost layers or directly below the sediment / water interface of organic - rich sediments during early diagenesis (Kolodny, 1981). Exntensive phosphate - rich deposits can, however, be of secondary origin formed through reworking and redeposition of phosphate - poorer sediments.

The presence of transported phosphatized limestone particles and amorphous phosphatic compounds in the pelagic limestone beds, in the hardground - stromatolitic unit and in the calcarenite unit, in the Osios Loukas area lead to the assumption that it must have been an external source of phosphate, marine (P absorbed in faecal pellets and organic matter) or continental (reworking of phosphate - rich developments) or both in the area during the Late Maastrichtian - Middle Paleocene. In addition dissolution of faecal pellets and phosphatized limestone particles increased the phosphorus concentration in the interstitial waters during lithigication, and phosphorous reprecipitated as pure apatite rims around already available phosphatic nuclei (faecal pellets, phosphatized limestone particles) or contaminants in the calcitic micritic matrix. The possibility that the hardground - stromatolitic unit could have served as a primary "trap" for phosphate precipitation, as some workers (O' Brien et al., 1981; Lucas and Prevot, 1984) have pointed out for microbial mats and iron - hydroxides, cannot be excluded.

GENERAL DESCRIPTION OF THE FLYSCH SEQUENCE

The lower units of this flysch sequence the first 4.2 m, appear only in the southern part of the Osios Loukas area. Thus two characteristic sections across the flysch sequence were taken, one in the southwest and another in the southwest. The flysch sequence constists of the following lithological units **(Fig. 3)**:

Unit 1: yellow - grey calcareous mudshales (1 m), overlie a thin year (10 cm) of yellowish - orange massive mudstone, directly overlying the hardground. These shales are thin - bedded with parallel lamination. Unit 2: gray - green calcareous mudshales (3.2 m), with bedding of moderate thickness and parallel lamination. The transition between the first two shaly units occurs through another thin layer (5 cm) of yellowish - orange mudshale with thin parallel lamination. Units 1 and 2 represent the lower shaly part of the sequence or the "pre-flysch" stage.

Unit 3: red calcareous mudshales with random intercalations of yellowish mudstones (94m), thin-bedded with parallel lamination and rich in planktonic foraminifera. The intercalations do not extend more than a few metres. Unit 4: intercalations of red mudshales, thin-bedded with parallel lamination, with grey laminated siltstones (6 m). The intercalations are of considerable lateral extension. Units 2 and 3 represent the upper shaly parts of the sequence, facies G, pelagic and hemipelagic shales, according to Mutti and Lucchi's classification (1972).

Unit 5: yellow-brown marls with intercalations of sandstone beds (136 m). The first 56 m consists of pure marls with no intercalations of sandstones,while the remaining 80 m comprises marls-sandstones intercalations. Unit 6: massive sandstones with intercalations of shales (>25 m). The thickness of the sandstone banks increases at the upper parts of the unit from 5 to 50 cm. The unit is strongly tectonized and the precise thickness cannot be measured with accuracy. Unit 7: conglomerates (>20m), consists mainly of pebbles of sandy and shaly material, but also of limestone and green-schist rocks. The upper sandy-marly, marly-sandy and conglomeratic flysch units are equivalent to facies D, C and A respectively, according to Mutti and Lucchi's classification (1972). The clastic rocks classification is based on Lundegard & Samuels (1980).

THE LITHOLOGY OF THE SHALY PARTS OF THE SEQUENCE

The underlying shaly parts of the Osios Loukas sequence, the "preflysch" units 1 and 2 **(Fig. 3)**, begin with a thin layer of yellow-orange semi-consolidated non-laminated mudstone (already described), passing upwards to unit 1, yellow-green calcareous mudshales (28% $CaCO_3$), 1 m thick, thin-laminated, with horizontal stratification and parting. They consist of quartz, feldspars, micas, phosphatic peloids and phosphatized limestone particles in a calcitic micrite matrix. A few benthonic foraminifera were the only fossils present **(Plate V, 2, 3)**. The depositional environment of this unit is shallow marine with an increasing contribution of micritic calcite mud.

The overlying unit 2 consist of gray-green calcareous mudshales (33% $CaCO_3$), 3.2 m thick, the lower part of which is a thin (5 cm) layer of yellow-orange mudshale (18,6% $CaCO_3$) resembling that at the begining of unit 1, except that it has parallel lamination and only a minor content of phosphatic compounds. The unit of gray-green calcareous shales consists of quartz, feldspars, micas, iron oxides and clay minerals in a micritic carbonate matrix. In addition benthonic planktonic foraminifera species gradually appear in this unit, suggesting deposition in a successively deepening envirnonment, as a result of an increase in rate of subsidence. In the middle of unit 2 is an interval (c. lm thick), where the mudshales appear forming massive carbonate-rich lenses (48% $CaCO_3$) with "rose-like" parting, possibly formed by dissolution of the carbonate matrix at an early diagenetic stage and consequent carbonate recementation.

The following unit 3, 94 m thick, is made up of red calcareous madshales(38% - 57% $CaCO_3$), thin-bedded, with random intercalations of yellowish-grey layers a few cm thick extending for only a few metres. These red calcareous shales are packed with calcitic tests of planktonic foraminifera. The mineralogical composition comprises quartz, feldspars, micas, iron oxides, organic matter in a micritic matrix of calcite, clay, iron oxides and organic matter. The depositional environment of these mudshales seems to be open marine with occasional mud flows that deposited the yellow mudshales in restricted interlayers.

The marly part of the flysch sequence closes with unit 4, the intercalations of red shales and grey siltstones, 6 m thick, thin-bedded, with extensive lateral continuity. The red shale layers are as carbonatic as the previous unit

(34.4% $CaCO_3$, while the grey siltstone layers have only a small amount of carbonate (10.5% $CaCO_3$). These intercalations represent disturbances in the prevailing carbonatic pelagic sedimentation by sudden large-scale mud flows of coarser material (clay to silt size).

CLAY MINERALOGY OF THE BASAL FLYSCH UNITS

The yellow-orange mudstone, overlying the hardground-stromatolitic bed, is characterized by an illite, illite-vermiculite and chlorite-smectite mixed-layer clay mineral assemblage. The yellow-green calcareous mudshales (unit 1), contain an illite, chlorite and illite-vermiculite mixed-layer clay mineral assemblage. The yellow mudshale in the lower parts of unit 2, contains only chlorite - smectite mixed layers, while the overlying grey-green calcareous mudshales of unit 2 also contain an illite, chlorite, illite-vermiculite mixed-layer clay mineral assemblage. The red calcareous mudshales (unit 3) clay mineral content is mainly made up of illite and chlorite, with only a minor contribution of mixed - layers. Similarly, the intercalations of red mudshales and grey laminated siltstones (unit 4), is characterized by an illite and chlorite, with small amounts of mixed-layer, clay mineral assemblage.

GEOCHEMISTRY OF THE BASAL FLYSCH UNITS

The geochemical analyses of the basal flyschunits are presented in **Table 2.**

The underlying mudstone layer and the calcareous mudshales of unit 1 present a more or less constant chemical composition apart from the gradually upwards increase of the calcitic micrite. An average SiO_2/Al_2O_3 ratio of 4.5 suggests the important contribution of siliclastic minerals, such as quartz, feldspars as compared with clay minerals. An average high Fe_2O_3 content of 8.7% can be attributed not to the presence of amorphous iron compounds but to the abundance of glauconite grains. The relatively high P_2O_5 content, 1.7%, is correlated with the presence of faecal pellets and phosphatized limestone particles. The average MnO/TiO_2 ratio is 0.15 implying a rather rapid sedimentation rate for the clastic input.

The geochemical profile of the grey-green calcareous mudshales of unit 2 differs slightlyfrom that of the yellow - green calcareous mudshales of unit 1.

Table 2: Geochemical analyses of the basal parts of the flysch sequences (units 1-4) and their calcium - carbonate content.

Πίνακας 2: Γεωχημικές αναλύσεις των κατώτερων τμημάτων της ακολουθίας του φλύσχη (ενότητες 1-4) και το περιεχόμενό τους σε ανθρακικό ασβέστιο.

Samples-Lithology	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	K_2O %	MgO %	MnO %	Na_2O %	P_2O_5 %	TiO_2 %	$CaCO_3$ %
OS6/ph.mudstone	48,1	10,3	8,9	1,6	1,7	0,09	0,9	1,7	0,6	19,7
OS7/y-g.mudshales	46,5	9,9	8,6	1,6	1,7	0,08	0,9	1,7	0,5	28,0
OS9/o-y.mudshale	41,6	17,8	6,2	1,1	3,2	0,06	1,2	0,4	0,8	18,6
OS10/g-g mudshale	39,4	16,8	6,0	1,0	3,1	0,06	1,1	0,4	0,8	33,0
OS11/g-g.mudshale	35,2	10,4	4,3	1,7	2,4	0,06	0,9	0,2	0,5	48,0
OS15/r.mudshale	31,6	8,3	3,6	1,6	2,1	0,12	0,7	0,2	0,4	38,0
OS20/r.mudshale	33,3	9,1	4,6	1,8	2,0	0,09	0,7	0,1	0,6	48,0
OS30/r.mudshale	23,2	6,6	2,9	0,7	1,5	0,22	0,7	0,1	0,3	57,0
OS40/r.mudshale	24,2	6,7	3,1	0,7	1,6	0,24	0,7	0,1	0,3	38,0
OS43/r.mudshale	37,2	11,9	5,2	2,1	2,9	0,26	1,1	0,1	0,6	34,3
OS47/g.siltstone	60,5	14,3	6,0	2,4	3,2	0,07	1,7	0,1	0,9	10,5

The average SiO_2/Al_2O_3 ratio is 2.6 suggesting an increase in the clay mineral content relative to quartz and feldspars. The Fe_2O_3 content decreases to an average value of 5.5%. The P_2O_5 content decreases to an average value of 0.3%, since there is little phosphatic material in this unit. The average MnO/TiO_2 ratio is 0.08, suggesting there was still a rather rapid clastic sedimentation rate.

The lower shaly parts of the Osios Loukas sequence, viz. units 1 and 2, represent a mixture of allocthonous clastic material and reworked Parnassian autocthonous material, with a gradually decreasing contribution of the latter which points to a slow, gradually increasing subsidence in a still shallow marine setting. The variations in the aluminum silicates / clay minerals ratio of the clastic influx in these two units, may be controlled only by the size of the transported particles, depending on the intensity of the terrestrial denudation, the tectonic activity and the climate of the adjacent land masses. An additional reason might be that the source rocks are of a different mineralogical composition.

The red calcareous mudshales of unit 3 show a slight diversity in their major components according to fluctuations in the $CaCO_3$ content. The average SiO_2/Al_2O_3 ratio is 4.8 suggesting a relative increase in the contribution of aluminum silicates to clay minerals.

Their Fe_2O_3 content is lower than in the previous units with an average value of 3.5%. The P_2O_5 content decreases substantially to an average value of 0.13%. An average MnO/TiO_2 ratio of 0.4 implies a considerable decrease in the clastic sedimentation rate to rather low values, as is also suggested by the condense framework of these calcareous mudshales, packed with planktonic foraminifera in a micritic matrix. During the deposition of the red calcareous mudshales of unit 3, the true rapid subsidence began, resulting in calm pelagic conditions only periodically disturbed by small-scale mud-flows, during the deposition of the yellow mudshales intercalations.

The red mudshales of unit 4 have an average SiO_2/Al_2O_3 ratio of 3.1, pointing to an increase in the amount of clay minerals relative to quartz and feldspar, while the grey laminated siltstones have SiO_2/Al_2O_3 ratio of 4.2, implying a relative increase in aluminum silicates, as expected since they were deposited as a result of the intrusion of silt-flows in the area. The Fe_2O_3 content of unit 4 increases to an average value of 5.7%. The P_2O_5 content remains low with an average value of 0.12%. The higher K_2O content (average 2.4%), suggests a greater contribution of K-feldspars and micas, while a higher Na_2O content of 1.45% suggests an increase in the amount of plagioclase present. The average MnO/TiO_2 ratio of the red mudshales interlayers is p.45, which implies a rather slow clastic sedimentation rate, as for the underlying red calcareous mudshale of unit 3, while the MnO/TiO_2 ratio of the grey laminated siltstones is 0.07, demonstrating a rapid sedimentation rate for the clastic input. The difference in the clastic sedimentation rate of the red mudshales and grey siltstones supports their formation through the alternation of calm pelagic carbonate sedimentation and more rapid silty mud flows.

CONCLUDING REMARKS

The Osios Loukas flysch sequence is found to be one of the most complete flysch sequences in central Parnassus. The transition from the carbonate to the clastic facies took place during the Early Paleocene - Middle Paleocene and is characterized by the presence of the hardground - stromatolitic unit which developed in the submarine plains and the phosphatic calcarenite / calcilutite unit deposited in an intraplatform depression. However, during the latest Maastrichtian to earliest Paleocene deposition was interrupted, leading to the development of an Fe-P mineralized discontinuity surface in the plains and an intraformational carbonate conglomerate in the depression.

During the latest Middle Paleocene - Late Paleocene after a sudden shallowing up the area slowly commenced to subside, giving rise to the deposition of the sediments forming the thin orange-yellow mudstone layer, the yellow-green calcareous mudshales of unit 1 and the grey-green calcareous shales of unit 2. These beds represent a mixture of the first allocthonous clastic influx supplied in the area and reworked autocthonous Parnassian material (e.g. limestone particles, glauconite, faecal pellets). The clastic supply, characterized by a high sedimentation rate, was coarser (higher contribution of quartz, feldspars) during the deposition of unit 1 and finer (more abundant in clay minerals and micas) during the deposition of unit 2.

Owing to the increased subsidence of the area, a deeper semipelagic to pelagic environment prevailed during the deposition of the sediments forming the red calcareous mudshales of unit 3. The clastic influx was coarse (more abundant in quartz, feldspars) and was deposited slowly. The intensity of the clastic supply was, however, occasionally increased by small-scale mud flows, which resulted in the deposition of the yellow mudshale interlayers within the red calcareous mudshales. The open marine sedimentation continued during the deposition of the red mudshales of unit 4, regularly receiving rapidly accumulated mud-silt size particles in the form of mud-flows, which led to the formation of the lateral continuous grey laminated siltstone layers.

In summary, the Late Cretaceous horst and graben tectonism affected the Osios Loukas area during the Maastrichtian, so that there was a change from shallow - water into pelagic conditions. Subsequent rejuvenation of the tectonism in the Late Maastrichtian created a paleotopography of the sea floor, characterized by the presence of submarine plains surrounding an intraplatform depression. The latest Maastrichtian regression had a greater effect than the tectonically imposed subsidence and caused an interruption in sedimentation during the latest Maastrichtian - earliest Paleocene. During the late Early Paleocene-Middle Paleocene, as an effect of the Early Paleocene transgression in combination with local tectonic effects, shallow - water tidal conditions with probable periodic emersions prevailed in the plains, while relatively shallower marine conditions prevailed in the depression. Tectonism was re-activated once again during the Late Paleocene leading first to a sudden shallowing, then a gradual subsidence of the area. At this stage the paleo-relief (submarine plains-depression) was nearly flat, on which the deposition of the basal shaly beds of the sequence (4 m, units 1 and 2), viz. the yellow-green mudshales and the grey-geen mudshales, took place in a shallow marine setting.

Only during the deposition of the upper shaly parts of the sequence, the shaly flysch (100 m, units 3 and 4), viz. the red calcareous mudshales and the intercalations of red calcareous mudshales and grey siltstones, were open marine conditions finally established, owing to increased subsidence during the Eocene.

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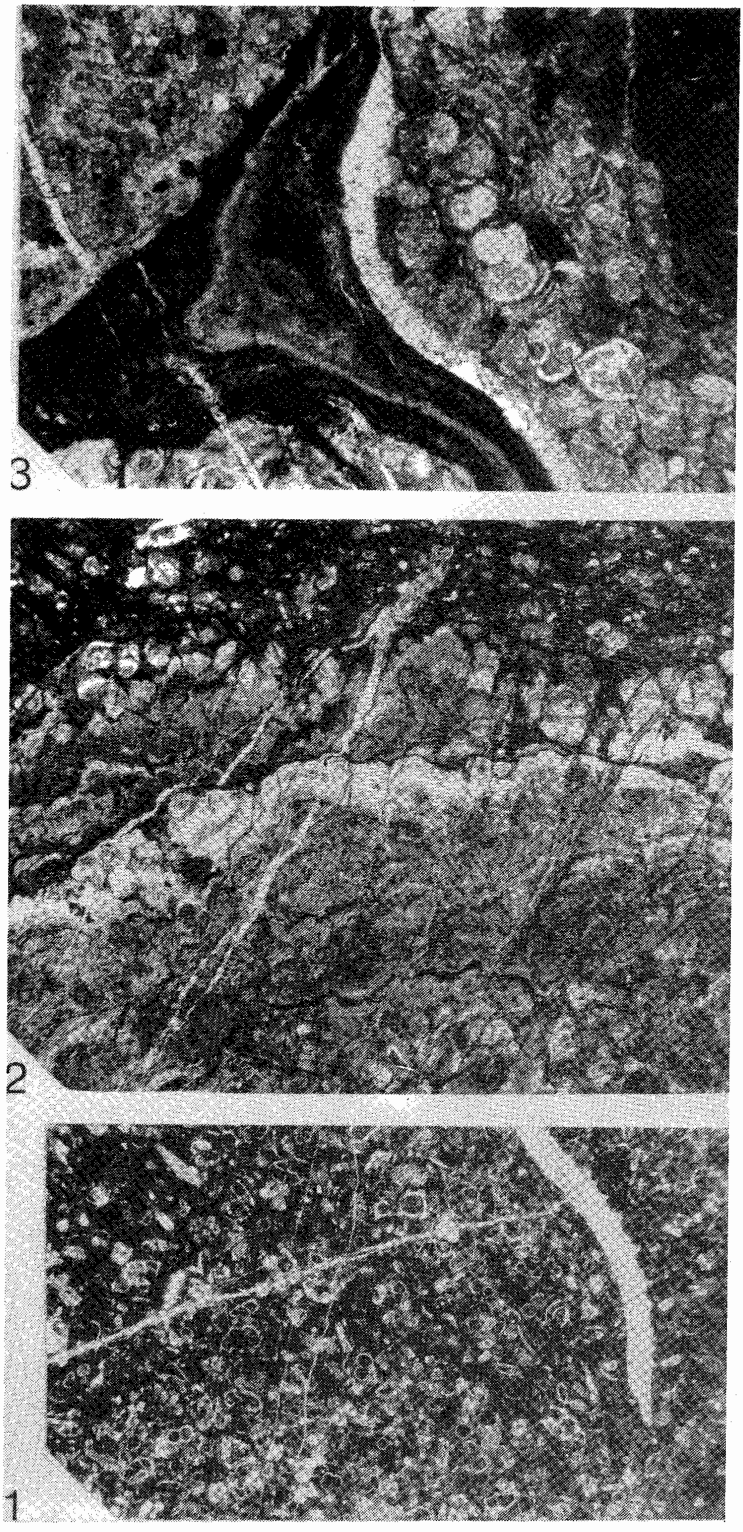


Plate I: (1) The pelagic limestone of Upper Maastrichtian age with Globotruncanidae. Other fossils present are brachiopods, echinoderms and ostracodes fragments. x 15. (2) The stromatolitic crust, the upper parts of LLH-type, penetrated by sinuous sheaths resembling rhizolites (calcified filaments). x 15. (3) A fibrous marine type of calcitic cement developing along an iron oxide crust, inside the reworked horizon overlying the stromatolites. x 30.

(1) Ο ανωκρητιδικός ασβεστόλιθος με Globotruncanidae. □λλα απολιθώματα παρόντα είναι θραύσματα από βραχιονόποδα, εχινόδερμα και οστρακώδη. x 15. (2) Τα ανώτερα τμήματα LLH τύπου της στρωματολιθικής κρούστας, όπου παρατηρούνται διατρήσεις ελικοειδών ινιδίων, τα οποία ομοιάζουν με ριζόλιθους (ασβεστοποιημένα ινώδη ριζίδια) x 15. (3) Ινώδες ασβεστιτικό τσιμέντο αναπτυσσόμενο κατά μήκος τμήματος κρούστας σιδηροξειδίων, εντός του ορίζοντα επανεπεξεργασίας, ο οποίος υπέρκειται των στρωματολίθων. x 30.

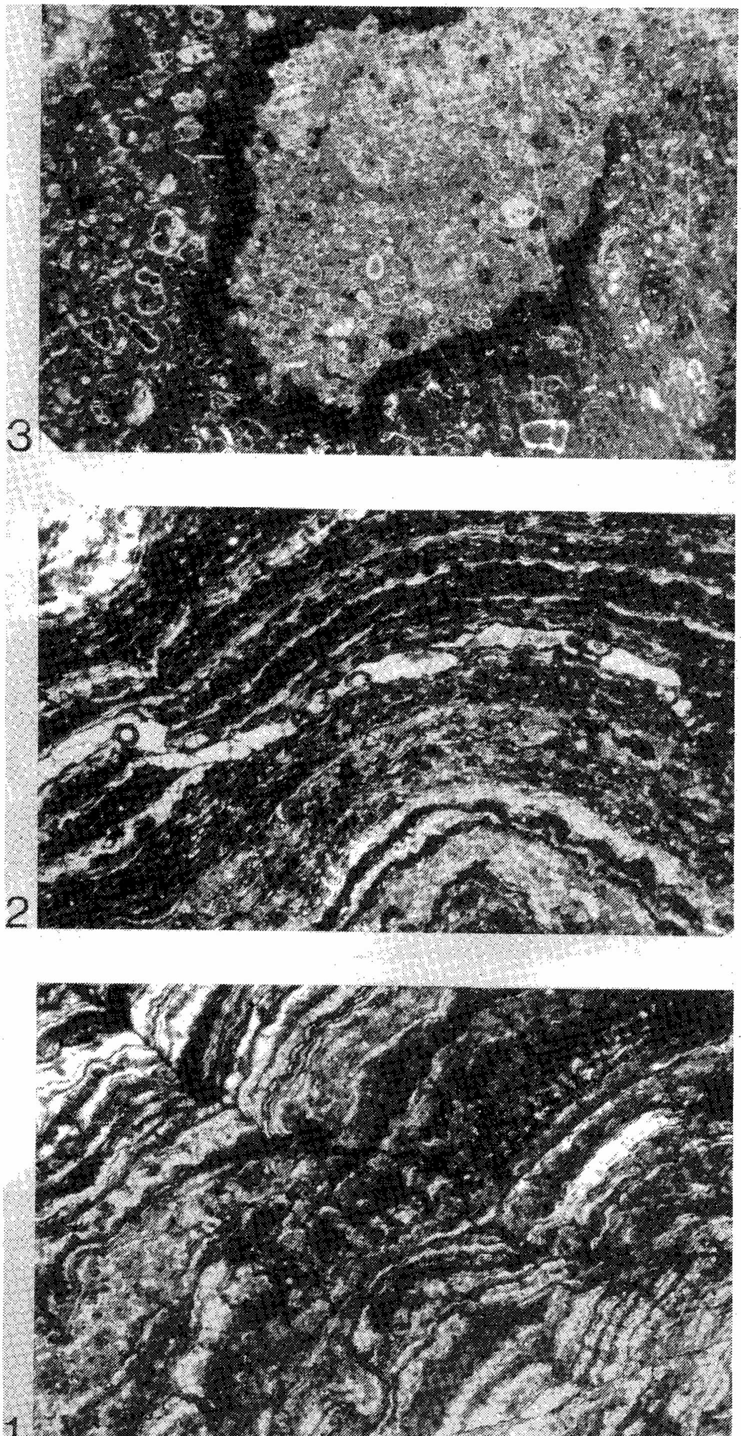
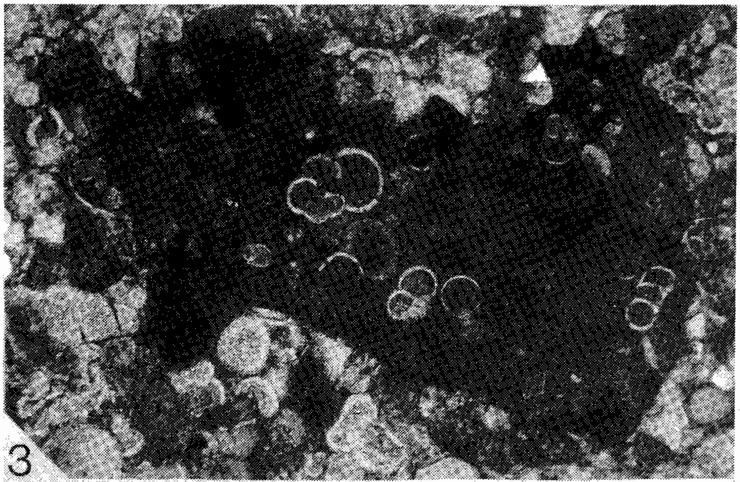


Plate II: (1-2) The Fe-P-organic rich laminae encrusting the complex nucleus of the nodules, appearing above the reworked mixing horizon of the hardground - stromatolitic unit. The presence of alternating layers of organic - rich material and sediment, in combination with their morphology show that these nodules are algal oncolites. x 15. (3) Preomission trace fossil (burrow) on Early - Middle Paleocene foraminiferal wackestone, with its wall hardened and mineralized. Post - omission or omission boring filled with Middle Paleocene micritic material. It appears inside the reworked mixing horizon overlying the stromatolites and may represent a second hardground. x 15.

(1-2) Οι ενδιαστρώσεις (πλούσιες σε Fe-P και οργανικό υλικό) που περιβάλλουν τον πολύμεικτο πυρήνα των κονδύλων, οι οποίοι εμφανίζονται εντός της ενότητας hardground στρωματολίθων υπεράνω του ορίζοντα ανάμειξης. Η παρουσία διαδοχικών στρωμάτων υλικού πλούσιου σε οργανική ύλη και ιζήματος, σε συνδυασμό με τη μορφολογία τους επιτρέπει την αναγνώρισή τους ως algal oncolites. x 15. (3) Preomission trace fossil (ιχνοαπολίθωμα διάτρησης) εντός του Κάτω - Μέσου Παλαιοκαινικού ασβεστολίθου. Post - omission or omission boring πληρωμένο με Μεσο - Παλαιοκαινικό μικριτικό υλικό. Εμφανίζονται εντός του ορίζοντα επανεπεξεργασίας που υπέρκειται των στρωματολίθων.



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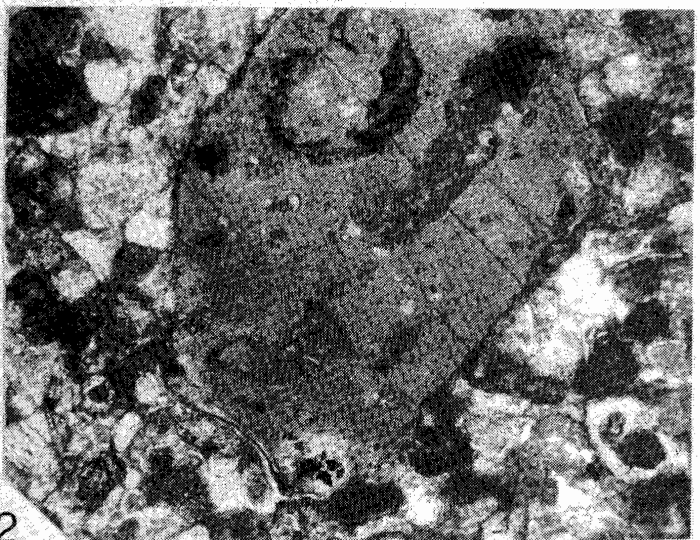

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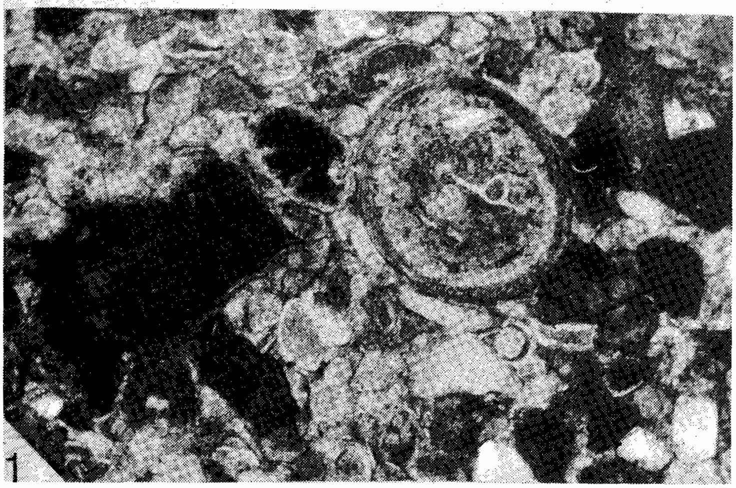

1

Plate III: (1) Detail of a probably faecal phosphatic pellet with an outer rim of pure apatite, the result of secondary phosphorus precipitation around a pre-existing phosphatic nuclei, inside the phosphatic calcarenite. x 30. (2) A phosphatized foraminiferal wackestone particle of Maastrichtian age, as a compound of the phosphatic calcarenite. x 30. (3) A phosphatized foraminiferal wackestone particle of Paleocene age inside the phosphatic calcarenite. x 30.

(1) Λεπτομέρεια ενός πιθανού faecal pellet, περιβαλλόμενο από ένα λεπτό στρώμα καθαρού απατίτη, αποτέλεσμα δευτερογενούς συγκέντρωσης φωσφόρου γύρο από ένα προϋπάρχον φωσφορικό πυρήνα, εντός του φωσφορικού ασβεστοαρενίτη. x 30. (2) □να τέμαχος φωσφοριτιωμένου Μαιστριχτιακού ασβεστολίθου, ως συστατικό του φωσφορικού ασβεστοαρενίτη. x 30. (3) □να τέμαχος φωσφοριτιωμένου Παλαιοκαινικού ασβεστολίθου εντός του φωσφορικού ασβεστοαρενίτη x30.

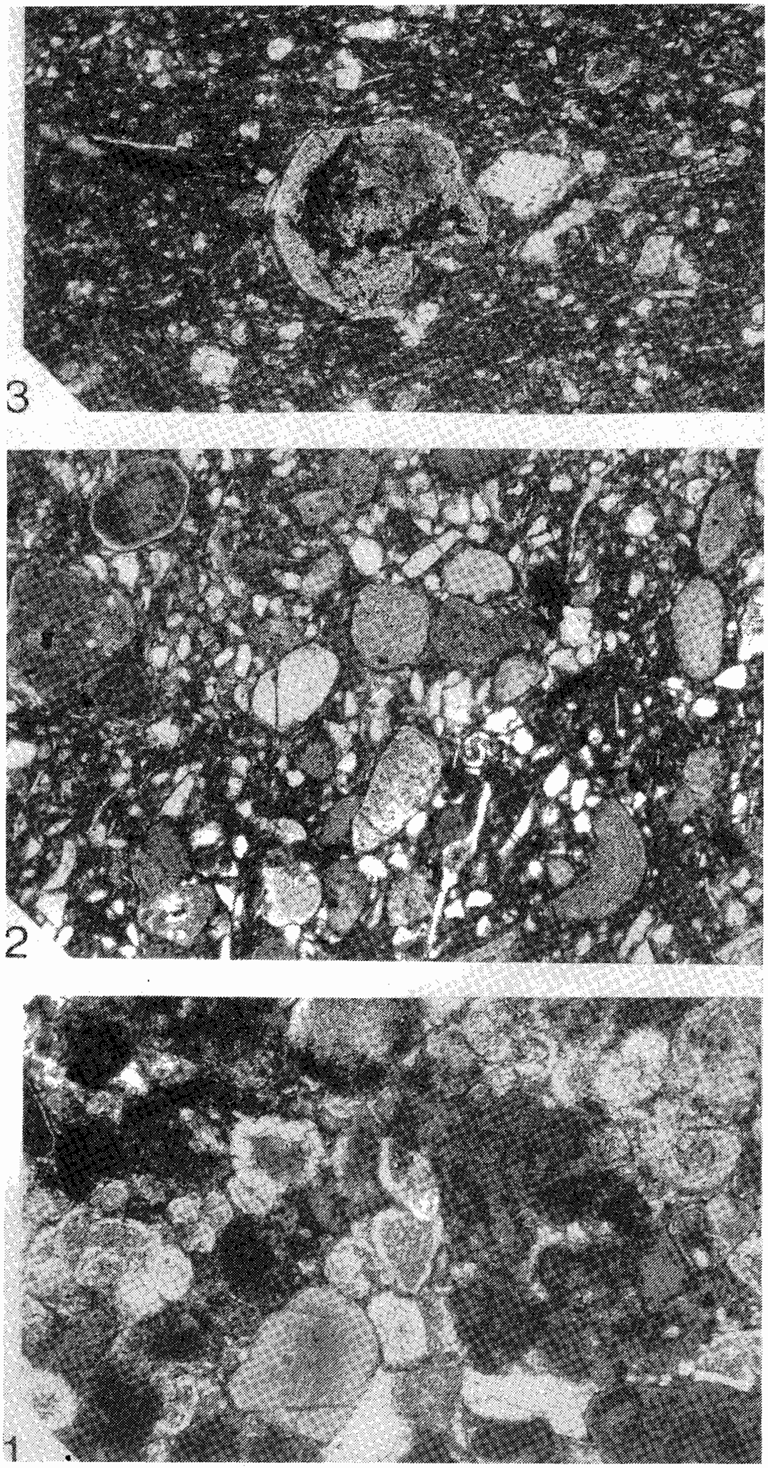

Plate IV: The phosphatic calcarenite with abundant planktonic foraminifera of Paleocene age in the bounding micritic matrix. x 120. (2) The phosphatic calcilutite characterized by the disappearance of the planktonic foraminifera and a dramatic increase in quartz, feldspar and glauconite content. x 120. (3) The red calcareous mudshales, at the upper part of the phosphatic calcarenite unit x 120.

(1) Ο φωσφορικός ασβεσταρενίτης με παρόντα Παλαιοκαινικά πλανγκτονικά τρηματοφόρα εντός μικριτικής συνδετικής ύλης. x 120. (2) Ο φωσφορικός ασβεστολουτίτης, χαρακτηριζόμενος από την εξαφάνιση των πλανγκτονικών τρηματοφόρων και την σημαντική αύξηση της παρουσίας γαλαξία, αστρίων και γλαυκονίτη. x 120. (3) Οι κόκκινες ανθρακικές αργιλο-μάργες, στα ανώτερα τμήματα της ενότητας του ασβεστοαρενίτη. x 120.

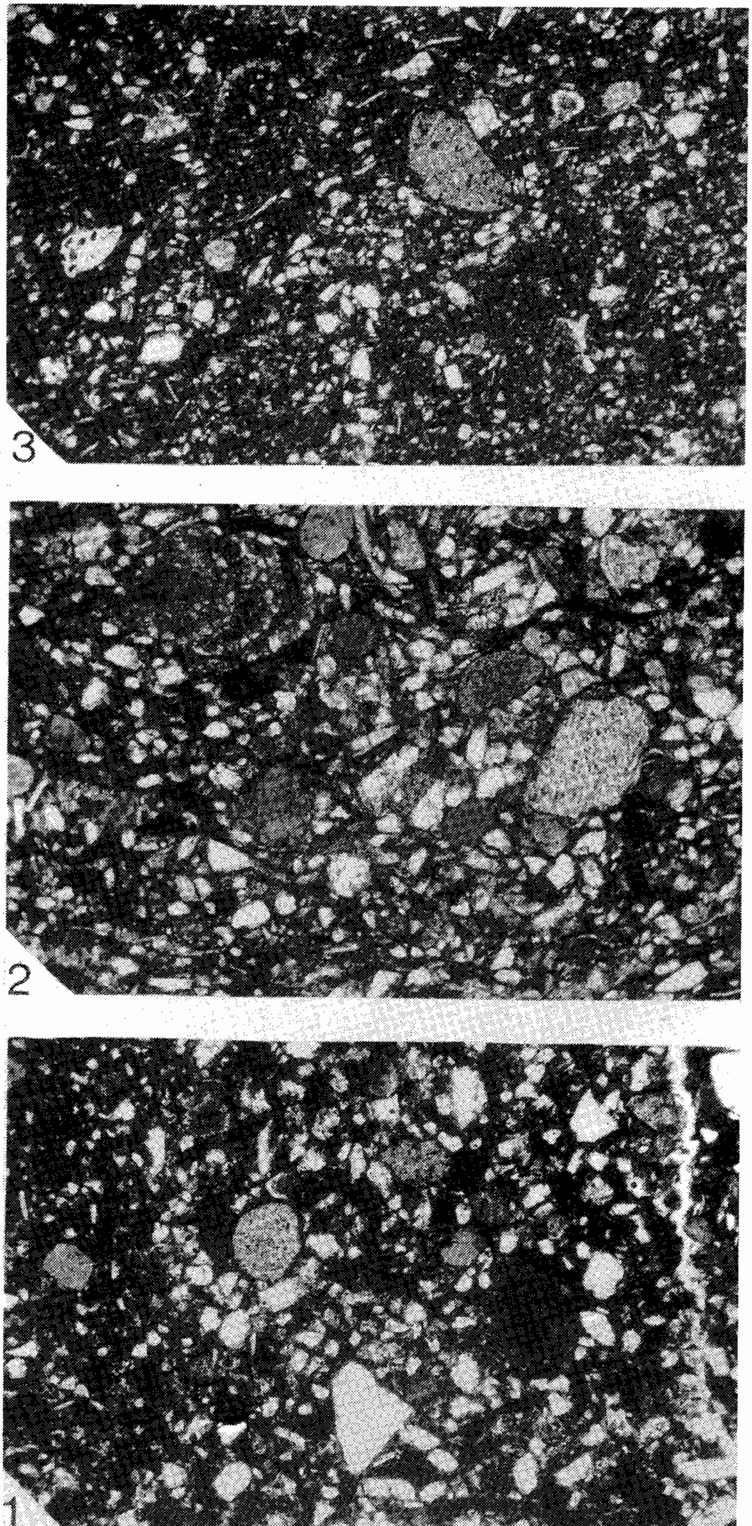

Plate V: (1) The thin orange-yellow mudstone layer underlying unit 1. X 30. (2) The lower parts of the grey-green calcareous mudshales of unit 1. X 30. (3) The upper parts of the grey-green calcareous mudshales of unit 1. X 30.

(1) Το λεπτό στρώμα πορτοκαλο-κίτρινου mudstone που υπέρκειται της ενότητας 1. x 30. (2) Τα κατώτερα τμήματα των γκριζο-πράσινων αργιλο-μαργών της ενότητας 1. x 30 (3) Τα ανώτερα τμήματα των γκριζο-πράσινων αργιλομαργών της ενότητας (1) x 30.