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TRIASSIC NANNOPLANKTON LIMESTONES OF DEEP BASIN ORIGIN IN THE CENTRAL MEDITERRANEAN REGION*

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ABSTRACT

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Samples of Triassic pelagic limestones collected in several regions of the Central Mediterranean area were examined with the electron microscope. They show calcareous nannoplankton existing already from Middle Triassic time. The Middle Triassic nannofossils are contained in nodular limestones such as the "Ammonitico Rosso" of Epidaurus (Greece); the Upper Triassic ones are contained in nodular limestones like the Ammonitico Rosso of Hallstatt (Austria), as well as in *Halobia* cherty limestones of the Pindos basin in Italy, Yugoslavia and Greece. In the *Halobia* limestones it is possible, in spite of the recrystallization effects, to recognize such an abundance of organic forms — even if in fragments — that we can suppose the original sediment to be a kind of nannoplankton ooze.

Because of the very low accumulation rate (few metres/m.y.) of the Middle Triassic Ammonitico Rosso limestones, the coccoliths cannot be considered a significant factor of carbonate pelagic sedimentation at this time; the very high accumulation rate (up to 25 metres/m.y.) of the Upper Triassic cherty limestones in the Pindos basin, on the contrary, allows the nannoplankton to be considered a very important agent of calcareous pelagic sedimentation. The authors hypothesize that the Dogger—Malm, mainly represented by radiolarites, was only a temporary interlude in the Mesozoic pelagic carbonate sedimentation.

GEOLOGICAL FRAMEWORK

During the Middle Triassic strong tectonism affected the Central Mediterranean area, producing widespread synsedimentary faulting associated with fissural mafic volcanic rocks (Scandone, 1975). This tectonic phase consisted of an abortive attempt at rifting, which was not able to open real oceanic areas, but did produce a thinning of the continental crust over large areas. As a consequence of these processes, strips of thinned continental crust, thou-

*The geological research was carried out by P. Scandone, the micropaleontological analysis by S. Di Nocera.

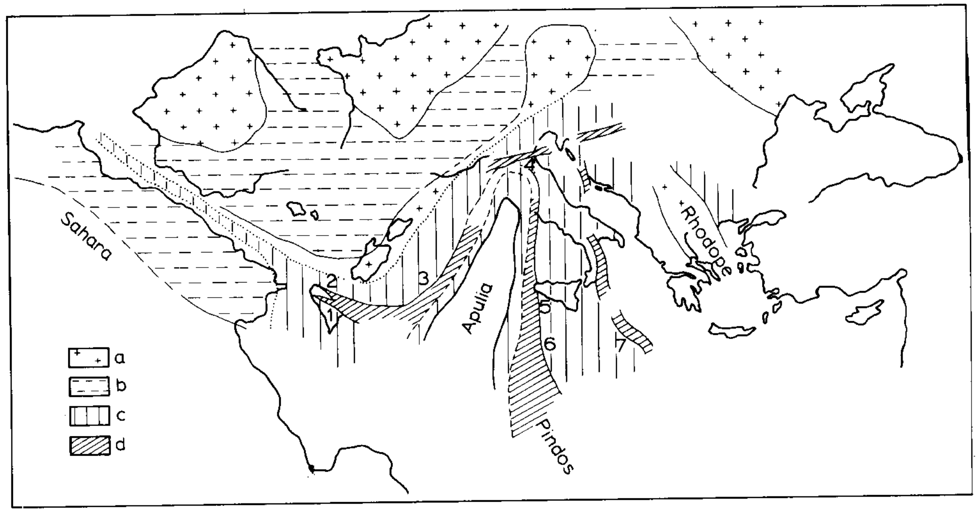


Fig.1. Palinspastic restoration of the Upper Triassic paleogeography in the Central Mediterranean area (after Scandone, 1975).
Legend: *a* stable areas with slight subsidence; *b* subsident basins with Germano-Andalusian facies; *c* shallow-water carbonates with Alpine facies; *d* "seaways".
Provenance of the analysed samples from the Middle and Upper Triassic pelagic limestones: *1* Sicani Mts., Sicily; *2* Imerese, Sicily; *3* Lagonegro, Southern Apennines; *4* Hallstatt, Austria; *5* Boka Kotorska, Montenegro; *6* Pindos, Greece; *7* Epidaurus, Greece.

sands of kilometres long and hundreds of kilometres wide, underwent rapid subsidence. The rate of sedimentation did not counterbalance the rate of subsidence, so that during the Late Triassic deep marine basins were developed throughout the Mediterranean region. The elongation of these basins, as well as their connections, is shown in Fig.1. The most remarkable element is the Pindos basin, which extended from Greece as far as western Sicily; the other elements are less evident, and as yet have been only partially reconstructed. All these seaways had close intercommunications, as witnessed by the homogeneity of the fauna, and connected somewhere eastwards with the oceanic Paleotethys.

MIDDLE AND UPPER TRIASSIC PELAGIC LIMESTONES

Fig.1 represents the paleogeography during the Late Triassic, when pelagic deposition was widespread over the whole Mediterranean area. In the Hellenides and Dinarides a deep-water pelagic environment had already been present locally since the Middle Triassic, and was represented by nodular limestones like "Ammonitico Rosso". The Ammonitico Rosso facies also existed locally during the Late Triassic, as for instance in the famous Hallstatt beds of Austria, but the most common type of Upper Triassic deposits consists of *Halobia* limestones. These form uniform sequences of cherty lime mudstones and subordinate pelagic turbidites, with rare intercalations of clays and marls. Also tuffites are sporadically present, mainly in the lower part of the formation. Radiolarians, spicules of sponges and pelagic pelecypods are the most common fossils.

The *Halobia* limestones range from 100 m to more than 500 m in thickness. Assuming that the Late Triassic lasted 20 m.y., 500 m of limestones (in which, moreover, the packing is very close and the pressure-dissolution processes are widely developed, as shown by the many stylolites) represent the product of an extremely high sedimentation rate. Also admitting that the deposits include both true pelagic sediments and a subordinate amount of intraformational turbidites, 25 m/m.y. is nevertheless an exceptionally high value. To find an explanation for this fact we studied the pelagic limestone composition and observed by the electron microscope the many samples of Middle and Upper Triassic limestones, collected in several regions of the Central Mediterranean area (southern Italy, Austria, Yugoslavia, Greece). The recrystallization processes are frequent and intense (Plate I), so that the primary texture and composition of the mud is modified, but in many cases well-preserved organic forms are recognizable*. Moreover, in several samples fragments of certain organic origin are so abundant that they form almost the totality of the micrite. We formulate the hypothesis that the original sediment consisted wholly of nannoplankton ooze.

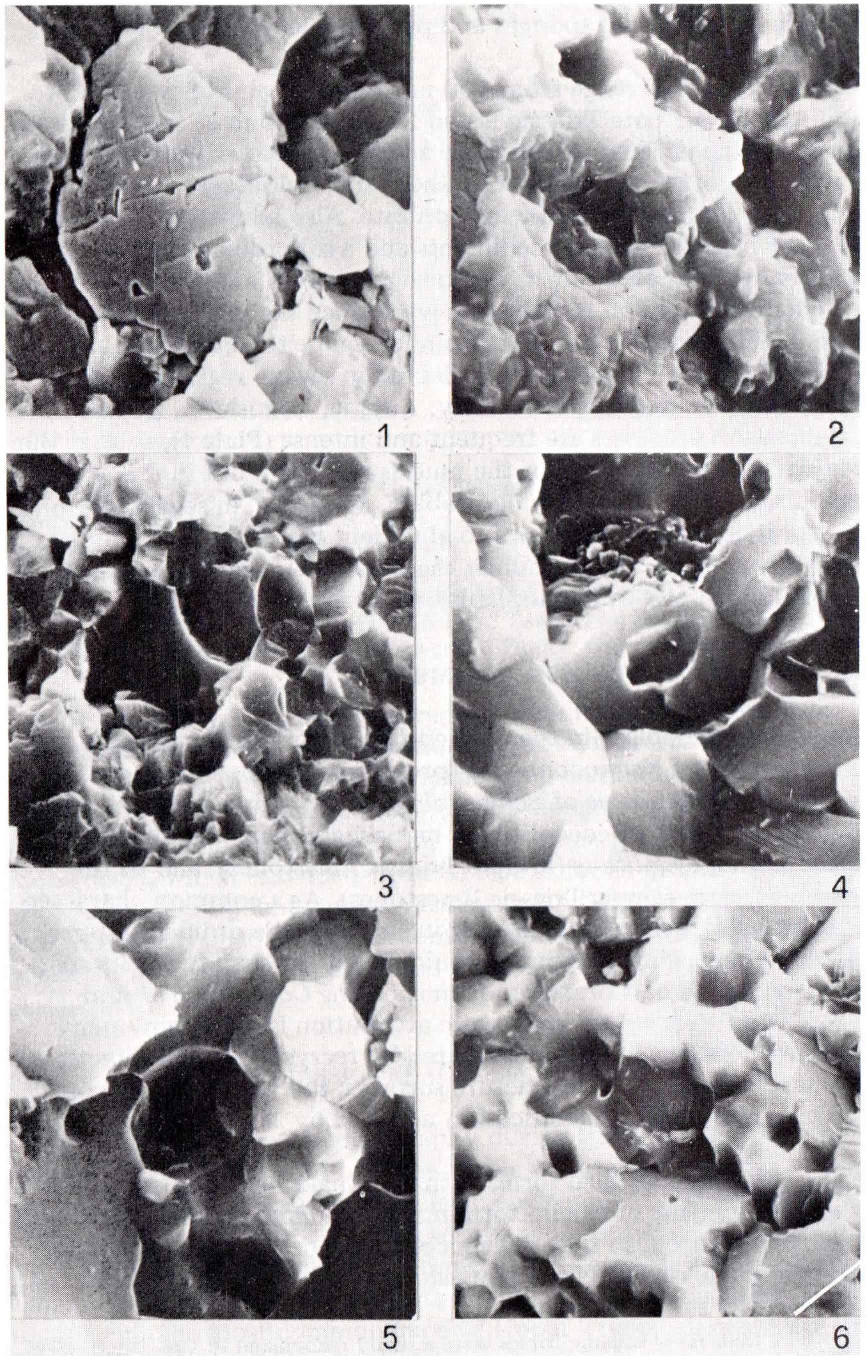
DESCRIPTION OF THE NANNOFOSSIL ASSEMBLAGE

The nannofossil assemblage in the studied pelagic limestones consists of numerous individuals of *Nannoconus* sp. (present in Middle and Upper Triassic limestones), rare individuals of *Schizosphaerella* sp. (Upper Triassic limestones), and of rare forms of coccoliths dubiously assignable to the family Zygolithaceae, genus *Zygolithus* (Middle Triassic limestones), and to the family Podorhabdaceae (Upper Triassic limestones). As a common characteristic, all the studied individuals are greater in size than the ordinary Upper Jurassic—Lower Cretaceous nannoplanktonic forms. We shall furnish here a short description of the best preserved forms, calling *Coccolith Tr1* and *Coccolith Tr2* two forms whose systematic attribution is uncertain, many taxonomic characters having been obliterated by recrystallization effects. All the samples have been studied on fracture surfaces; the description is conformable to the morphologic classification adopted by Noël (1965).

Coccolith Tr1 (Fig.2a). Elliptical form, with marginal ring delimiting a vast central area. The elements of calcite forming the marginal ring appear to be joined by recrystallization, so that the coccolith acquires a massive appearance. On the right side of Fig.2a elements steeply slanting with reference to

*We underline here that likely organic forms were already recognized in 1967 by Fischer et al. in Upper Triassic pelagic limestones of the Austrian Alps.

PLATE I



the radial plane, imbricated in an anticlockwise procession, are poorly exhibited. Moreover, remnants of a bar aligned with the minor axis of the ellipse seem to be recognizable in the central area.

Size of the coccolith: major axis 8.2 μm; minor axis 4.3 μm; width of the ring 2.5 μm.

The few preserved characters suggest the attribution of the described form to the genus *Zygolithus*. The genus *Zygolithus* is known from Late Jurassic up to Eocene. The form here dubiously assigned to this genus is contained in Middle Triassic nodular limestones from Greece (Epidaurus).

Coccolith Tr2 (Fig.2b). Elliptic form in distal view, probably consisting of two shields having a vast central area. The distal shield is formed by 32—36 elements having smooth external borders. The swelling in the central area should correspond to the base of the broken solid spine.

Size of the coccolith: major axis 11 μm; minor axis 7 μm; width of the ring 3.5 μm.

The poor conditions of preservation and the lack of the solid spine allow at the most a dubitable attribution to the family *Podorhabdaceae*. Forms of this family are known in Upper Jurassic sediments. The described form is contained in Upper Triassic cherty limestones from southern Italy.

Incertae Sedis

Family Schizosphaerellidae Deflandre 1959
Genus *Schizosphaerella* Deflandre and Dangeard 1938

Schizosphaerella sp. (Fig. 2c)

Cast of a spherical form. The picture has been obtained by direct reproduction of a diapositive. The external surface shows numerous calcite granules with pentagonal contour, having about the same dimensions (0.4 μm), which appear arranged along the parallels of a sphere.

PLATE I

Recrystallization effects on the Triassic pelagic limestones.

1, 2, 3. Fragments of organic forms which partially escaped recrystallization. Fig. 1 (x 4000) and 2 (x 2500) exhibit elements of calcite probably belonging to shield of coccoliths; in Fig. 3 (x 2000) probable spiral portions of *Nannoconus* are preserved. The surrounding micrite is fully recrystallized. Middle Triassic nodular limestones like Ammonitico Rosso; Epidaurus, Peloponnese (Greece).

4, 5. Organic forms whose original microstructure has been entirely obliterated by recrystallization. Fig. 4: elliptic coccolith (x 5000). Upper Triassic cherty lime mudstones; Madonna del Balzo, Sicani Mountains, Sicily (Italy). Fig. 5: circular coccolith (x 5000). Upper Triassic cherty lime mudstones; Lagonegro, Southern Apennines (Italy).

6. Common aspect of the micrite in the Upper Triassic cherty lime mudstones (x 1500). Lagonegro, Southern Apennines (Italy).

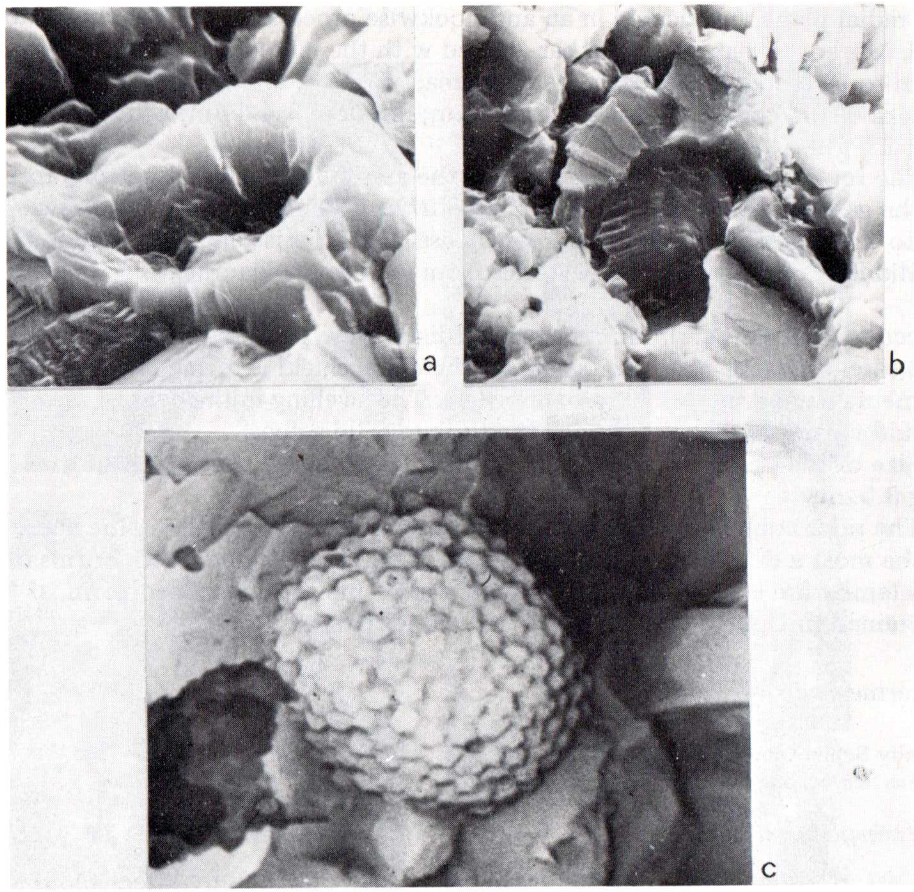


Fig. 2 a. Organic form dubiously attributed to the genus *Zygolithus* (x 3000). Anisian nodular limestones like Ammonitico Rosso; Epidaurus, Peloponnese (Greece). b. Organic form dubiously attributed to the family Podorhabdaceae (x 2000). Upper Triassic cherty lime mudstones; Madonna del Balzo, Sicani Mountains, Sicily (Italy). c. *Schizosphaerella* (x 6600). Upper Triassic cherty lime mudstones; Boka Kotorska, Montenegro (Yugoslavia).

Diameter: 7 μm.

The genus *Schizosphaerella* is frequent in the Jurassic, and has been sporadically mentioned in Upper Triassic sediments. The described form is contained in Upper Triassic pelagic limestones from southern Yugoslavia.

Family Nannoconidae Deflandre 1959
Genus *Nannoconus* Kamptner 1931

Nannoconus sp. (Fig.3a, b, c, d).

Four individuals are described, three in transverse section and one in oblique section. The transverse sections have a circular contour and a well

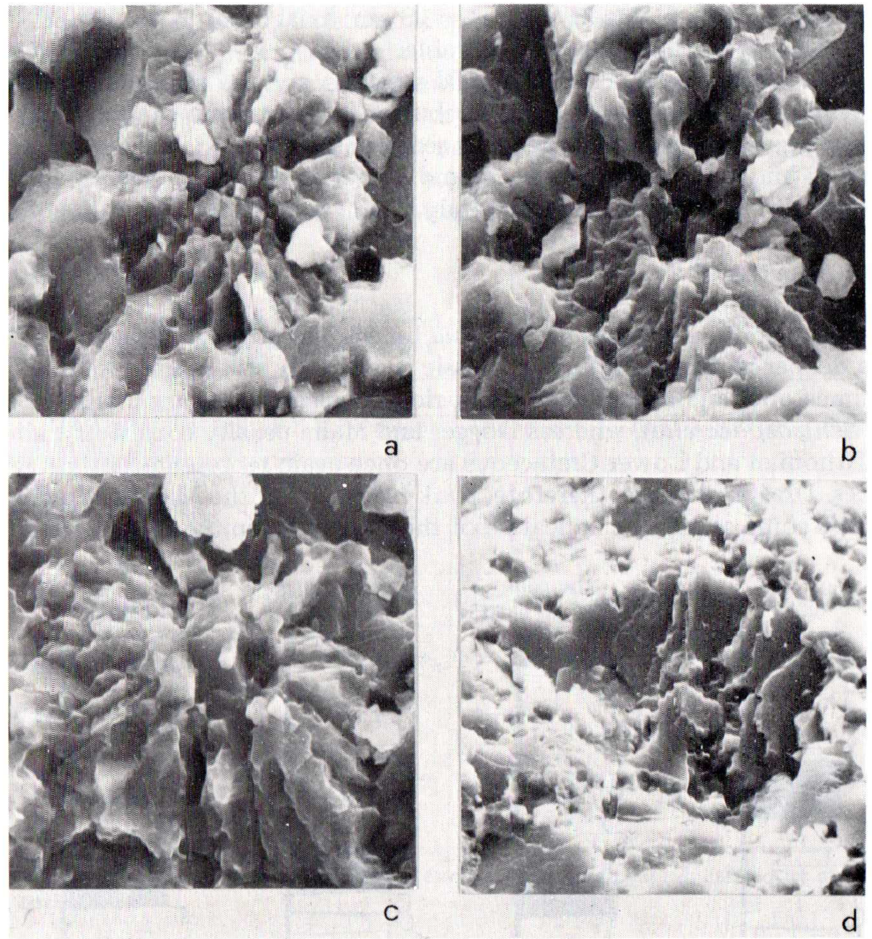


Fig. 3 a—c. Transverse sections of *Nannoconus* sp. (respectively x 2000, x 2500, x 2500). a, b. Upper Triassic cherty lime mudstones; Madonna del Balzo, Sicani Mountains, Sicily (Italy). c. Middle Triassic nodular limestones like Ammonitico Rosso; Epidaurus, Peloponnese (Greece). d. Oblique section of *Nannoconus* sp. (x 1000). Middle Triassic nodular limestones like Ammonitico Rosso; Epidaurus, Peloponnese (Greece).

evident axial canal irregularly filled with calcite granules. The central area consists of radially arranged elements, of variable shape and size. We think that the radial structure could result from recrystallization phenomena which obliterated the original spiral arrangement around the axial canal. Such phenomena are not rare in forms of *Nannoconus* contained in Upper Jurassic—Lower Cretaceous pelagic limestones (see, i.e. Di Nocera, 1973, Fig.12a). Fig. 3d shows an oblique section of *Nannoconus* sp. The spiral arrangement and the axial canal are rather well preserved.

Dimensions: Fig.3a, diameter 18 μm; axial canal 4 μm. Fig.3b, diameter

21 μm; axial canal 7 μm. Fig.3c, diameter 18 μm; axial canal 3 μm. Fig.3d, diameter ab.16 μ; axial canal not measurable.

The lack of free individuals and of axial sections, and the poor conditions of preservation do not allow specific attributions. The genus *Nannoconus* is known in Upper Jurassic and Cretaceous sediments. The described forms are contained in Middle Triassic (Fig.3c, d) and Upper Triassic (Fig.3a, b) pelagic limestones from Greece and Southern Italy.

SOME SPECULATIONS

In all the examined sections the *Halobia* limestones grade gradually upwards to deeper-water deposits. The Liassic is generally still represented by pelagic limestones and subordinate clays, rich in calcareous nannoplankton (mainly *Schizosphaerella*), whereas Dogger and Malm usually consist of radiolarites. Tithonian and Lower Cretaceous are once again represented by pelagic limestones. Drastic changes, therefore, took place during the Middle Jurassic. Fig.4 shows some sequences indicative of the deposition in the Pindos basin

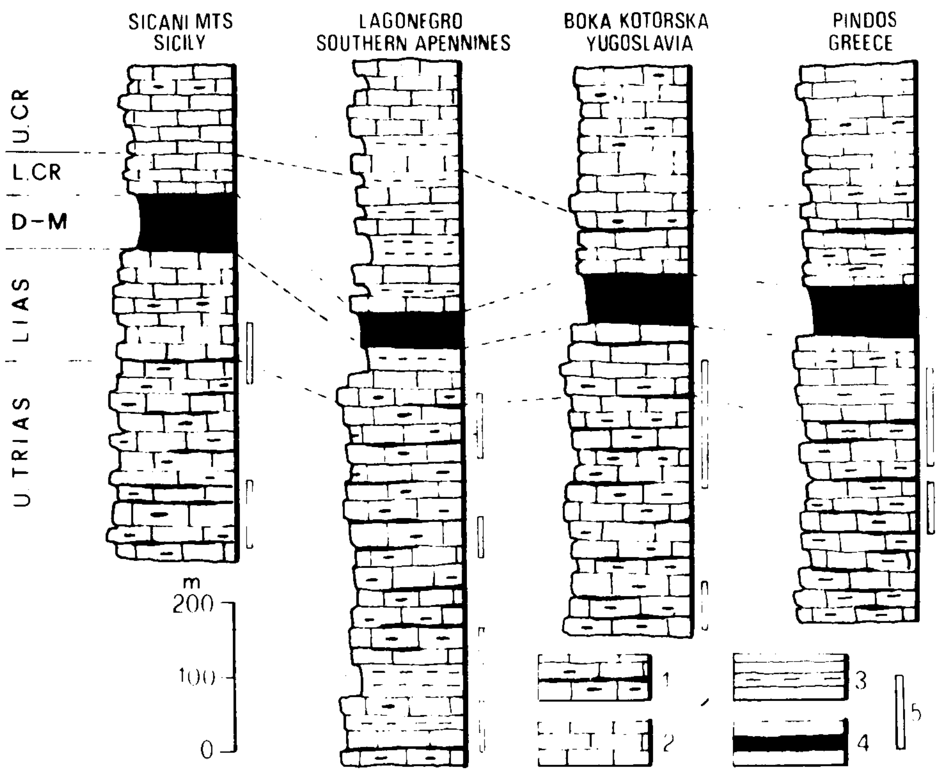


Fig.4. Columnar sections representative of some significant Pindic sequences. *1* = cherty lime mudstones; *2* = lime mudstones and allodapic limestones; *3* = claystones; *4* = radiolarites; *5* = position of the samples examined with the electron microscope.

from Late Triassic to Late Cretaceous. The studied sections point out that the rates of sediment accumulation decrease from values of 5 to 25 m/m.y. during the Late Triassic (*Halobia* limestones) to as little as 1—2 m/m.y. during the Dogger—Malm (radiolarites). During the Tithonian—Neocomian a calcareous pelagic sedimentation began again, but the accumulation rate values are still very low (1—2 m/m.y.). During Late Cretaceous, finally, the accumulation rate values slowly increased up to 6—7 m/m.y. (Table I).

TABLE I

Accumulation rates measured in several sequences of the Pindos basin, relative to Upper Triassic, Liassic, Dogger—Malm, Lower Cretaceous and Upper Cretaceous intervals

Ages	Boundaries (m.y.B.P.)	Accumulation rates (m/m.y.) Sicani	Lagonegro	Boka Kotorska	Pindos
	65				
Upper Cretaceous		2—3	5—7	1—5.7	5.5—6.3
	100				
Lower Cretaceous		1.5—2	5*—7*	1—2	1.7—2
	140				
Dogger—Malm		1.5—4*	1—4*	1.7—10*	2—8*
	175				
Liassic		5—6	2—3	2—10*	2—6
	195				
Upper Triassic		10—12	10—25	5—25	5—10
	215				

The numbers with asterisks represent exceptionally high values, caused by abundance of turbidites.

Now, if we examine other Mesozoic basins of the Central Mediterranean area (see Bernoulli and Jenkins, 1974), we see that the Lias—Dogger boundary generally coincides with a change in sediment composition, and with a sudden decrease in accumulation rate. The accumulation of pelagic sediments is controlled, of course, by the lysocline level (Berger, 1970) and by the calcium carbonate compensation depth. Garrison and Fischer (1969) widely discuss the CCD problem in the past, and propose two different models: the first model is based on actualistic criteria, the second on the assumption that in a given basin the subsidence rate is constant. The actualistic model places the calcite compensation depth at 4500—5500 m. We consider these values excessive for basins founded on continental crust, even though it is thinned crust, as in the case of the basins studied. Values around 3000 m seem to be more acceptable. In any case, it is really hard to imagine that at the Lias—Dogger boundary, the depth of the sea floor in all the basins simultaneously exceeded the calcium carbonate compensation depth. It is more logical to suppose that the CCD shifted drastically upwards, causing the simultaneous change in the pelagic sedimentation and the sudden decrease of the accumulation rate in all the basins. Why the lysocline and the CCD migrated upwards, and why the nannoplankton productivity fell is unknown. A remarkable fact is that in the whole Mediterranean region this revolution coincided with the opening of the Southern Atlantic (Pitman and Talwani, 1972) and of the Central Tethys (Dewey et al., 1973; Scandone, 1975). We consider that this coincidence did not take place by chance. The opening of a real ocean — the Central Tethys — between Africa and Europe during the Liassic may be regarded as the primary cause of the rapid and drastic change in the distinctive oceanographic characteristics within all the basins founded on the adjacent continental margins.

CONCLUSIONS

Existence of calcareous nannoplankton in the Mesozoic seaways of the Central Mediterranean region is recognized already from the Middle Triassic. At this time, however, the accumulation rate was very low (few metres/m.y.), and coccoliths cannot be considered an important factor of carbonate sedimentation. In the Late Triassic they became a very important agent of pelagic sedimentation, the accumulation rate of the deposits increasing from a few metres up to 25 m/m.y. During the Middle Jurassic, coinciding with the spreading of the Central Tethys, the role of the calcareous nannoplankton became negligible, and we can see a temporary interlude in the carbonate sedimentation. Radiolarites were deposited, and the accumulation rate fell to 1—2 m/m.y. From the Late Tithonian a renewal in the calcareous nannoplankton proliferation and a shifting downwards of the lysocline and of the CCD level restored a calcareous pelagic sedimentation. The accumulation rate during the Early Cretaceous was very low, similar to that of the Middle Jurassic. During the Late Cretaceous it increased up to 6—7 m/m.y., never reaching, in any case, values as high as those of the late Triassic.

ACKNOWLEDGEMENTS

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