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PALAEOGEOGRAPHIC IMPLICATIONS OF THE AGE OF RADIOLARIAN-RICH SEDIMENTS IN BEOTIA (GREECE)

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ABSTRACT

Radiolarian biostratigraphic investigations of the uppermost *in situ* sediments of the Pelagonian zone in Beotia establish that parts of the Pelagonian carbonate platform had already subsided to bathyal depths by late Mid Jurassic (Bathonian) time, allowing radiolarian sediments to accumulate. The possible cause of this facies change was Mid Jurassic block-faulting, resulting in disintegration of the Pelagonian zone to create fault-controlled basins, submerged highs ("seamounts") and shallow-water carbonate shelf areas. This palaeo-bathymetry persisted until uppermost Jurassic, followed by arrival of ophiolite-derived clastic sediment, then ophiolite thrust sheet. The driving mechanism of the block-faulting was probably crustal loading related to initial ophiolite obduction.

KEY WORDS: Hellenides; Pelagonian zone; Beotia; Greece; radiolarites; radiolaria; Jurassic.

1. INTRODUCTION

Beotia is one of the key areas in Greece for an understanding of the Mid Jurassic to Early Cretaceous tectonic evolution of the Hellenides (Fig. 1a). In Beotia, extensive Triassic-Jurassic shallow-water carbonates pass stratigraphically upwards into deep-water facies, with radiolarian cherts and mudstones. These deep-water sediments are commonly overlain by terrigenous and debris flow sediments of Berriasian age, dated by Calpionellids (Celet & Clément, 1971). Because of the presence of these Early Cretaceous clastic sediments ("flysch"), Beotia was previously considered as a separate palaeogeographic unit: the "Beotian zone" (Celet *et al.*, 1976), distinct from both the contiguous Pelagonian zone to the east, and the structurally underlying Parnassus-Giona zone to the west. However, more recently it was argued that the Triassic-Jurassic carbonate successions of the Beotian zone are in reality simply a westward extension of the Pelagonian platform (Robertson *et al.*, 1991; Thiébault *et al.*, 1994).

Until a few years ago, radiolarian-rich sediments (cherts and mudstones) stratigraphically overlying Jurassic shallow-water carbonates in central eastern Greece were all regarded as being Late Jurassic in age (Celet & Ferrière, 1978; Ferrière *et al.*, 1988). However, it was recently discovered that radiolarian cherts which accumulated in association with continental margin-type units in the Othris area (central Greece) are of late Mid Jurassic age (Danelian, 1994, 1995). The same time interval was also recently identified for radiolarites which overlie platform carbonates of the Pelagonian zone in the Kallidromon Mountains, central Greece (Danelian & Robertson, 1995).

Our aim here is to establish a precise age of the sediments overlying the carbonate platform in the Beotian area, based on the study of two successions: one to the south of the coastal village of Aliki and the other to the north of Makariotissa monastery (Fig. 1b). In this paper we present some details of radiolarian assemblages extracted from cherts and mudstones overlying shallow-water carbonate successions in these

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areas. We also discuss implications of the new radiolarian data for the Mid-Late Jurassic palaeogeography and tectonic setting of the Pelagonian zone (including Beotia) in central eastern Greece.

2. RADIOLARIAN RESULTS

a. Aliki chapel

South of Aliki (Fig. 1b) a thick succession of shallow-water carbonates is overlain by a few metres of thin-bedded (15-20 cm-thick), deeper-water limestones, mainly calciturbidites. The latter pass into red-brown radiolarian cherts and mudstones, of which only the first 8-10 m are exposed locally (Fig.2).

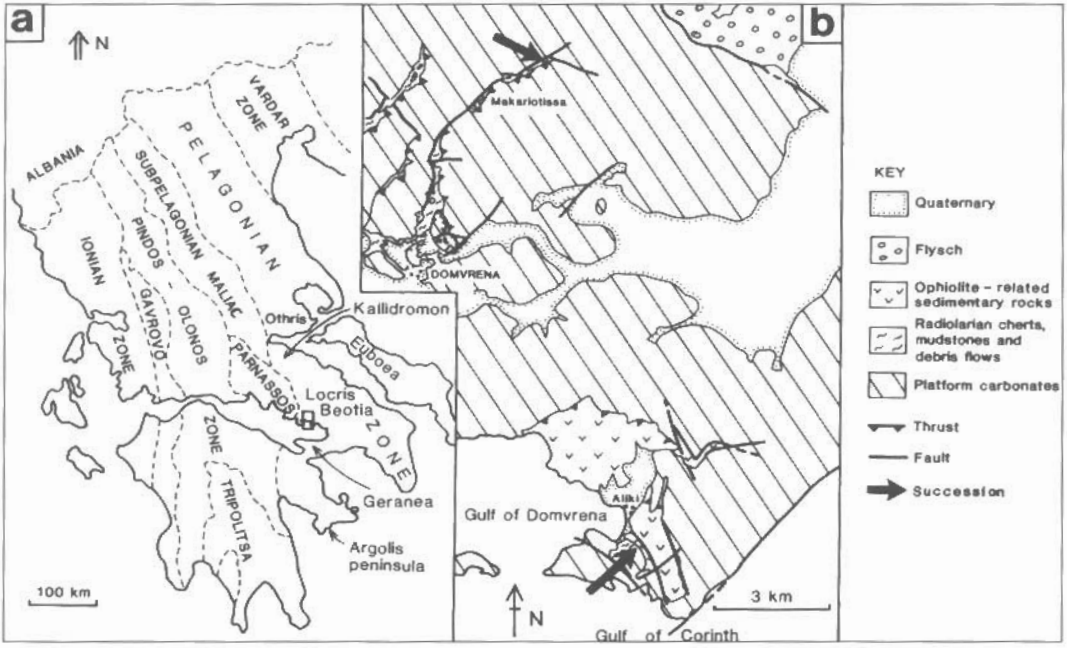

Figure 1: a: Outline of the main Mesozoic palaeogeographic zones in continental Greece. Square indicates the study area in Beotia. **b:** Geology of the area studied; after the Geological Map of Greece (1:50.00): Kaparelli and Vayia sheets.

Well-preserved radiolaria were extracted from a ribbon chert sample which was treated with dilute hydrofluoric acid (4% HF). The fauna are quite diverse, dominated by small Nassellaria. The following taxa are identified:

Archaeodictyomira primigena Pessagno & Whalen 1982
Archaeodictyomitra sp.cf. *A.exigua* Blome 1984;
Archaeodictyomitra sp.cf. *A.spelae* Chiari *et al.* 1997;
Archaeodictyomitra(?) sp.A *sensu* Baumgartner *et al.* 1995a, (Fig.3.e);
Eucyrtidiellum unumaense unumaense (Yao 1979), (Fig. 3.a);
Saitoum sp.cf. *S.trichylum* De Wever 1981;
Sethocapsa ulivii Chiari *et al.* 1997
Stylocapsa catenarum Matsuoka 1982, (Fig. 3.b);
Stylocapsa oblongula Kocher *in* Baumgartner *et al.* 1980, (Fig. 3.g);
Theocapsomma cordis Kocher 1981, (Fig. 3.c-d);
Tritrabs ewingi (Pessagno 1971) *s.l.* ?;
Transhsuum sp.cf. *T.maxwelli* Pessagno 1977;
Unuma sp.A *sensu* [illegible] (Fig. 3.f).

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The assemblage is characteristic of Unitary Association Zone (UAZ) 6 in the recent biozonation of Baumgartner *et al.* (1995b), and is assigned to a mid Bathonian age. The new results constitute the first direct evidence of the age of these radiolarian sediments.

b. North of Makariotissa

The mountains north of Domvrena (Fig. 1b) are mainly composed of thick Late Triassic-Jurassic shallow-water carbonates. Mid-late Oxfordian Ammonites were identified in pink nodular limestones at the top of an underlying carbonate succession (G.Dubar *in* Clément, 1970). These sediments are overlain by marly limestones with Madreporaria of latest Oxfordian-early Kimmeridgian age (L.Beauvais *in* Clément, 1970). Bedded radiolarian cherts and mudstones occur above these limestones, and then pass stratigraphically upwards into clastic sediments, considered as part of the "Beotian flysch" (Celet & Clément, 1971; Thiébault & Clément, 1992).

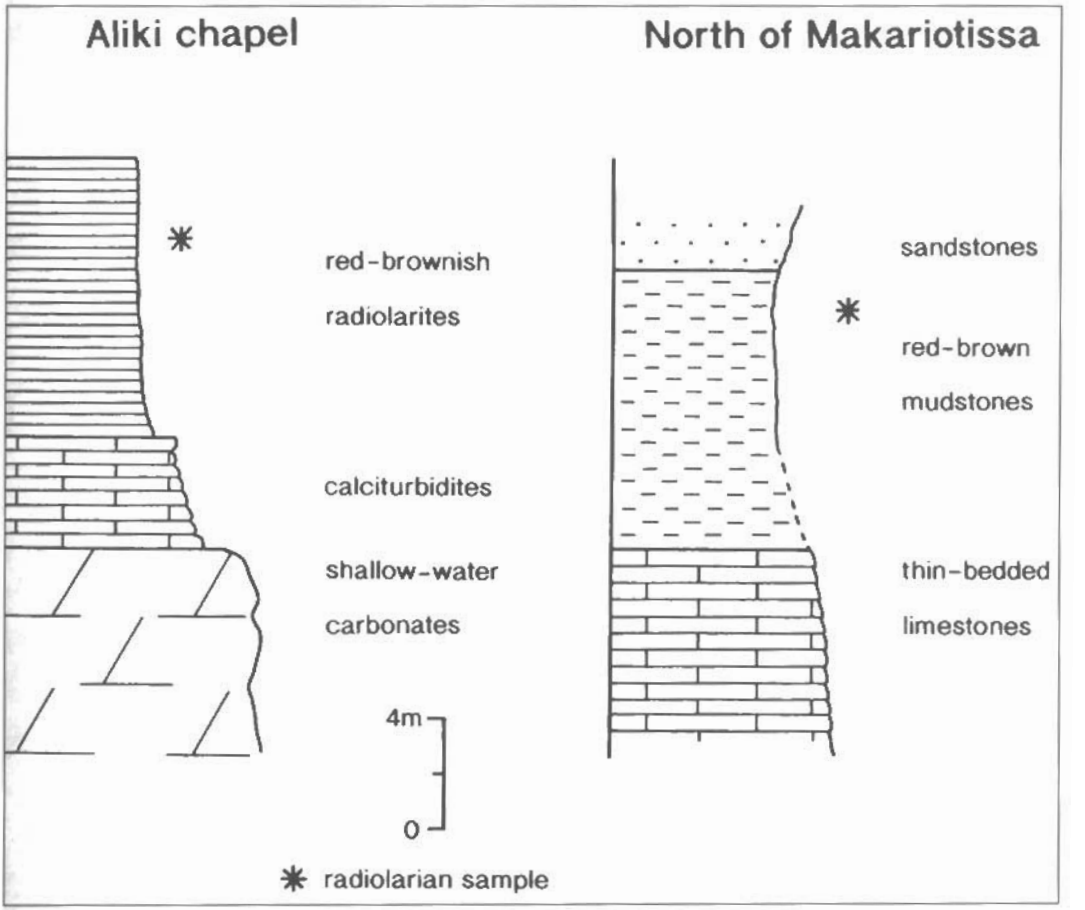

Figure 2: Lithostratigraphic logs of the two successions studied.

Simon (1987) coined the term "Makariotissa Member" for pelagic limestones, radiolarites and ophiolitic remains that occur in this area. He also extracted a well-preserved radiolarian fauna, which he considered indicative of a Tithonian age. After re-assessement of his illustrated morphotypes, we believe that this assemblage is of mid- late Oxfordian age (UAZ 9 of Baumgartner *et al.*, 1995b), based on the presence of *Archaeoditryomitra minoensis* (Mizutani, 1981) and *Orbiculiforma* (?) *heliotropica* Baumgartner *in* Baumgartner *et al.*, 1995a (our identification of Simon's (1987) plate 3, figure 2).

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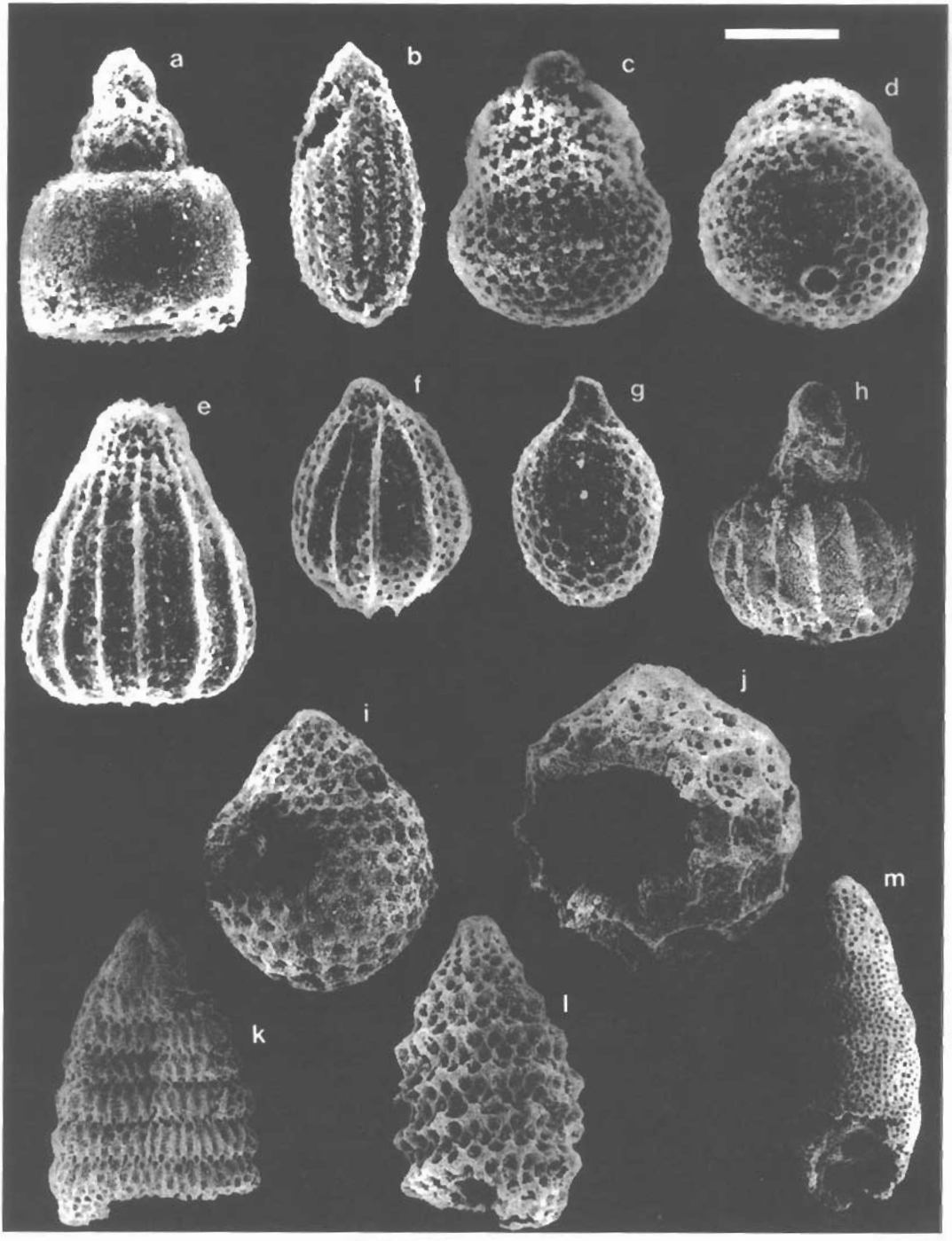

Figure 3: Scanning electron micrographs of Radiolaria from Alikı (a-g) and Makariotissa (h-m). Numbers in μm refer to the same scale bar (upper right). a) *Eucyrtidiellum unamaense unumaense*, 39 μm; b) *Stylocapsa catenarum*, 52 μm; c) *Theocapsomma cordis*, 41 μm; d) same specimen as fig. c, basal view, 40 μm; e) *Archaeodictyomitra* (?) sp. A, 50 μm; f) *Unuma* sp. A, 55 μm; g) *Stylocapsa oblongula*, 53 μm; h) *Eucyrtidiellum ptyctum*, 45 μm; i) *Zhamoidellum ovum*, 51 μm; j) *Willriedellum crystallinum*, 48 μm; k) *Pseudodictyomitra primitiva*, 64 μm; l) *Parvicingula dhimenaensis dhimenaensis*, 54 μm; m) [illegible]

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We have studied outcrops north of Makariotissa monastery (Fig. 1b), southwestern of the road. There, thin-bedded limestones, approximately 10 m thick, dip at 50° towards the SW and are in tectonic contact with shallow-water carbonates. Along the road, thin-bedded limestones pass into red-brown mudstones (the contact between the two lithologies is covered by scree/soil), which in turn pass stratigraphically upwards into sandstones and debris flows (Fig. 2). One sample of radiolarian mudstone, situated approximately 2 m below the clastic sediments, yielded a well-preserved fauna of radiolaria after treatment with hydrofluoric acid. The following taxa are identified:

Archaeodictyomitra minoensis (Mizutani 1981);

Archaeodictyomitra apiarium (Rüst 1885);

Cinguloturris sp.;

Eucyrtidiellum ptyctum (Riedel & Sanfilippo 1974), (Fig. 3.h);

Loopus sp.;

Parvicingula dhimenaensis dhimenaensis Baumgartner 1984, (Fig. 3.l);

Pseudodictyomitra primitiva Matsuoka & Yao 1985, (Fig. 3.k);

Solenotryma ichikawai Matsuoka & Yao 1985, (Fig. 3.m);

Tritrabs ewingi worzeli (Pessagno 1971) ?;

Williriedellum crystallinum Dumitrica 1970, (Fig. 3.j);

Zhamoidellum ovum Dumitrica 1970, (Fig. 3.I);

The assemblage is assigned to Unitary Association Zones (UAZ) 9-11, as characterised by the presence of *Williriedellum crystallinum*, *Parvicingula dhimenaensis dhimenaensis* and especially *Zhamoidellum ovum*, a species which is abundant in our sample. The UAZ 9-11 are correlated with the mid Oxfordian to early Tithonian interval (Baumgartner *et al.*, 1995b).

3. DISCUSSION

The Pelagonian zone (including Beotia) is interpreted as a shallow-water carbonate platform (hundreds of metres thick) of Late Triassic to uppermost Jurassic age (Celet & Ferriére, 1978). The platform was considered as an important barrier to regional sediment transport in pre-Tithonian time (Thiébault *et al.*, 1994). Radiolarian cherts and mudstones which occur at a large number of localities in central eastern Greece above Jurassic platform carbonates were previously considered to be all of late Kimmeridgian-early Tithonian age.

Taking into account our data from a number of localities and a re-evaluation of the age significance of radiolarian determinations by others, the following points can be made concerning the regional palaeogeographic setting (Fig. 4):

i) The new radiolarian results are in good agreement with previous Late Jurassic ages for radiolarian cherts and mudstones overlying the platform carbonates in the area around Makariotissa monastery (Clément, 1970). Moreover, the radiolarian assemblage documented by Simon (1987) suggests that the age of the pelagic carbonates and radiolarian mudstones overlying the carbonate platform might be restricted to the Oxfordian. The facies of the pink limestones ("marbre de Domvrena" of Clément, 1970) and the preservation of Ammonites within them reflect an open-marine environment of accumulation above the aragonite compensation depth (ACD). This area can be regarded as a relative high, or "seamount", possibly several hundred metres deep.

ii) South of the village of Aliki the shallow-water platform carbonates are overlain by Bathonian radiolarites. The age of these deep-sea sediments is comparable to radiolarites in the Kallidromon Mountains, also above neritic carbonates (Danelian & Robertson, 1995). The stratigraphy in these two areas (ca. 60 km apart) reflects a deepening of the platform to bathyal depths. The presence of similar successions in the Geranea (Clément, 1972) and Iti areas (Celet, 1976; his section B) suggests that radiolarites there may also be of late Mid Jurassic age, although this still needs to be confirmed.

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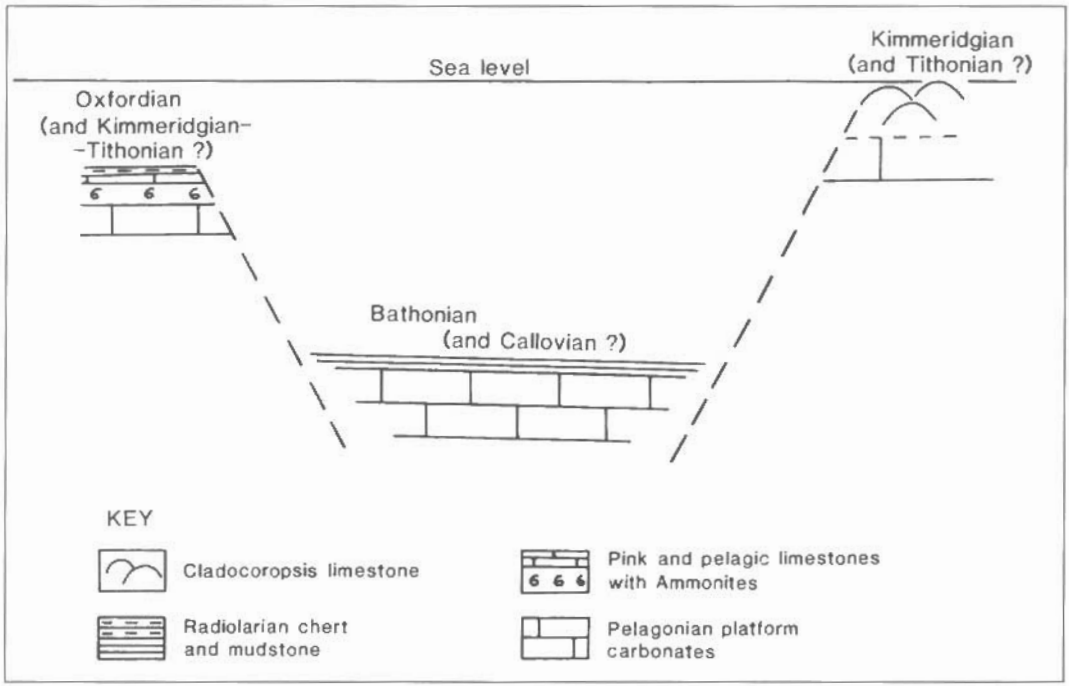

Figure 4: Palaeogeographic reconstruction of Mid/Late Jurassic depositional environments in the Pelagonian zone of central eastern Greece.

iii) Limestones with *Cladocoropsis* are reported from a number of localities in central Greece: in Euboea (Aubouin & Guernet, 1963; Baumgartner & Bernoulli, 1976); in Locris (Bassoullet & Guernet, 1970) and in Iti (Celet, 1976, his section C). *Cladocoropsis* is a Late Jurassic Ischyrosponge (Stromatoporoidea), generally found within south-Tethyan back-reef facies of late Oxfordian-Kimmeridgian age (Termier *et al.*, 1977). In addition, in one of the stratigraphically best documented areas of the Pelagonian zone, in Locris, *Cladocoropsis* appears to be present in sediments of Tithonian age ("Prophitis Elias" succession, Bassoullet & Guernet, 1970). Also, in the western margin of the High Karst carbonate platform of Montenegro (Yugoslavia), "*Cladocoropsis*" limestones developed as a coral-stromatoporoidean reef complex during Oxfordian-Kimmeridgian time, while radiolarites dominated deep-sea environments of the adjacent Budva zone (Gorican, 1994).

In areas of Greece studied, the carbonate platform underwent block-faulting during the Mid Jurassic. As a result, isolated reefs developed on elevated blocks within the Pelagonian zone, influenced by high global sea level in the Late Jurassic time (Leinfelder, 1993), while radiolarian sediments accumulated within downfaulted basins. The possible cause of block faulting of the Pelagonian carbonate platform was crustal loading of the continental margin, associated with the initial emplacement of ophiolites (as inferred for Euboea; Robertson 1991). A later stage of ophiolite emplacement was marked by deepening and accumulation of ophiolite-derived clastic sediments, including polymict debris flows, of Tithonian-Berriasian age, that appear above the radiolarian sediments in the area studied.

Small ophiolite outcrops in the area (e.g. near Geranea) represent isolated remnants of once extensive ophiolites. The question of the location of the "root zone" of these ophiolites (i.e. "Pindos" or "Vardar") is outside the scope of this paper. However, we note that the evidence of platform collapse in central Greece by late Mid Jurassic time suggests that it is likely that no regional carbonate platform remained as a barrier to the dispersal of ophiolite-derived sediments at this time, contrary to the suggestion of Thiébault *et al.* (1994).

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4. CONCLUSIONS

The Pelagonian zone can no longer be considered as a homogeneous shallow-water platform during late Mid and Late Jurassic time. Our radiolarian biostratigraphic results from southern Beotia and the Kallidromon Mountains (Danelian & Robertson, 1995) establish that an extensive area of the Pelagonian carbonate platform had subsided by the late Mid Jurassic (Bathonian), allowing radiolarian sediments to accumulate. Block faulting of the Pelagonian platform gave rise to basins in which radiolarian sediments accumulated, submerged highs ("seamounts") on which Ammonitico Rosso was deposited, and remnant shallow-water carbonate platforms colonised by *Cladocoropsis* sp. The probable cause of block faulting was related to initial ophiolite obduction within the Neotethyan ocean. This differentiated palaeogeographic setting persisted until the uppermost Jurassic (Tithonian) when ophiolite-derived sediments reached the Beotian area, prior to overthrusting by ophiolites.

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