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NEW RESULTS ON RADIOLARIAN BIOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE EARLY CRETACEOUS TO TURONIAN OF THE PINDOS ZONE IN THE CENTRAL PINDOS MOUNTAINS (MAINLAND GREECE)

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ABSTRACT

Several sections of Early to Mid-Cretaceous siliceous and clastic sediments of the Pindos Zone, in the central Pindos Mountains of western Greece, are studied in detail by means of sedimentology and radiolarian biostratigraphy. Within the pre-Cenomanian section, predominate red radiolaritic facies, which were proved to contain conspicious Green Levels associated with radiolarian turbidites and black shale layers with high organic-carbon contents. These levels possibly reflect worldwide oceanic anoxic events. With abrupt onset in the late Early to early Middle Cenomanian, calciclastic event deposits (orbitoline horizons) locally replaced this basinal succession, initiating terrigeneous and organic-rich influx (turbidites) introduced axially from northern source areas.

KEY WORDS: Cretaceous; Pindos Basin; biostratigraphy; radiolaria; black shales; orbitolines; continental Greece.

1. INTRODUCTION

In the Early to Mid-Cretaceous Tethys, siliceous and organic-rich sediments were often associated facies (e.g. De Wever & Baudin 1996, Erbacher 1994). They were possibly linked to worldwide oceanic anoxic events (OAE 1&2 of Schlanger & Jenkyns 1976), e.g. the Early Aptian Selli-Level in the Umbro-Marchean Apennines (e.g. Coccioni et al. 1989). Furthermore, in various Mediterranean basinal sequences, breccias and flysch-like deposits were characteristical features during the tectonically very active late Mid-Cretaceous (e.g. Galli 1993, Richter et al. 1994). The Olonos-Pindos Zone of western Greece exposes such basinal, thrust-imbricated sediments, that document continental margin and ocean basin sequences (e.g. Degnan & Robertson 1991, Robertson 1994). The Lower to Mid-Cretaceous basin fill comprises Radiolarian-bearing siliceous sediments (Marnes rouges, Fleury 1980, De Wever & Origlia-Devos 1982, Thiebault et al. 1981), and clastic facies (Premier flysch du Pinde, Aubouin 1957, Fleury 1975, Richter & Müller 1993, Wagreich et al. 1996). Terrigeneous influx, most significant since Cenomanian times, correlates with occurrences of black shales (Antoniou 1993) and orbitoline-rich event beds (Orbitolinenhorizont des Cenoman, sensu Renz 1955).

This paper presents first results from an integrated study of the radiolarian biostratigraphy, sedimentology, and facies which attempts to analyze more precisely the event-stratigraphic meaning of the Pindos Basin, for further paleoenvironmental interpretations in the scope of local to global controls.

2. STRATIGRAPHIC SUBDIVISION OF THE STUDIED SECTIONS

Within the central Pindos Mountains of mainland Greece, several sections along road and river cuts in the area west of Kalambaka (western part of the district Trikala) were recorded, sampled and tectonically

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backstripped (Fig. 1). The compiled representative column of Lower to Mid-Cretaceous strata can be seen in Fig. 2. We propose a subdivision into five major subunits (members A-E) of different composition and facies which are dated by radiolaria (see section 2.) and redeposited fauna.

A lower interval (A-C; pre-Cenomanian) is composed of radiolarite-type sediments with a marked red/green cyclicity in the scale of mm to several m: Member A (ca. Late Valanginian to Barremian; 13-15 m) overlies Calpionellide-bearing pelagic limestones, and is composed of cyclic successions of red claystones, thin, red radiolarian-sand layers and cherty mudturbidites (biogenic grading). Member 2 (Late Barremian to lowermost Aptian, 13 m) is marked by rather thick (20-80 cm) radiolarian-rich turbidites. The upper 6 m represent the most pronounced Green Level (Level 3; see 3.). Member 3 (Aptian-Albian, ?lowermost Cenomanian; ca. 20 m) is composed of rhythmic alternations of claystones and cherts, including a mere claystone interval of 6 m in the middle (with Green Level 5). An upper interval is characterized by widespread clastic facies, which reach up to 50-60 m in total thickness. Only some incomplete outcrops of finegrained siliceous facies, ranging between the Middle Turonian and Early Coniacian, can be observed with a trend to increasing mudturbidite intercalations higher up, and only thin sandstone intervals. Member D (ca. Middle to Late Cenomanian, at least 25 m) of the 'standard section' resembles a carbonate allochthonous unit, commencing with the turbiditic orbitoline-horizon (1.5 m, marker bed) followed by thick, finegrained debris flow deposits. Member E (Middle to Late Turonian; at least 30 m; 'first Pindos flysch') is composed of rhythmic successions of sand- and siltstone turbidites and red claystones.

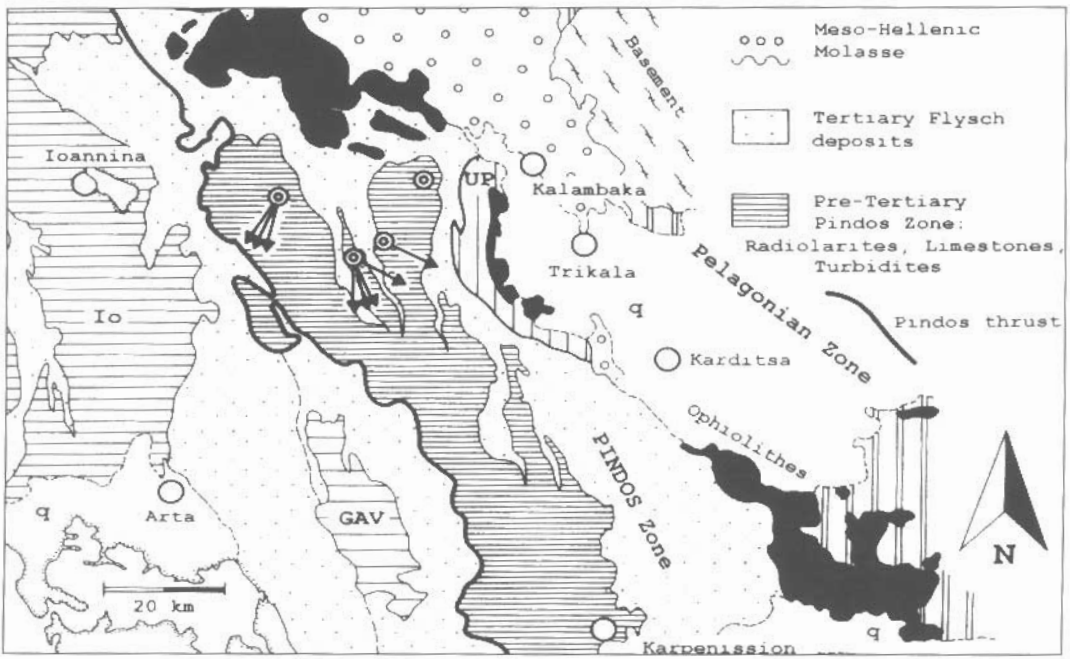

Fig. 1: Regional setting of the studied area, in which the northernmost outcrops of Greek pre-Tertiary Pindos Series (s.s.) in the central and southern Pindos Mountains are found. Cretaceous strata are exposed in numerous West-vergent thrusts and folds. Double circles show location of studied sections. Arrows indicate reconstructed Mid-Cretaceous turbidite paleocurrents. Abbreviations: q: Quarternary, Io: Ionian Zone, Gav: Gavrovo Zone, UP: Ultrapindic Subzone. *(Compiled from the Geological Map of Greece 1:500000)*

3. ATTEMPT TO A RADIOLARIAN BIOCHRONOLOGY

For biostratigraphic age dating more than 80 samples were collected from different lithologies of the radiolaritic sediments (claystones, radiolarian 'sands' and radiolarian mudturbidites). Most of the samples

yielded recrystallized and corroded tests. From some levels however, reasonably to well preserved specimen could be extracted. After identification to species level by scanning electron microscopy, age estimates of the samples were established using and combining the most recently published range charts for the earliest Cretaceous (Baumgartner et al. 1995), and for the Aptian to Early Turonian (O'Dogherty 1994, Erbacher 1994). Up to now the following age assignment of some selected sample levels can be made:

- Radiolarian assemblage of the (Late Barremian)-Early Aptian (base of Green Level 3):
Thanarla pseudodecora (Tan), *Pseudodictyomitra carpathica* (Lozyniak), *Pseudo-dictyomitra* cf. *hornatissima* (Squinabol), *Parvicingula usotanensis* Tumanda, *Xitus alievi* (Foreman), *Amphipyndax mediocris* (Tan), *Stichocapsa euganea* Squinabol, *Podobursa typica* (Rüst) and others.

- Radiolarian assemblage of the latest Albian to early Early Cenomanian (1 m below the orbitoline horizon):
Archaeodictyomitra simplex Pessagno, *Thanarla spoletoensis* O'Dogherty, *Thanarla cucurbita* O'Dogherty, *Thanarla* cf. *pulchra* (Squinabol), *Torculum coronatum* (Squinabol), *Stichomitra communis* Squinabol, *Stichocapsa euganea* Squinabol and others.

- Radiolarian assemblage of the late Early to early Middle Cenomanian (red claystone interbed in member D):
Pseudodictyomitra pseudomacrocephala (Squinabol), *Crolanium pulchrum* (Squina-bol), *Novixitus mclaughlini* Pessagno, *Torculum coronatum* (Squinabol), *Torculum dengoi* (Schmidt-Elfing), *Stichomitra communis* Squinabol, *Stichomitra magna* Squinabol, *Cyrtocapsa perspicua* Squinabol, (?) *Podocapsa* cf. *guembelii* Rüst and others.

- Radiolarian assemblage of the Middle to Late Turonian; co-occurring with *Marginotruncana sigali* (Reichel) (red claystone interbed in member E):
Dictyomitra formosa Squinabol, *Archaeodictyomitra squinaboli* Pessagno, *Pseudo-dictymitra tiara* (Holmes), *Pseudodictyomitra pseudomacrocephala* (Squinabol), *Stichomitra communis* Squinabol, *Hemicryptocapsa polyhedra* Dumitrica, *Hemicrypto-capsa tuberosa* Dumitrica, *Crucella cachensis* Pessagno, *Hexapyramis pantanellii* Squinabol, *Patellula verteroensis* (Pessagno), *Orbiculiforma railensis* Pessagno and others.

4. SEDIMENTARY CHARACTERISTICS

4.1 GREEN LEVELS OF THE EARLY CRETACEOUS

Five major Green Levels (0,3-6 m) occur within the sharply contrasting sequence of red sediments: Green to yellowish claystones, light-coloured to greenish pelitic turbidites, green to black layered, knobby to nodulous cherts which are interbedded with black shales (0,5-15 cm) of different fabrics. Levels 1 and 2 of the Late Valanginian to Barremian as well as the base of the Early Aptian Level 3 contain strongly silicified, homogeneous and dense black shales (0,5-2 cm) associated with black cherts. Spot tests revealed organic-carbon contents of 2% to 5,5%. The top of Level 3 marks the change to finely laminated black shales (6-15 cm; 1,6% to 10% organic carbon). Laminated fabric (<1 mm) prevails in the Aptian-Albian Levels 4 and 5. Silty interlayers and plant debris hint at detritic origin. The Early Aptian event furthermore shows intercalations of silicified turbidites and greywacke-like detritic pelites, with an interesting clast association made up of abundant recrystallized spumellarian tests, phosphatic debris, cherts and silt- to claystone clasts and lenses (up to 2 mm), which possibly resemble weathered volcaniclastics. Subordinate carbonate and biogenic elements, sponge spicules, glauconite, few biotite and chlorite, quartz, chromite and probably scarce altered volcanics occur. (Additional mineralogical and geochemical studies are in progress.)

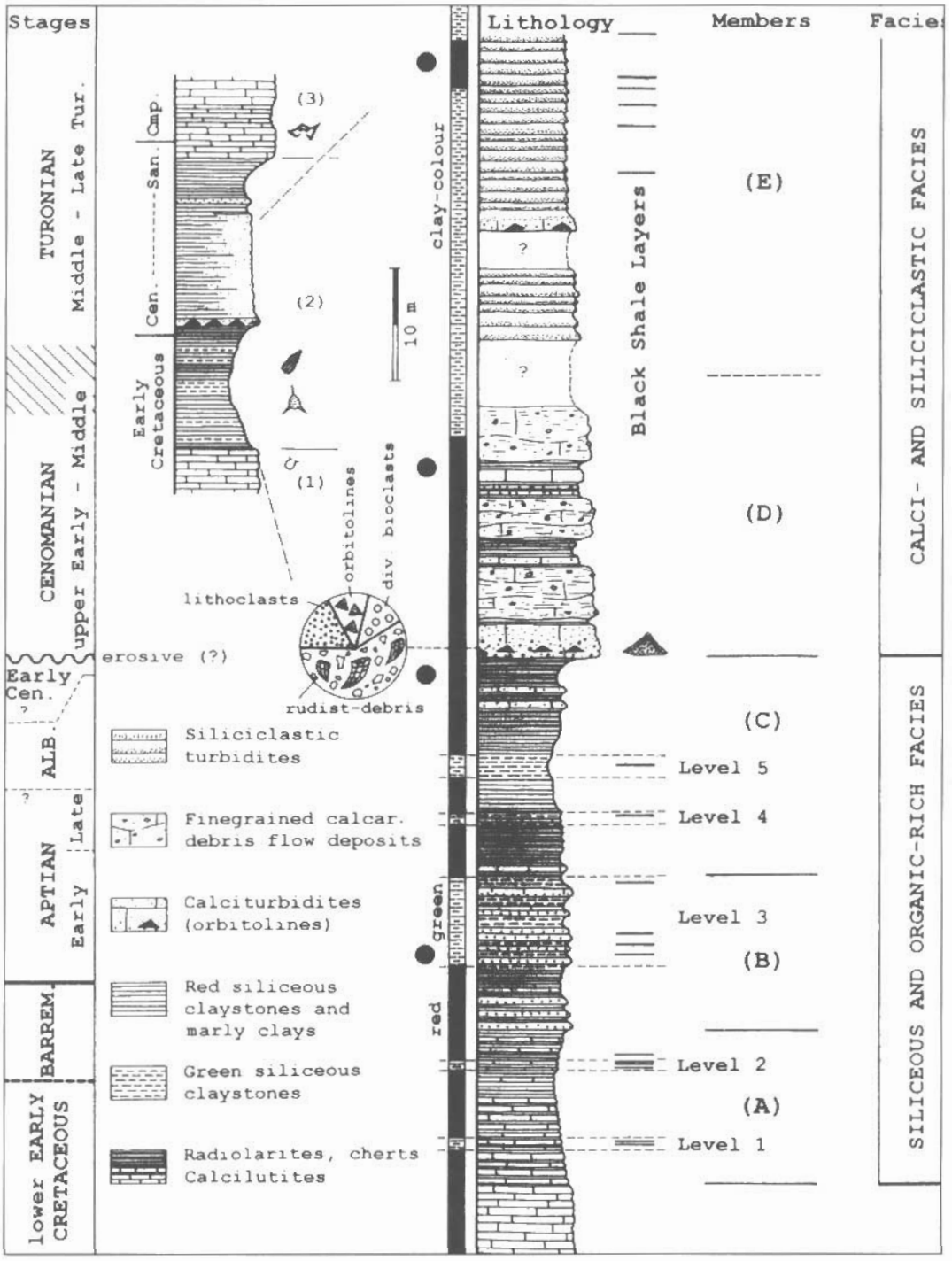

Fig. 2: Simplified composite stratigraphic column of the Olonos-Pindos Lower Cretaceous to Turonian section in the central Pindos Mountains (location of detail sections in Fig.1). Position of green and organic-rich levels, proposed lithostratigraphic subdivision, and position of the presented radiolarian assemblages (see text, Chp.2), are indicated (black dots). Inset shows general stratigraphic position (terminology after Fleury 1980): (1) Calcaires à Calpionelles, (2) Marnes rouges à Radiolaires, (3) Siliceous [illegible]

4.2 REDEPOSITIONAL EVENTS OF THE MIDDLE CENOMANIAN TO TURONIAN

In continuous section, the clastic interval roughly shows a thinning- and fining-upward trend, as well as a vertical facies change from calciclastic, fine-grained rudites (member D) to sandy and silty turbidites in the Turonian (member E), with a second orbitoline-bearing bed near the base. The basal orbitoline horizon bears abundant reworked penecontemporaneous free tests of orbitolinidae, like *Conicorbitolina conica* (d'Archiac) and planctic foramini-fera, e.g. *Planomalina buxtorfi* (Gandolfi) or *Praeglobotruncana* cf. *gibba* Klaus as well as rudist debris. Moderate amounts of neritic lithoclasts prove shelf edge erosion.

The siliciclastic turbidite facies comprises lithic arenites, composed of carbonate lithoclasts and biogenics elements, cherts, quartzites, phyllites and detritic quartz. Furthermore, muscovite, chlorite and few serpentine, chromite, plagioclas phenocrysts, shale fragments and very rare doleritic and porphyric volcanics can be observed. Higher up in the section, black bituminous Bouma Te-subdivisions of sandy as well as muddy turbidites contain strikingly high amounts of up to 32% organic carbon. Paleocurrent indicators (flute- and dendritic ridge casts, ripple cross lamination) definitely prove a northern origin, and thus axial supply of this terrigeneous material (see fig.1).

5. RESULTS AND DISCUSSION

The following new data and results from the presented biostratigraphical, sedimentological and geochemical studies can be summarized and further interpreted:

- Early to Mid-Cretaceous radiolarite-type and clastic sediments of the central Pindos Mountains were recorded in detail, and subdivided into five members and facies associations. A precise radiolarian biochronology is being applied.
- Five major Green Levels with increased organic carbon contents (black shales) could be found and their position clarified: Levels 1 and 2 occur in the Late Valanginian to Barremian, Level 3 in the Early Aptian, Levels 4 and 5 in the later Aptian to Albian.

Green radiolarite levels of the Aptian-Albian in the Budva Zone are taken by Gorican (1994) as partly corresponding with the oceanic anoxic events 1A and 1B of Arthur et al. (1990). The Green Levels documented further south, in the Pindos, are less siliceous, but stratigraphy hints at a correlative position, e.g. of the Early Aptian Level 3. Co-occurrences of organic-rich sediments, radiolaria and phosphorites are generally supposed to be indicators of fertile water masses (upwellings; e.g. Vekios & Chiotis 1993, De Wever & Baudin 1996). Aptian-Albian green marls of different settings in Greece and other eastern Mediterranean sites can be genetically related to volcanic influence (Koch & Zimmerle 1996). Similar traces (e.g. glauconite, phosphorite) are reflected in the composition of the clastic beds of the Green Levels. Future mineralogical and geochemical investgations of the Pindos samples will examine a possible correlation.

- The abrupt onset of clastic deposition can now be dated very precisely by radiolaria and redeposited fauna of the orbitoline horizon, as later Early to early Middle Cenomanian.
- Siliciclastic replenishment and allochthonous organic-rich facies started at the latest in the Middle or Late Turonian, youngest intercalations were found in the Early Coniacian.

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