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Decastronema barattoloi (DE CASTRO), characteristic fossil of the Palaeocene and the Eocene peritidal sediments from the Adriatic carbonate platform

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ABSTRACT

The renewed deposition in the Palaeogene and the oldest part of the non-interrupted Palaeocene succession is characterized by the presence of Decastronema barattoloi *(DE CASTRO), cyanobacterial tubes originally described in the Apennines. The reinterpretation of limestones from several sections located in the Kras region (NW part of the AdCP: Basovizza, Dolenja vas, Sopada, Čebulovica) confirmed the presence of these microfossils in peritidal sediments of Danian age (SBZ 1). The Cuisian (Late Lower Eocene) sediments, from eastern Istria (Brnjci section), Cres Island (Koromačna Cove section) and Ravni kotari (Benkovac–Korlat section) contain individuals of this species in great numbers. The cyanobacterial tubes are scattered in laminated, fine grained mudstones and wackestones, immediately above the Cretaceous sediments (occasionally above bauxites or breccias). The* Decastronema*-bearing sediments pass upward into the Foraminiferal limestones of Cuisian age (SBZ 11, based on conical agglutinated foraminifera and alveolinids), allowing the age determination of the cyanobacterial remnants. The Palaeocene specimens are minute (up to about 180 µm long), thick walled tubes that occur with the index fossil* Bangiana hanseni *DROBNE. The Eocene forms accompanied by ostracods, pelecypods, and miliolid and rotaliid foraminifera are segmented tubes, up to 400 µm long and usually thin walled.*

Keywords: *Decastronema barattoloi*, Adriatic Carbonate Platform, Palaeocene, Eocene, peritidal environment

1. INTRODUCTION

RADOIČIĆ (1959) described minute cylindrical tubes from Cretaceous sediments in the External Dinarides and established the new species *Aeolisaccus kotori*. Since then, the number of publications interpreting mat-forming cyanobacteria has increased over the years. There have been discrepancies in their taxonomic identification as microfossils as well as in determining the age of sediments containing them. The unique architecture of the microfossils as characteristic of cyanobacterial sheaths was recognized by DE CASTRO (1975).

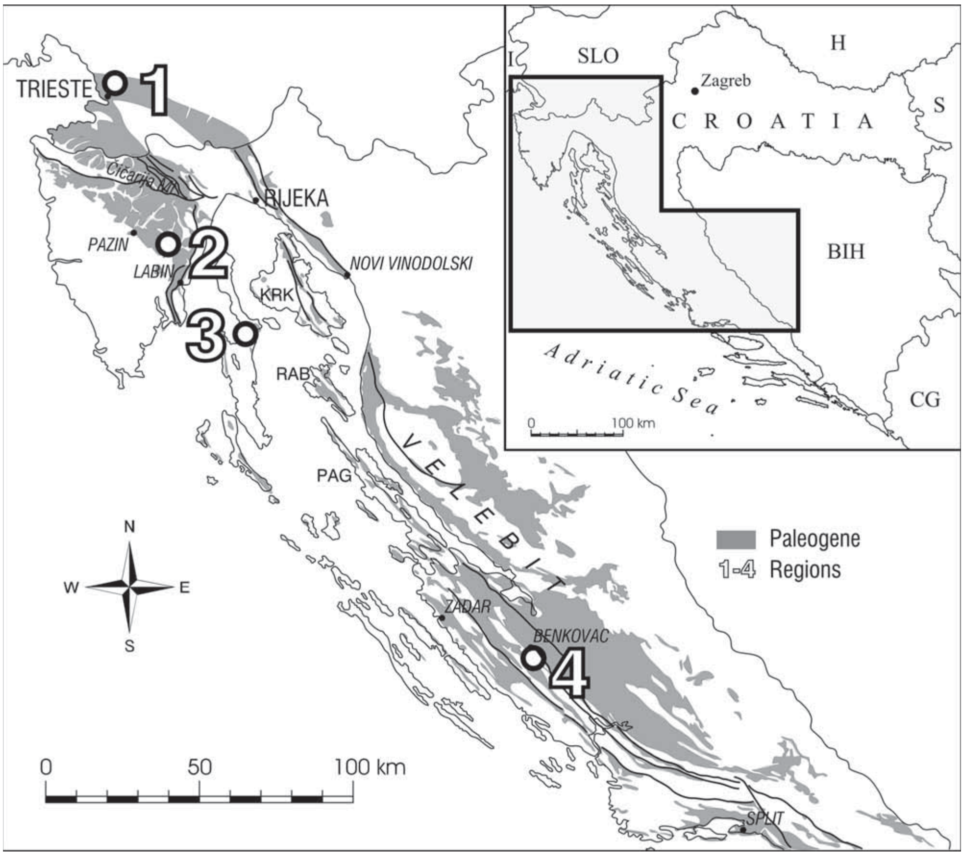

Figure 1: Simplified geological map of the Palaeogene domains, remnants of the Adriatic carbonate platform showing location of the regions considered in this paper, adapted from ĆOSOVIĆ et al., (2008): 1) The Kras region, 2) Istria, 3) Cres Island (Northern Adriatic Islands), 4) Ravni kotari region.

Later on, DE CASTRO (1989) described another species, *A. barattoloi*, smaller than *A. kotori*, from Coniacian to Santonian sediments of Mt. Mutria (Apennines, Central Italy). Using the high resolution of the SEM, the extent to which the specimens have preserved their original architecture and investigation of their presumed modern counterparts among the abundant mat-forming species of *Scytonema* from the intertidal flats of the Bahama carbonate platform, GOLUBIC et al., (2006) transferred *Aeolisaccus* to *Decastronema.* From 2006 onwards those taxa recognized as cyanobacteria (i.e. *A. kotori* and *A. barattoloi*) are referred to the genus *Decastronema*.

Studies of the Middle Eocene, shallow-marine platform sediments from the Adriatic Carbonate Platform (AdCP, *sensu* VLAHOVIĆ et al., 2005) in the early 1970s (BIGNOT, 1972) identified the presence of cylindrical tubes of cyanophyceans similar to the recent *Microcoleus.* Shortly after specimens of *A. barattoloi* were described in sediments of Mt. Mutria (DE CASTRO, 1989), this species was recognized in sediments from the central part of the AdCP, (Ravni kotari region, DROBNE et al., 1991; Fig. 1). Besides these occurrences, remnants of *A. barattoloi* have been disocvered in the Palaeocene part of the Maastrichtian to Danian succession in the Kras region, (Colle de Medea and Dolenja vas), by BARATTOLO (1998). By that time, more localities with sediments containing cyanobacterial tubes were recognized, including Basovizza, Sopada, and Čebulovica, all of Danian age. Their age attribution (Figs. 2, 3) is based on the presence of *Bangiana hanseni* DROBNE (Pl. I, Figs. D, E; DROBNE et al., 2007). What emerged as a striking characteristic is the fact that these microfossils occur in sediments of shallow marine origin, according to allochems and textural and structural features of sediments. These sediments were the first to be deposited after periods of emersion.

In the light of these recent works, we analyzed sediments from the south-eastern Istria bauxite cave (Brnjci) for the first time, together with sediments from previously studied (and published) sections from the NW part of the AdCP and from its central part. We reinterpreted the age attribution of the sediments known from the literature (sections Mali Mlun, Krpan and Soldatići, from central and SE Istria; Figs. 2, 3).

Biotic evolution in the AdCP settings within the Palaeocene and Eocene time span will enrich the limited knowledge of the role of *Decastronema barattoloi* in the stabilization of shallow marine environments and as a signal microfossil for the main transgressive cycles in the Perimediterranean region.

On the basis of the recent data, the goals of this research are to: 1) better define the biostratigraphic role of *Decastronema barattoloi*, 2) refine the knowledge of its role in the evolution of stressed settings.

2. GEOLOGICAL SETTING AND STRATIGRAPHY

Some of the questions regarding the development of the Adriatic carbonate platform (AdCP) concern the age and conditions of re-establishment of the marine regime after the Seno-

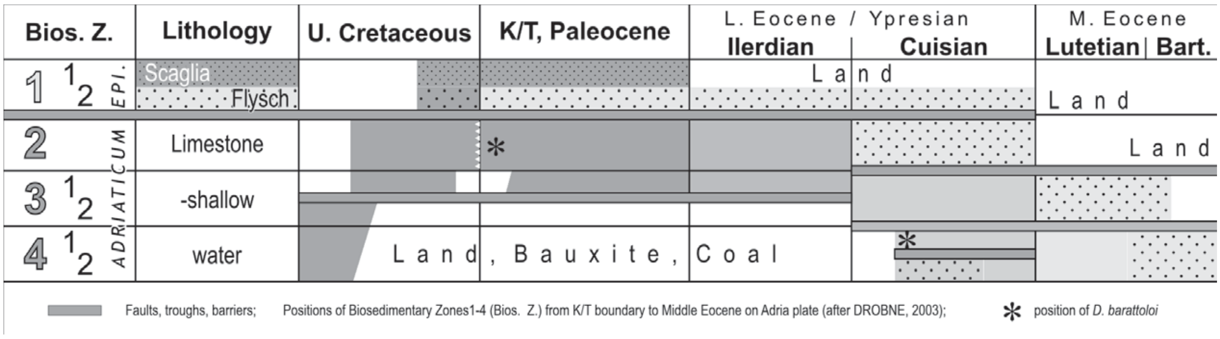

Figure 2: Model of successive biosedimentary zones (Bios. Z. 1 – Bios. Z. 4) from the Late Cretaceous to late Middle Eocene on the Adriatic carbonate platform (DROBNE, 2003; DROBNE & OGORELEC, 2006; DROBNE et al., 2008) with distribution of *Decastronema barattoloi* (DE CASTRO).

nian emersion. In addition, there has been no reconstruction of the palaeoenvironmental conditions where continuation of a marine regime occurred between the Upper Cretaceous and the Palaeogene. Within the region that now forms the External Dinarides, (considered here as comprising Italy, Slovenia and Croatia); a marine carbonate platform regime existed from the Late Triassic to the Middle Eocene, with several shorter or longer sedimentary breaks. The Palaeogene marine shallow-water carbonates were deposited on a sedimentary ramp system which culminated in Middle Eocene flysch deposits. During the Early Palaeogene, the region comprised an elongated NW-SE trending gulf located at the palaeolatitude of 32° N (MEULENKAMP et al., 2000). Tectonically, this time interval is characterized by the development (Palaeocene; OGORELEC et al., 2001; ZAMAGNI et al., 2008) and migration of a foreland basin (Eocene; ĆOSOVIĆ et al., 2004; VLAHOVIĆ et al., 2005). Alternatively, DROBNE and co-workers (DROBNE, 2003; DROBNE & OGORELEC, 2006; DROBNE et al., 2008) defined a model where four biosedimentary zones (BiosZ1 – BiosZ4; Fig. 2) followed stepwise, one after another, from the Late Cretaceous to Middle Eocene (Lutetian/Bartonian boundary). This was based on both HERAK's (1999) tectonic interpretation of the Dinarides (within the "geotectonic" unit Adriaticum), and their own detailed litho- and biofacies studies of many sections in the Kras region and Istria.

The transition between the well documented geological developments of the AdCP in the Cretaceous, into the relatively short-lasting platform history of the Palaeogene, is still one of the most disputed events in the geologic history of the region. From the great number of published papers (from the late 19th Century, *e.g.* STACHE 1889 to recent, *e.g*. DROBNE et al., 2007), it is known that in the NW part of the carbonate entity, (Kras region in SW Slovenia), continuous sedimentation in transitional environments occurred between the Maastrichtian and Palaeocene. The Upper Cretaceous rudist-bearing limestones are overlain by the Liburnian Formation (Fig. 3). These brackish to shallow marine sediments of various facies characteristics and fossil assemblages underlie the Eocene *Alveolina-Nummulites* limestone. The near continuous K/T successions are exposed in several sections, where the Dolenja vas section is one of the most studied (DROBNE et al., 1988, 1989, 1995, 1996; DROBNE & OGORELEC, 1991; JURKOVŠEK et al., 1996; OGORELEC et al., 1995, 2007). The Basovizza, Čebulovica and Sopada sections (PUGLIESE et al., 1995; JURKOVŠEK et al., 1996; OGORELEC et al., 2001; RICCAMBONI, 2005; ZAMAGNI et al., 2008) are also stratigraphically and sedimentologically well documented. The re-studied sediments are packstones to wackestones (recrystallized biomicrites) with dasycladaleans, charophyta and corals (TURNŠEK & DROBNE 1998). Foraminifera are scattered throughout the matrix and are presented by discorbids, miliolids and *Bangiana hanseni* DROBNE (Pl. I, Fig. D), considered as index fossils for the Danian (DROBNE et al., 2007).

For the west part of the Adriatic carbonate platform (extending from the Istrian peninsula in the NW, to central Dalmatia, including the northern Adriatic Island of Cres), the period between the latest Cretaceous to the Early Eocene was characterized by subaerial exposures and non-marine conditions. Generally, the Upper Cretaceous and Eocene deposits for this part of the carbonate entity, (Fig. 3), reveal that the Eocene deposits unconformably overlie the Cretaceous sediments. They comprise two formations: the Liburnian Formation characterized by marginal marine, paralic and palustrine carbonates of Early Eocene age, and the *Alveolina-Nummulites* Limestones with numerous tests of larger benthic foraminifera of Ypresian (SBZ 11/12) to Early Middle Eocene (SBZ 13/14), or to late middle Lutetian, SBZ 14 or even Bartonian SBZ 17/18 age (DROBNE, 1977; DROBNE et al. 1991; ĆOSOVIĆ et al., 1994, 2004). Furthermore, the beginning of the Eocene transgression was almost simultaneous over the region and corresponds to a Cuisian age (Fig. 2). The studied level is composed of a micrite-supported variety of limestones (wackestones to packstones) where scattered miliolids and *Rotalia*-like foraminifera, ostracods, and fragments of pelecypods occur. Reworked *Microcodium* occurs in packstones (Brnjci section) representing subaerial exposure surfaces. The age attribution was assigned based on fossil content identified from overlying sediments.

3. MATERIAL AND METHODS

This paper presents microfossil data for two regions: Kras and Istria to Central Dalmatia (Fig. 1). Several sections (Basovizza, Sopada, Dolenja vas and Čebulovica), all of Palaeocene age, are located in the Kras region. The most recent overview

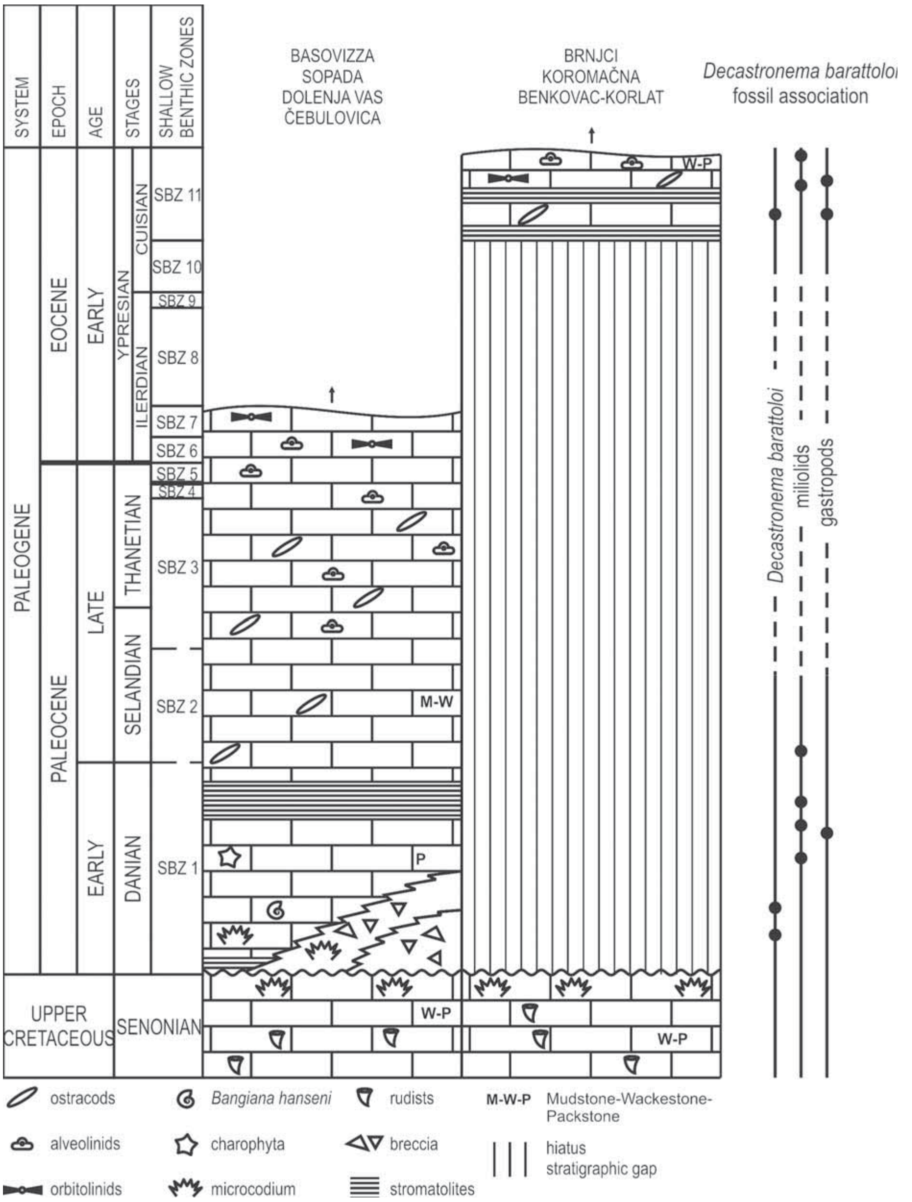

Figure 3: Schematic stratigraphic columns of the Palaeocene – Early Eocene sediments in the Kras region (Basovizza, Dolenja vas, Čebulovica and Sopada sections), and Cuisian sediments in SE Istria, Cres Island and Ravni kotari area (Brnjci, Koromačna and Benkovac – Korlat sections) with distribution of *Decastronema barattoloi* (DE CASTRO). SBZ shallow benthic zones (*sensu* SERRA-KIEL et al., 1998, LUTERBACHER et al., 2004), after DROBNE et al., 1991; ĆOSOVIĆ et al., 1994; KOIĆ et al., 1995 and OGORELEC et al., 2007.

on palaeontological and sedimentological descriptions of these sections is given in OGORELEC et al. (2001) OGORELEC et al. (2007) and TEWARI et al., (2007). The re-studied limestones were interpreted (*ibid.*) as having been deposited in low-energy, near-shore lagoonal environments based on sedimentary textures, structures (stromatolites, shrinking cracks, flat pebble conglomerates, and *Microcodium* aggregates), and remains of foraminifera and dasycladaceans. The limestones are of Danian age (SBZ 1; SERRA-KIEL et al., 1998).

In the present study, the Istrian to Central Dalmatian region is represented by the Eocene sections located in Istria, Cres Island and Ravni kotari (Fig. 1). In SE Istria, the transgressive Upper Cretaceous–Eocene succession can be observed in an abandoned Brnjci bauxite cave located in the vicinity of Labin. The 8.25 m thick section has been logged, sampled by TUNIS, TARLAO, MORO and ĆOSOVIĆ in July 2006 and has still to be described with respect to the sedimentary structures, texture and biotic components. The preliminary biostratigraphic results reveal that due to superposition (no erosional or no-depositional marks) the cyanobacterial bearing sediments are of Cuisian (SBZ 11) age. This is confirmed by the overlying *Alveolina* – "complex" Miliolid limestones with the age-diagnostic species *Alveolina axiampla boljunesis* DROBNE and *Alveolina levantina* HOTTINGER.

Stratigraphic reinterpretation of cyanobacteria-bearing limestones in the Mali Mlun, Krpan and Soldatići sections (in Central and SE Istria), originally investigated by BIGNOT (1972), was done by K. DROBNE using the depicted microfossils. Instead of being of Lutetian age, the re-described level is considered, based on associated foraminifers (*idem,* p. 143; pl. 44, fig. 2 and p. 161; pl. 43, fig. 5; pl. 47, fig.1; plate 46, fig. 3), to be of Cuisian age. The Koromačna sediments (ĆOSOVIĆ et al., 1994; KOIĆ et al., 1995), which overlie the Upper Cretaceous limestones, contain numerous micritic tubes referred to as remnants of cyanobacteria. The age determination is possible due to the presence of *A. levantina*, *Coskinolina liburnica* STACHE and *Periloculina dalmatina* DROBNE in the first sample which indicates a Cuisian (SBZ 11) age.

Oriented thin sections have recently been made from samples collected in the 1990s in order to identify foraminiferal species.

Clusters of *Aeolisaccus barattoloi* have been described from laminated limestones, characterized by irregular birds-eye and stromatolitic fabrics with *Perna istriana* STACHE, primitive agglutinated conical foraminifera, orbitoilitids, and *A. decastroi* SCOTTO DI CARLO (important for age attribution), in the Benkovac – Korlat section (DROBNE et al., 1991, p. 59). These limestones were interpreted to be of Cuisian age (SBZ 11) based on alveolinids and associated larger foraminifera.

Thin sections prepared from mud-supported varieties of the sampled limestones were examined under optical microscope. Samples from Brnjci cave were polished and briefly etched by HCl, dried, and studied using an SEM – Vega Tescan TS5136MM (operating or beam accelerating voltage 20 kV and back scatter detector (BSE)).

4. RESULTS AND DISCUSSION

Several studies of the Palaeogene shallow marine platform carbonates from the AdCP show the presence of cylindrical micritic tubes identified as a fossil counterpart of modern *Microcoleus* (BIGNOT, 1972). DE CASTRO (1989, p. 111) has described microfossils similar to *Aeolisaccus kotori* RADOIČIĆ from 20–80 cm thick, bedded sediments from Mt. Mutria (Apennines), squeezed between underlying bauxites and overlying Miocene beds. This form is smaller than those described from the Cretaceous: tubes are 33 μm long, with an inner diameter of 9 to 29 μm and an outer diameter between 16–36 μm. He named the form as *Aeolisaccus barattoloi*.

4. 1. Biostratigraphic position: Palaeocene

The oldest limestones containing this type of microfossil are known from the K/T succession in the NW part of the AdCP (from Kras region in SW Slovenia and NE Italy; Figs. 2, 3). BARATTOLO (1998) identified these microfossils as *Aeolisaccus barattoloi* from the Danian limestones (SBZ 1) in the Dolenja vas section and Colle di Medea. Danian sediments from the closely spaced Čebulovica and Sopada sections (DROBNE et al., 1995; OGORELEC et al., 2001) also contain these microfossils. Fragments of the cylindrical tubes are mainly observable in cross-sections as circles with thick walls (Pl. I, Figs. A, B, C, D; Tab. 1), up to 35 μm in outer diameter (21±7 μm), with an inner diameter of 14–21 μm, and a cylinder length of up to 178 μm (ranging between 100 and 178 μm). They are randomly scattered within a micritic matrix. Limestones from the Dolenja vas section were deposited in shallow-marine peritidal environments, while sediments from Čebulovica originated in a lagoon with variable salinity, (documented by the presence of charophycean specimens known as "*Lagynophora liburnica* STACHE" *sensu* STACHE, 1889). This environmental type is considered as unstable, due to the possible variations in salinity, shallow depth and proximity to land. In such circumstances, opportunistic forms are the first colonizers, pioneers that will eventually convert habitat into more suitable area for specialists. While today there is a general consensus as to rejection of the genus *Lagynophora* (FEIST & GRAMBAST-FESSARD, 2005), its taxonomic status was previously highly acknowledged.

4.2. Biostratigraphic position: Eocene

The second occurrence of *Decastronema barattoloi* coincides with the presence of the Cuisian (Ypresian) sediments in southeastern Istria (Labin environment, BIGNOT, 1972; Brnjci section, this paper), in the northern Adriatic island of Cres (Koromačna section; ĆOSOVIĆ et al., 1994; KOIĆ et al., 1995) and in Ravni kotari (Benkovac – Korlat section; DROBNE et al., 1991). Interestingly, the cyanobacterial tubes occur within the oldest Palaeogene sediments, those deposited immediately above the Cretaceous deposits and thus representing the first transgressive unit (Figs. 2, 3). Filaments of *D. barattoloi* in the Brnjci section are dispersed as linear accumulations within the micritic matrix, (Pl. II, Fig. A). The cylindrical tubes are disposed in such a way that their long axes are parallel one to another, suggesting that the filaments were distributed in a way that resulted in more or less continuous coverage (mat-forming sheets). They appear as hollow tubes with an outer diameter of 32 to 42 μm (mean deviation of 5 μm), an inner diameter of 20 μm, and from 120 to 370 μm long (Pl. II, Fig. C). In cross-section they are circular (Pl. II, Figs. B, C), with outer diameters of 32 to 42 μm, while the inner diameter is about 20 μm (Tab. 1). The associations of benthic foraminifera, (small thin shelled miliolids and discorbids), small ostracods with thin carapaces, and charophyte remains, together with the sedimentary texture and structures (thin bedded), all suggest deposition in a low-energy, restricted environment, probably in a brackish lagoon. The overlying sediments, rich in larger benthic foraminifera (orbitolitids, alveolinids, "complex" miliolids and conical agglutinated ones), suggest inner (lagoonal) shelf settings. In the Koromačna section (Cres Island; Pl. II, Fig. D), filaments are cylindrical tubes up to 375 μm long, with an inner diameter of 53 μm and outer diameter of 80 μm.

In the studied part of the Benkovac – Korlat section (DROBNE et al., 1991, p. 59), the predominance of mud-supported lithologies, packstones with relatively abundant carbonate mud, and lack of wave-related fabrics, indicate that deposition occurred in a protected, shallow-marine setting. Agglutinated foraminifera, *Alveolina*, "complex" miliolids, and *Orbitolites* thrived in a protected and vegetated inner shelf environment placed above the *Decastronema*-bearing sediments. The tubules of *Decastronema* remnants have an inner diameter of 36 μm ± 9 μm expressed as mean derivation (Pl. II, Figs. E, F). The wall appears dark and thick in thin section, with an external diameter ranging from 45 to 64 μm. The segmented tubular hollows are 136–345 μm long (241 ± 105 mean deviation).

The presence of *Decastronema barattoloi* in sediments from the AdCP coincides with the Ilerdian/Cuisian boundary (Figs. 2, 3). This interval, although known from dramatic changes in the open marine biota, recently has been recognized in changes in shallow-water biota due to rising temperature and changes in the trophic resource regime.

PLATE I

Photomicrographs of *Decastronema barattoloi* (DE CASTRO) and *Bangiana heneseni* DROBNE of the Danian (SBZ 1)

A, B Recrystallized biomicrites, wackestones, Basovizza section, sample RRB – B15.

C Recrystallized biomicrite, wackestone, Sopada borehole S 37.

D Wackestone, Dolenja vas section, sample Dv W 1/6605.

E Metković-Sjekoše section, sample ME-SJ 10/4-7429. Figures A, B and C are taken from RICCAMBONI, 2005 with his permission, and figures D, E from DROBNE et al., 2007.

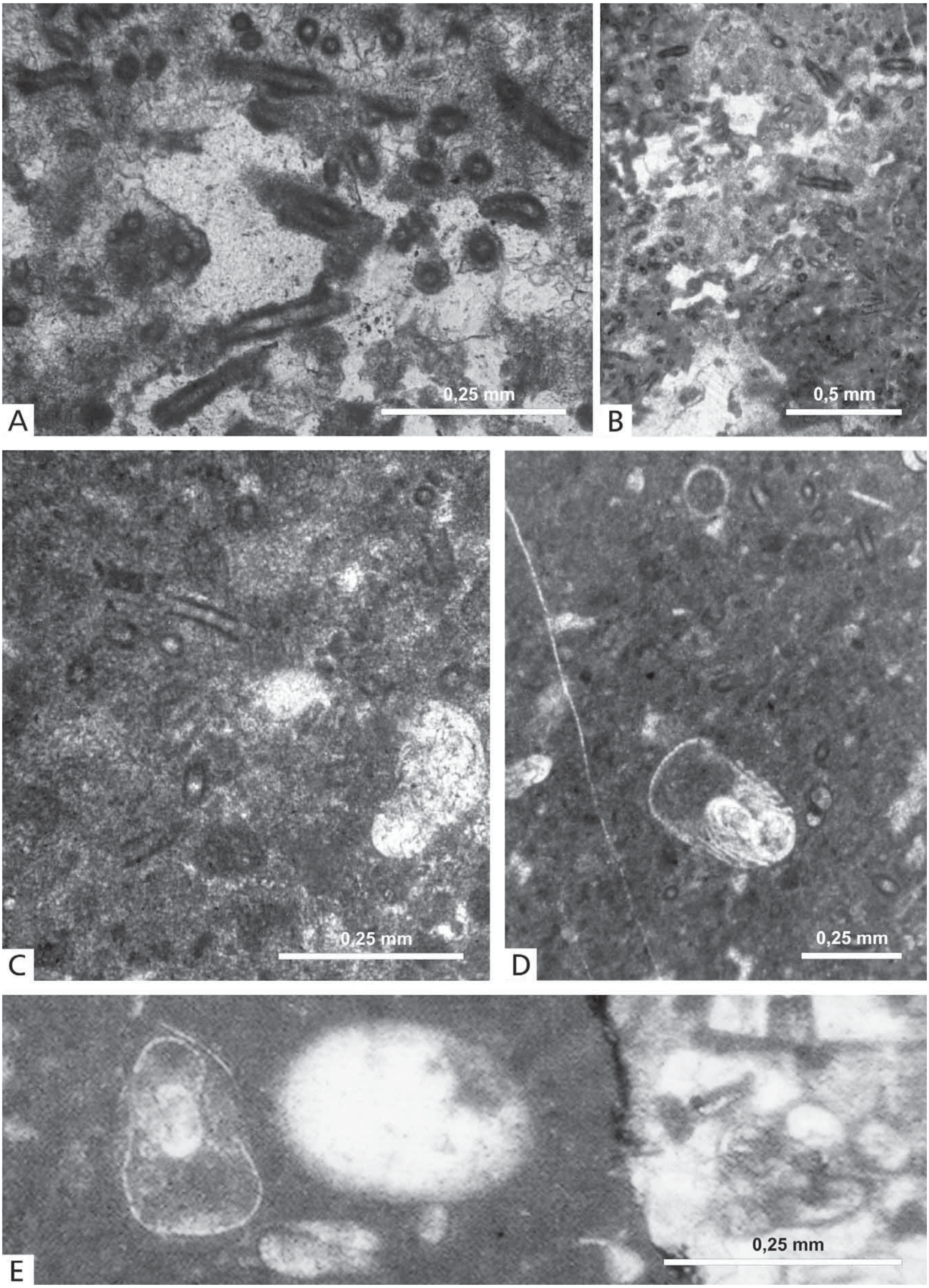
A
0,25 mm
B
0,5 mm
C
0,25 mm
D
0,25 mm
E
0,25 mm

PLATE II

Photomicrographs of *Decastronema barattoloi* (DE CASTRO) of Cuisian (SBZ 11)

A, B, C Brnjci section, sample BR–10.

D Koromačna section, Cres Island, sample KOR 2.

E, F Benkovac – Korlat section, sample Be–Kor 6/ 5656.

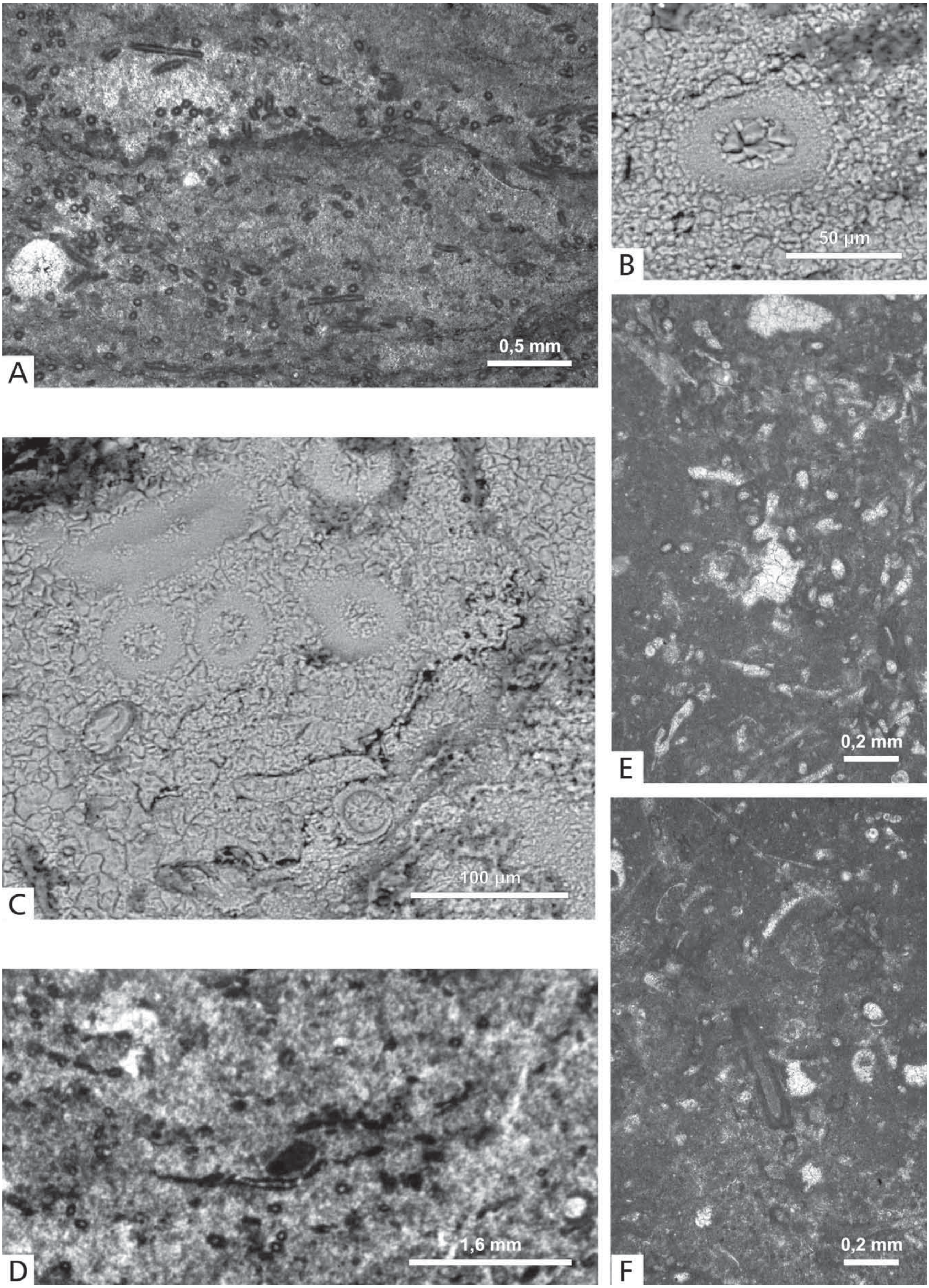
A
0,5 mm
B
50 μm
C
100 μm
D
1,6 mm
E
0,2 mm
F
0,2 mm

Table 1: Size characteristics and age relationships of *Decastronema barattoloi* (DE CASTRO), with textural features and biotic components.

Sections	Textures	Benthic foraminifera	Other biota	Age	Interpreted settings	*Decastronema barattoloi:* dimensions
Basovizza Dolenja vas Sopada Čebulovica	Wackestones Packstones	*Bangiana hanseni* Drobne Miliolids	Charophyta, Ostracods, Pelecypods	Danian SBZ 1	Inner most ramp, lagoons with restricted conditions	Length= 100–178 µm Inner diameter= 14–21 µm Outer diameter= 21–35 µm
Brnjci	Wackestones Packstones	Miliolids Rotaliids	Ostracods, Pelecypods, *Microcodium sp.*	Cuisian SBZ 11	Inner most ramp with restricted conditions	Length= 120–370 µm Inner diameter= 20 µm Outer diameter= 32–42 µm
Fučinska Koromačno	Wackestones Packstones	Rotaliids	Ostracods	Cuisian SBZ 11	Inner most ramp with restricted conditions	Length= 375 µm Inner diameter= 53 µm Outer diameter= 80 µm
Benkovac-Korlat	Wackestones Packstones	Miliolids Rotaliids	Pelecypods	Cuisian SBZ 11	Inner most ramp with restricted conditions	Length= 136–345 µm Inner diameter= 27–45 µm Outer diameter= 45–64 µm

4.3. Sedimentary environments

The Palaeocene in the Kras region is dominated by charophyta, rotaliid foraminifera (*Bangiana hanseni* in particular; DROBNE et al., 2007, pl. I, fig. D) and ostracods. The Eocene sediments from Istria, the northern Adriatic islands and Ravni kotari, contain in addition to cyanobacteria, rotaliid foraminifera, small miliolids, ostracods, and pelecypods in varying amounts. The presence of the cyanobacterial filaments across the time interval suggest that their appearance is related to colonization of newly emergent marine environments. Thus, *Decastronema* specimens can be recognized as organism-pioneers. Their role in populating environments is somehow controversial: they can operate as stabilizers providing an opportunity for other organisms to thrive, or they can prevent further diversification of organisms. Their abundance determines their role: if cyanobacteria are abundant (a condition known as "cyanobacterial proliferation") they form surface cover mats (GOLUBIC et al., 2006), and inhibit the introduction of other organisms and further biodiversification. If they are common, but not over expanded, they can be considered as organisms that change the environment in a manner that results in it being more hospitable by producing oxygen, and maintaining certain chemical properties and nutrient levels, all of which improve conditions for further colonization. In addition, sediments deposited under such conditions may have different taphonomic and diagenetic histories to sediments deposited in areas where cyanobacterial filaments are absent, (some skeletal grains are under represented, and some are more deteriorated). Scattered occurrences of microfossils from all studied sections favour the latter option. The widespread cyanobacterial remains are interpreted as a consequence of the increased concentration of nutrients. The intensive weathering on the land in the early Palaeocene and Early Eocene brought terrigenous input into the coastal settings, provoking low-light conditions, and susceptibility to salinity variations. *Decastronema* communities have benefited from all of these conditions. Such ecological changes in the shallow-marine environments of the AdCP were most probably linked with the palaeogeography of the area.

The differences between Palaeocene and Eocene filaments are summarized in Table 1. The Palaeocene forms are thick walled and smaller, up to ~180 µm long, hollowed tubes. The Eocene tubes (even segmented) reach up to 400 µm in length with varying wall thickness between 10 to 20 µm. Thus, *Decastronema barattoloi* is a potentially useful paleoenvironmental indicator, and therefore, this review is partly intended to be used as a tool to aid the reconstruction of depositional environments.

5. CONCLUSIONS

The Palaeocene (Danian) and Early Eocene (Cuisian) sediments from the External Dinarides (Kras region, Istria, Northern Adriatic Island, and Ravni kotari) are characterized by the presence of cyanobacterial filaments of *Decastronema barattoloi* (DE CASTRO). The Palaeocene specimens are minute (up to 180 µm), thick walled tubes that occur with the index fossil *Bangiana hanseni* DROBNE. The Eocene forms accompanied by ostracods, pelecypods, and miliolid and rotaliid foraminifera are segmented tubes, up to 400 µm long and usually thin walled. Their abundance within laminated sediments, redefined the stratigraphic range of the genus *Decastronema* from the Cretaceous to the Early Eocene. These microfossils are common within shallow-marine platform, peritidal sediments in the Perimediterranean region. Their concentration has been interpreted as a result of unstable (severe) palaeoecological conditions which favour the development of cyanobacterial mats. Nutrient enrichment favoured cyanobacterial distribution and generated the possibility to develop more diverse benthic assemblages in the subsequent evolutionary stages of the Adriatic Carbonate Platform.

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