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Paleocene beds of the Liburnia Formation in Čebulovica (Slovenia, NW Adriatic - Dinaric platform)

Paleocenske plasti Liburnijske formacije v profilu Čebulovica (NW Jadransko - dinarska platforma)

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Key words: biostratigraphy, algae, foraminifera, microfacies, paleoenvironment, Liburnia Formation, Maastrichtian, Paleocene (Danian, Selandian, Thanetian, SBZ 1 - SBZ 4), carbonate platform, Slovenia
Ključne besede: biostratigrafija, alge, foraminifere, mikrofacies, paleookolje, Liburnijska formacija, maastrichtij, paleocen (danij, selandij, thanetij, SBZ 1 - SBZ 4), karbonatna platforma, Slovenija

Abstract

The Liburnia deposits have been studied in a 150 m thick succession in vicinity of Čebulovica, on NW part of the Adriatic-Dinaridic carbonate platform. The studied section is exposed in road-cut of the motor-way Ljubljana - Koper (Trieste). The alternation of brackish deposits with characeans and marine sediments with dasycladaceans and foraminifera is the main feature of the succession. The marine sediments were deposited in intertidal settings of shallow-water ramp and coastal lagoons. About 60 emersions with typical structures on contact bedding planes and microcodium *(Paronipora)* were registered.

Owing to different stable isotope composition of $\delta^{13}C$ and $\delta^{18}O$ three types of limestone: marine, brackish and that one with freshwater influence were recognised. They were deposited at water temperature riching 27° to 30° C.

Limestone from the lower part of the succession (Danian, SBZ 1) contains characeans, *Lagynophora*, gastropods, algae *Aeolisaccus barattoloi* De Castro along with sporadic occurrences of foraminifera *Bangiana hanseni* (n.gen. n. sp.). In the upper part of the section (Selandian, SBZ 2) numerous algae *Decastoporella tergestina* Barattolo, *Drobnella slovenica* Barattolo, *Hamulusella liburnica* (Buser et Radoičić), *Microsporangiella buseri* Barattolo, *Cymopolia* spp. occur, while characean-bearing horizons are rare. The limestones with marine influences contain foraminifera *Kayseriella decastroi* Sirel and *Haymanella paleocenica* Sirel, along with textulariids, valvulinids and rare rotaliids.

The limestones of Maastrichtian age with *Rhapydionina liburnica* Stache form the base of the studied section. To overlying deposits, Thanetian in age (SBZ 3, SBZ 4) were attributed by foraminifera *Miscellanea juliettae villattae* Leppig, *Assilina yvettae* Schaub, *A. azilensis* (Tambareau), *Lacazina blumenthali* Reichel et Sigal, *Pseudolacazina donatae* (Drobne) and *Discocyclina* sp. The youngest deposits are alveolinid-nummulitid limestones with *Alveolina daniensis* Drobne of Early Ilerdian age (SBZ 6).

In the Čebulovica section the correlation between marine fauna and non-marine flora permitted to establish more than 5 million years of the Liburnia Formation deposition after the K/T boundary till Selandian. In the succession the Late Paleocene transgression or

the sea level change is reflected. This Thanetian to Ilerdian transgression connected the sedimentary areas in the northern margin of Tethys. Characeans and foraminifera allow the correlation westward to Pyrenees, while dasycladaceans and foraminifera eastward across Herzegovina, Apulia, Cephalonia Island and Greece to Turkey.

Kratka vsebina

V useku nove avtoceste in stare ceste med Postojno in Divačo so v 150 m debeli skladovnici razkriti paleocenski apnenci Liburnijske formacije. Značilna je vertikalna menjava ne-morskih in morskih plasti z bioto haracej na eni in dasikladacej s foraminiferami na drugi strani. Plasti podplimskega in medplimskega značaja so bile odložene na plitvi "rampi", v priobalnih lagunah, pogosto tudi v brakičnih in zaslajenih okoljih. Registriranih je preko 60 kratkotrajnih emerzijskih faz z značilnimi teksturami na kontaktnih ploskvah in z mikrokodiji *(Paronipora)*.

Po izotopski sestavi $\delta^{18}O$ in $\delta^{13}C$ ločimo 3 skupine apnencev: morske, brakične ter tiste, ki jih je zajela vadozna diageneza. Temperatura morja je občasno dosegla 27° do 30° C.

V spodnjem delu profila (danij, SBZ 1) med fosili dominirajo haraceje, *Lagynophora*, polži ter alga *Aeolisaccus barattoloi* De Castro ob redkih foraminiferah *Bangiana hanseni* (n.gen. n.sp.) v biomikritnih apnencih tipa mudstone - wackestone. V zgornjem delu profila (selandij, SBZ 2) so številne alge *Decastroporella tergestina* Barattolo, *Drobnella slovenica* Barattolo, *Hamulusella liburnica* (Buser et Radoičić), *Microsporangiella buseri* Barattolo, *Cymopolia* sp. in redkejši horizonti haracej. V apnencih s povečanim morskim vplivom (biospariti tipa packstone - grainstone) se pojavijo foraminifere *Kayseriella decastroi* Sirel, *Haymanella paleocenica* Sirel, med tekstulariidami, valvulinidami in redkimi rotaliidami.

Podlaga profilu so maastrichtijski apnenci z vrsto *Rhapydionina liburnica* (Stache). V krovnih plasteh so določene plasti thanetija (SBZ 3, SBZ 4) s foraminiferami *Miscellanea juliettae villattae* Leppig, *Assilina yvettae* Schaub, *A. azilensis* (Tambareau), *Lacazina blumenthali* Reichel et Sigal, *Pseudolacazina donatae* (Drobne), *Coskinon rajkae* Hottinger et Drobne, *Discocyclina* sp. Najmljaše plasti pripadajo alveolinsko-numulitnemu apnencu z vrsto *Alveolina daniensis* Drobne (SBZ 6, spodnji ilerdij).

Na Krasu smo v profilu Čebulovica s korelacijo morske favne z ne-morsko floro interpretirali redek fenomen, do 5 milijonov let trajajoče obdobje nastajanja plasti Liburnijske formacije po kredno / terciarni meji do vključno selandija. V zaporedju plasti se zrcali pozno paleocenska morska transgresija oz. dvig morske gladine. Ta v thanetiju in ilerdiju poveže sedimentacijske prostore na severnem robu Tetisa. Haraceje in foraminifere nudijo primerjave na zahod do Pirenejev, dasikladaceje in foraminifere pa na vzhod preko Hercegovine, Apulije, otoka Krfa in zahodne Grčije do Turčije.

INTRODUCTION

The highway construction between Postojna and Trieste provided the opportunity to study Liburnia beds of Paleocene age (Figs. 1 and 2). They were described in detail by G. Stache in the years 1859 to 1920. It is a sequence between rudist and alveolinid-nummulitid limestone which grades after a short hiatus in the crisis time of the K/T boundary in an intralittoral environment of the Adriatic-Dinaric carbonate platform. Today they are termed the Liburnia Formation (Jurkovšek *et al.*, 1996a).

Our objective was to perform lithologic and facial analyses of collected material. An especially rare opportunity has been offered for correlation of beds of brackish origin with those of marine development as documented by abiotic analyses.

The obtaind biostratigraphic and lithologic data on Paleocene beds in the Kras area enable correlation with contemporaneous beds in broader Mediterranean region, from Turkey (Sirel, 1998) via Greece (Fleury, 1980; Mavrikas, 1993; Accordi *et al.*, 1998) and Maiella Mts. in Abuzzi (Pignatti, 1994; Vecsei *et al.*, 1996), Herzegovina (Sliškowić *et al.*, 1978; Drobne *et al.*, 2000) to Istria (Bignot, 1972; Tari - Kovačić *et al.*, 1998; Marjanac T. *et al.*, 1998; Marjanac & Ćosović, 2000; Sakač & Gabrić, 2000) to Karst of Trieste (Pugliese *et al.*, 1995; Brazzatti *et al.*, 1996). Many genera and species are also common on the Paleocene development in Northern Pyrenees (Tambareau, 1972; Massieux *et al.*, 1989; Peybernés *et al.*, 2000).

The regional investigation of Čebulovica area was accomplished by B. Jurkovšek and

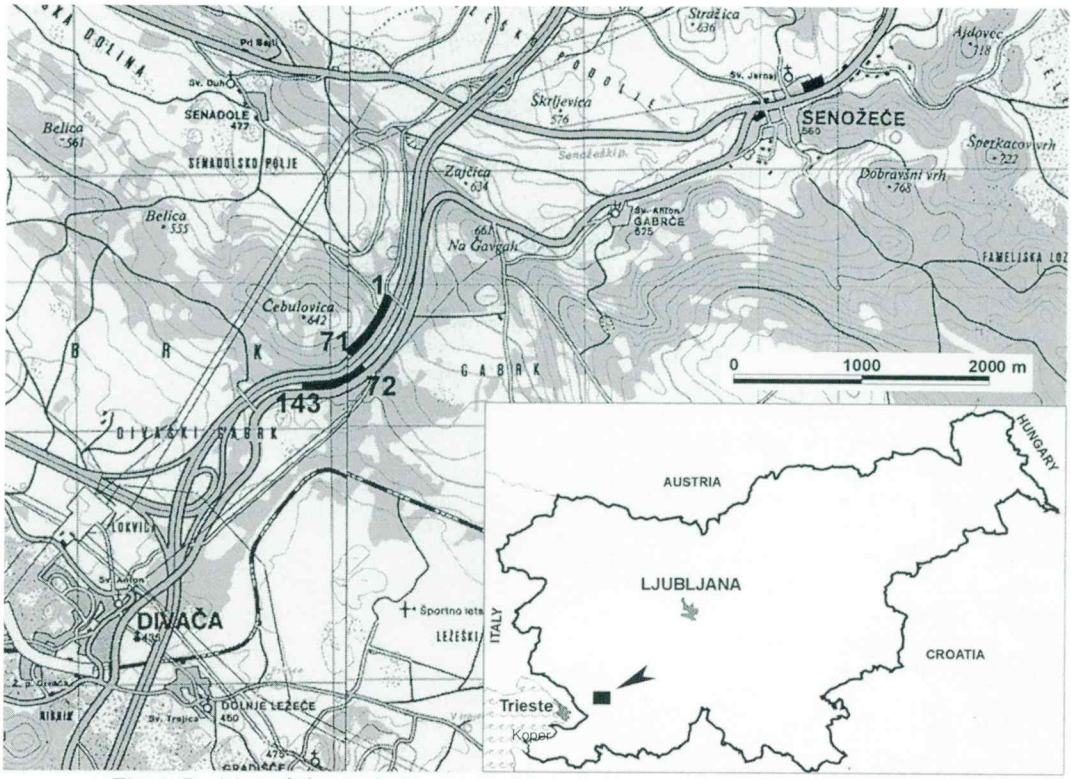


Fig. 1. Position of the studied section of Paleocene carbonate rocks of the Liburnia Formation at Čebulovica

Sl. 1. Položaj raziskanega profila paleocenskih karbonatnih plasti Liburnijske formacije pri Čebulovici

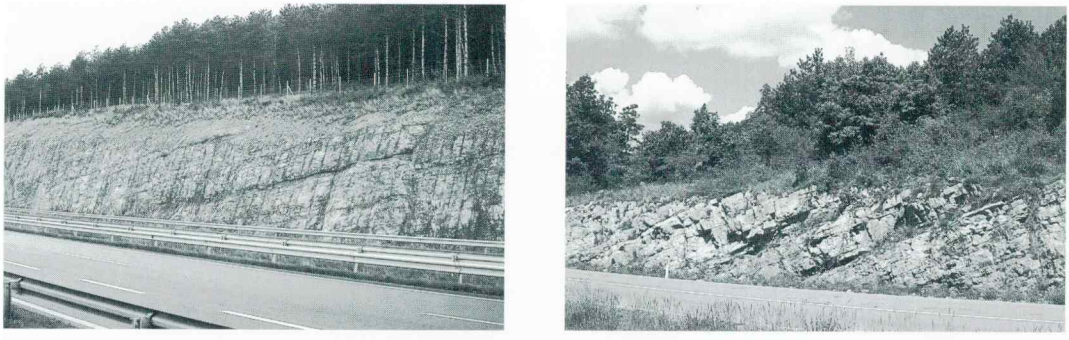


Fig. 2a. Lower part of the studied sequence along the highway at Čebulovica (samples Čeb 1-71)
Fig. 2b. Upper part of the investigated sequence along the old road between Senožeče and Divača (samples Čeb 72-143)

Sl. 2a. Spodnji del raziskanega profila ob avtocesti pri Čebulovici (vzorci Čeb 1-71)
Sl. 2b. Zgornji del raziskanega profila ob stari cesti med Senožečami in Divačo (vzorci Čeb 72-143)

Photos / Fotografije : M. Toman

M. Toman and the profile elaborated by B. Ogorelec and M. Toman, at the early beginning also by Luka Šribar. Microfossil determination, biostratigraphic and final chapters were performed by K. Drobne, isotopic analyses of $\delta^{18}O$ and $\delta^{13}C$ by T. Dolenec. Sedimentological analyses, microfacies interpretation of carbonate rocks and graphics

were done by B. Ogorelec. All documentation is maintened in the archive of Geological Survey of Slovenia.

PREVIOUS STUDIES

G. Stache (1889) was the first who studied Paleocene carbonate rocks and named them collectively the "Liburnia stage" (Liburnische Stufe) after the Liburnia area along the Adriatic coast, between the rivers of Raša and Krka. They were subdivided into three parts: lower foraminiferous limestone, upper foraminiferous limestone and the beds between them which were named the Kozina beds.

Later, different names were given to some members of the Liburnia Formation. Lower foraminiferous limestone was named Vreme beds (Pavlovec, 1963, Tab.1), while the upper foraminiferous and operculina limestone were named the Trstelj beds. Owing to numerous algae (Buser & Radoičić, 1987) and other lithological characteristics, Delvalle and Buser (1990) introduced a new name for the upper foraminiferous and miliolidal limestone - the Slivje Formation according to the village of Slivje located in the southwestern margins of Brkini. Thickness of the Liburnia Formation varies in the studied area of Kras. According to Hamrla (1959, 1960), it amounts to 400 m. The thickness of the upper foraminiferous limestone (the Slivje limestone) ranges from 50-150 m in the studied area (Jurkovšek *et al.*, 1996a, 55, Fig.10).

Geology of the western part of Slovenian Dinarides, more precisely, the broader area of the Trieste-Komen plateau, was extensively studied during the last fifteen years. Particularly interesting are the beds at the K/T boundary for their shallow water carbonate development and biostratigraphy, paleontology, sedimentology of Paleocene beds: (Drobne *et al.*,1988, 1989, 1994, 1995, 1996; Pugliese *et al.*, 1995; Jurkovšek *et al.*,1996a,b, 1997; Delvalle & Buser, 1990; De Castro *et al.*, 1994; Caffau *et al.*, 1995; Knez, 1994, 1996; Knez & Pavlovec, 1990; Dasycladaceans: Barattolo, 1998; Corals: Turnšek & Drobne, 1998; abiota: Dolenec *et al.*, 1995; Ogorelec *et al.*,1995; Hansen *et al.*,1995, 1996; Marton *et al*; 1995; Palinkaš *et al.*, 1996; Otoničar & Košir, 1998; Late Cretaceous dinosaurs, crocodiles: Debeljak *et. al.*, 1999). All geological bibliography concerning Slovenian and Italian part of Kras is compiled in the papers of Pavlovec *et al.* (1989) and Martinis (1989).

GEOLOGICAL SITUATION OF THE PROFILE

The Čebulovica section is situated in the middle of a 4 km wide area between the Raša and Divača faults of dinaric direction (Buser, 1968, 1973).

Except for a few metres at the K/T boundary, the studied profile is well exposed in a 650 metres long roadcut and encompases 160 m thick carbonate succession. The lower part of the profile (samples Čeb 1-71), was taken along the new highway cut while the uppermost forty metres of the profile (samples Čeb 72 to 135) were studied along the old road (Figs.1 and 2). The profile terminates along a tectonic boundary. Field work was accomplished during the highway construction between 1996 and 1997.

For microfacial and paleontological analyses, over 160 samples were collected with regard to the changes of facial associations.

In the profile, the majority of beds belongs to the Liburnia Formation, characterised by alternation of marine, brakish and fresh-water sedimentary environment.

In its lower part the Čebulovica profile is apparently quite monotonous, although several lithologic types of limestone alternate. This indicates longlasting uniform sedimentation conditions in a shallow and quiet marine environment in which perennial emersions and fresh-water influence occurred. Breccias and paleokarstification are related to the emersion phases. In the profile, over 60 such interruptions of sedimentation were recognised.

LITHOLOGY AND MICROFACIES

The profile begins immediately below the K/T boundary, continues with bedded lime-

stone of the Danian to Thanetian age and terminates with alveolinid-nummulitid limestone of the Ilerdian age (Figs. 3 and 10).

Maastrichtian: The beds underlying the K/T carbonate breccia belong to gray, slightly bituminous biomicritic limestone. Its Upper Cretaceous, Maastrichtian age is indicated by rare foraminifera of *Rhapydionina liburnica* (Stache) (Pl. 1, fig. 1). Besides *Rhapydionina*, other small foraminifers, thin molluscan shells and algae also occur. According to the texture, the limestone can be classified as mudstone to wackestone. The beds are from 5 to 20 cm thick and commonly show faint lamination. Limestone was deposited in a very shallow protected subtidal environment with traces of pyrite pigment and organic matter.

K/T boundary: The boundary is represented by emersion limestone breccia with up to several cm thick clasts which still have been plastic at the time of deposition. Local emersion phases and paleocarstic phenomena, are indicated by solution cavities, shrinkage pores and rhysocodium structures (Fig. 3; Pl. 1, fig. 2). In the matrix of biomicritic limestone, characean gyrogonites, foraminifers and small gastropods occur. Intensive bioturbation can also be observed.

Rocks indicating the boundary are developed similarly as in Dolenja vas (Drobne *et al.*, 1988, 1995, 1996), Sopada (Jurkovšek *et al.*, 1996a, Ogorelec *et al.*,1995) and Padriciano (Pugliese *et. al.*, 1995; Brazzatti *et al.*,1996).

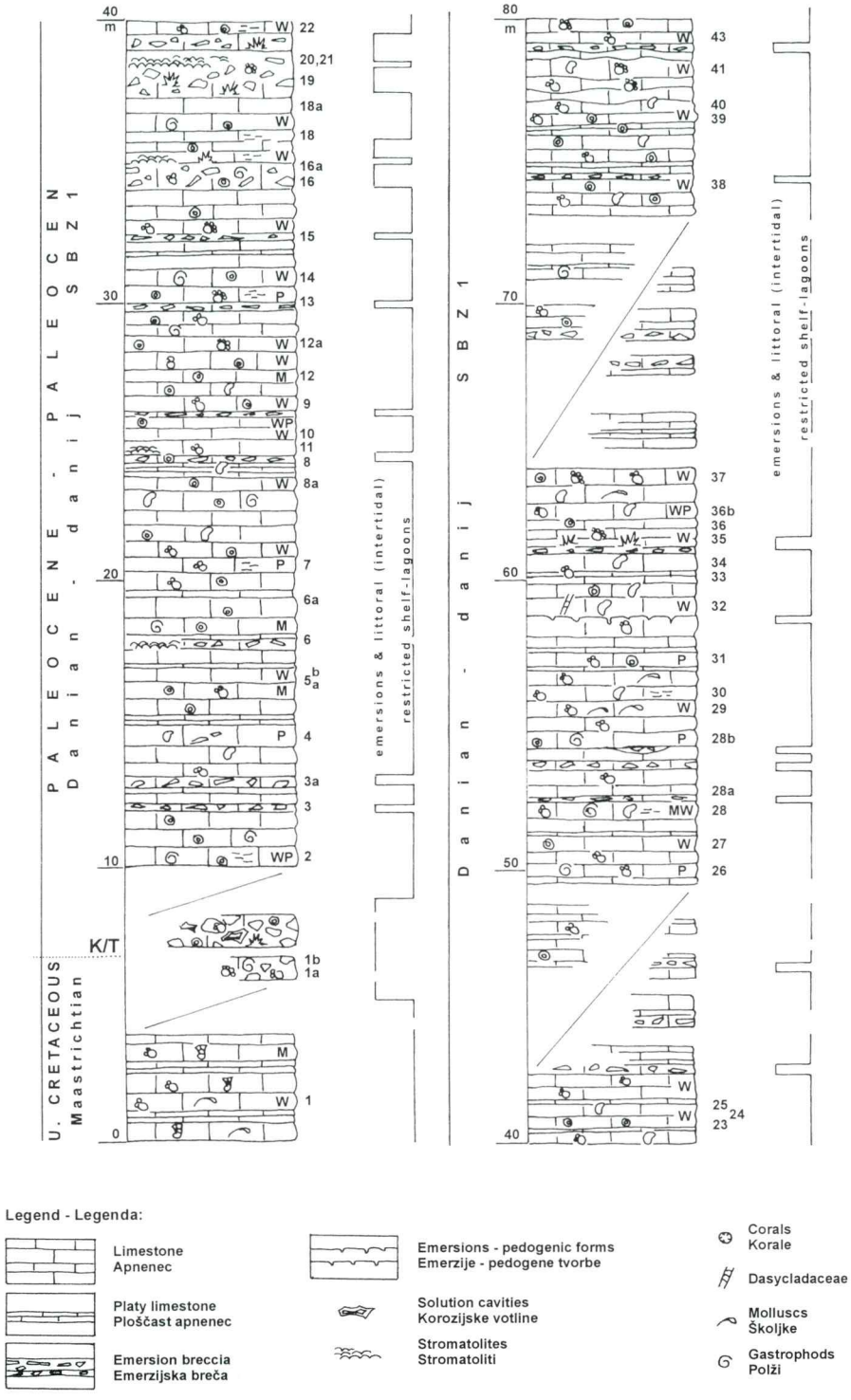
Paleocene: In the entire 120 metre interval of the lower part of the profile (samples Čeb1-71, Fig. 1) 10-30 cm thick beds of medium-gray and dark-colored limestone occur. It is characterised by alternation of various textural types (Fig. 3). The most common is biomicritic limestone of the mudstone and wackestone type. The dominant fossils are small foraminifers, ostracods, characean gyrogonites and lagynophoras. Some of the samples also contain small gastropods and molluscs. The mudstone and packstone type is also encountered. Some beds are so rich in characean gyrogonites that they can be referred to as characean limestone.Very commonly, mm-sized lamination can be observed in the limestone (Pls. 1, 2, 3).

Biomicritic limestone is commonly interrupted by beds indicating intratidal facies and short emersions (Figs. 4-6). They are characterised by flat pebble conglomerate, shrinkage pores (loferitic limestone), stromatolites, and particularly emersion breccias and rhysocodium structures. Microcodium *(Paronipora)* occurs in different varieties, most commonly in cylindrical lamellar colonies, but very frequently its calcite prisms are thoroughly destroyed (Pl. 1, fig. 2; Pl. 5, fig. 2). In the some layers, colophane is common, too.

Limestone from the lower part of the Čebulovica profile (Čeb 1-71) has been deposited as carbonaceous mud in a very shallow and low-energy environment of protected shelf and lagoons. Supratidal breccia and paleosoil layers indicate episodic emersion phases in the study area. In the lowermost 120 m of the profile, 38 of such phases were recognised. The presence of characeans and lagynophoras indicates episodic desalinization of marine water or changing of marine and brakish or even fresh-water environment. In the literature such type of sedimentation is termed as palustrine environment or palustrine limestone (Freytet, 1964; Freytet & Plaziat, 1982). The authors studied Upper Cretaceous and Paleocene beds in southern France. Palustrine sedimentary environment of Liburnia Formation in SW Slovenia is recently studied by Otoničar and Košir (1998; Košir, 1998). The influence of freshwater on sedimentation of characean limestone and meteoric conditions during early diagenesis can also be confirmed by isotopic analyses of $\delta^{13}C$ (Fig.12, this contribution).

According to the standard microfacies classification (SMF, Wilson, 1975), the limestone from the lower part of the Čebulovica profile can be classified as SMF 16-20 which denotes an environment with limited water circulation and muddy sea bottom. Mudstone and wackestone textural types of limestone prevail. Facial zones FZ 7-8 are characterised by sedimentary condition of restricted shelf, lagoons and intertidal cast belt. Thin emersion breccias correlate with SMF 24.

Episodic hypersaline conditions instead of brackish ones can be assumed by rare stromatolitic beds and small gypsum crystals which replaced calcite. Monotonous sedimentation in littoral and lagoonal envi-



Legend - Legenda:

Limestone
Apnenec

Platy limestone
Ploščast apnenec

Emersion breccia
Emerzijska breča

Emersions - pedogenic forms
Emerzije - pedogene tvorbe

Solution cavities
Korozijske votline

Stromatolites
Stromatoliti

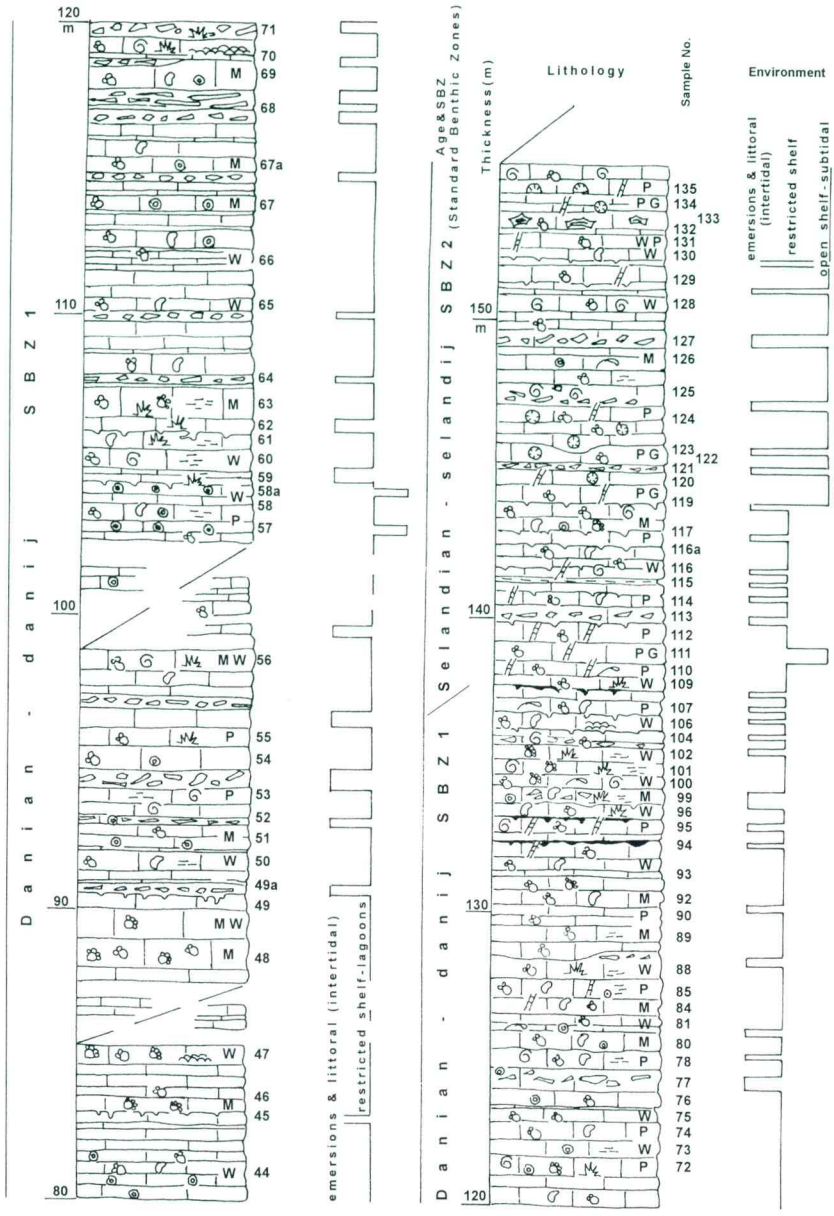
Corals
Korale

Dasycladaceae

Molluscs
Školjke

Gastrophods
Polži

Fig. 3. Lithostratigraphic column of Paleocene beds of Liburnia Formation at Čebulovica
Sl. 3. Litostratigrafski stolpec paleocenskih plasti Liburnijske formacije pri Čebulovici



Ostracoda
Ostrakodi

Lagynophora

Characean gyrogonites
Girogoniti haracej

Echinoderms
Ehinodermi

Foraminifera in general
Foraminifere v splošnem

Rhapydionina liburnica

Mikrokodiji (*Paronipora* sp.)

Ooids
Ooidi

Shrinkage pores
Izsušitvene pore

M, W Textural type of rock
Strukturni tip kamnine
(Dunham, 1962)

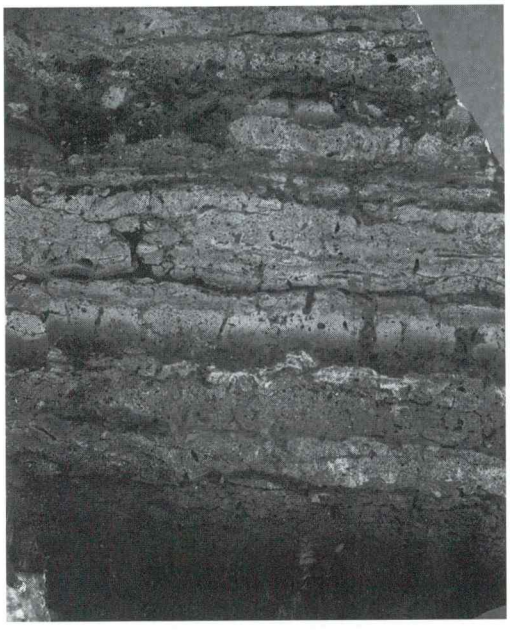


Fig. 4. Laminated limestone with textures indicating intertidal sedimentary environment (shrinkage pores and mud cracks). Čeb 64, 0,8x

Sl. 4. Laminiran apnenec s teksturami, značilnimi za medplimsko okolje (izsušitvene pore in razpoke). Čeb 64, 0,8x

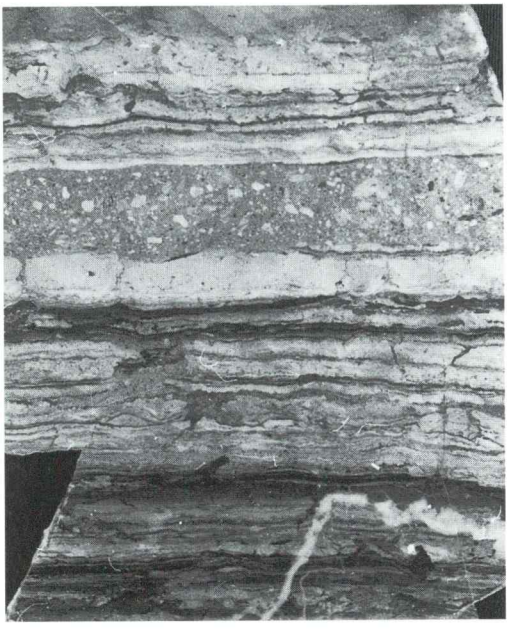


Fig. 5. Stromatolitic limestone passing into laminite with intertidal textures and fine - grained emersion breccia. Čeb 70, 0,8x

Sl. 5. Stromatolitni apnenec prehaja v laminit z medplimskimi teksturami in drobnozrnato emerzijsko brečo. Čeb 70, 0,8x

ronment of a restricted shelf was only seldom interrupted by somewhat higher energy index. This is indicated by the presence of ooids in the samples Čeb 56 an 58. They were displaced from the open shelf (Pl. 3, fig. 3). Very rarely and to a small extent some limestone beds underwent early diagenetic dolomitisation. Dolomitised are only the horizons which were affected by supratidal conditions. The proportion of micritic dolomite does not exceed 10 % of the bulk rock.

Uppermost 35 m of the profile (samples Čeb 72 to 135) are characterised by lighter and somewhat more thickly bedded limestone. Limestone is still biomicritic wackestone and packstone. Among fossils, foraminifers, mainly miliolids prevail, and they are accompanied by ostracods. In many beds characeans, lagynophoras, dasycladals and small gastropods can also be encountered. The algae are particularly abundant in the samples Čeb 95 to 124 (Pls. 4, 5, 6).

In the upper part of the profile sedimentation was interrupted by numerous short-lasting emersion phases. In a 30 metre interval, 22 emersion phases occur. They are recognised as paleosoil layers characterised

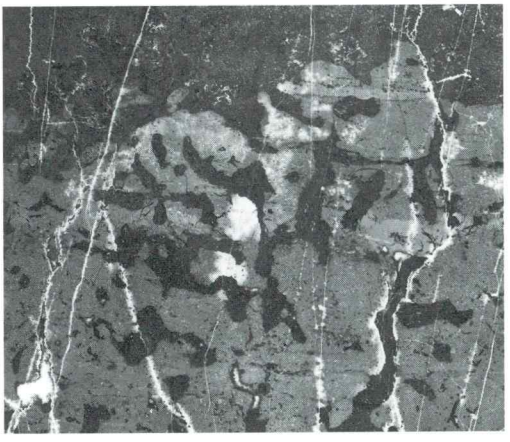


Fig. 6. Biocorrosion contact along two micritic layers, indicating short lasting emersion - pedogenetic pseudo-microkarst (see also Fig.9) Čeb 119, 0,5x

Sl. 6. Biokorozijski emerzijski kontakt med dvema mikritnima plastema - pedogeni pseudo-mikrokras (glej še sl.9). Čeb 119, 0,5x

Fig. 7. Emersion breccia along the layer contact. Čeb 125

Sl. 7. Drobna emerzijska breča na kontaktu dveh plasti. Čeb 125

Fig.8. Gastropode accumulation in biosparitic limestone. Čeb 126

Sl. 8. Številni polži v biomikritnem apnencu. Čeb 126

Fig. 9. Layer of dolomitised biomicritic limestone, truncated by an emersion surface and intensively burrowed with cavities (see Fig. 6); - pedogenetic microkarst Čeb 119

Sl. 9. Plast dolomitiziranega biomikritnega apnenca s številnimi biokorozijami votlinicami (glej sl. 6); - pedogeni mikrokras. Čeb 119

Photos / Fotografije : K. Drobne

by microcodium structures, by shrinkage pores, stromatolites and supratidal breccias. In some solution cavities gravitational cement occurs indicating vadose diagenetic environment (Pl. 4, fig. 2).

Above the sample Čeb 118, the limestone gets lighter and shows higher energy index. It is packstone to grainstone, intrabiomicrite to biocalcarenite according to the texture, which was deposited in a shallow subtidal open shelf. Characteristics of the littoral facies and characeans become very rare. Solitary corals are rare. The most common fossils in some layers are dasycladaceans (Čeb 120-124, 134; Fig. 10; Pl. 6, fig. 2).

In a 50 metre thick section above the Če-

bulovica profile, 7 limestone samples were collected (Čeb 137-143). They were not included in the profile owing to discontinuity of the sample position and vegetation cover. This carbonate section is schematically shown in Fig.10. It is interesting for the occurrence of large foraminifers and other biota, and microfacies.

According to the texture, this limestone can be classified as packstone to grainstone, or biocalcarenite (Pl. 7, fig. 1 and 2). Besides nummulitids and alveolinas, the biota also consists of coralinacean algae (Pl. 6, fig. 3) echinoderms, miliolids and rare corals. Limestone was deposited on a shallow shelf characterised by relatively high energy. According to the standard classification it belongs to the FZ zone 6. The sample Čeb 143 is followed by a broad tectonic zone and belongs to alveolina limestone (Pl. 7,fig. 3).

BIOSTRATIGRAPHY

Biostratigraphic interpretation applied in this paper is mainly based on larger foraminifera using the Shallow Benthic Zonation (SBZ 1-20, Serra -Kiel *et al.*, 1998). The zones are defined by appearance of index species throughout particular sections in the Tethyan realm, from Pyrenees to East India, from K/T boundary to Oligocene. The biozones are more or less in accordance with the nannoplankton and planktonic zonations (some discrepancies are known around Pc/E boundary), with the magnetostratigraphy and with the absolute age. In the Trans-tethyan longrange biota-based correlation data from the following sections in SW Slovenia and Istria are included: Dolenja vas, Veliko Gradišče, Golež, Pićan and Ragancini-Lišani (Drobne & Pavlovec, 1991).

In the subdivision of Paleogene in Shallow Benthic Zones SBZ 1 - SBZ 20 the propositions of International Subcommission for Chronostratigraphic units of Paleogene stratigraphy are considered (Jenkins & Luterbacher, 1992; Odin & Luterbacher, 1992).

The studied carbonate rocks from the section Čebulovica are of Danian and Selandian (Paleocene) age. These Paleocene sediments overlie Upper Maastrichtian deposits, and are overlain by limestones of Thanetian and Ilerdian age. The particularity of the studied section is alternation of marine, lagoonal and brackish sediments, suggesting connection between marine and hyposaline settings, close to coastline during the deposition. Characteristics of intertidal and supratidal environment are reflected in emersions of which about 60 were established.

About 150 m thick sediment succession with facies alternation, permits determination of brackish deposits after marine organisms. In general, characean remains incorporated in limestones, studied from thin - sections, do not allow the determination on the species level. This work represents the first attempt to correlate and define the age of these different facies in Kras. On the top of this succession, well defined is the Late Paleocene Thanetian transgression resp. rise of the sea level that covered after 5 million years the entire region of present SW Slovenia (Figs. 3, 10; Pls. 1, 3, 4, 5, 7).

Marine biota

Shallow-marine limestone contains dasycladaceans and smaller benthic foraminifera known as r-strategists related to meso- to eutrophic conditions, such as discorbiids, polymorphinids, milioliids, textulariids, valvulinids and rotaliids (Hohenegger *et al.*, 1989; 1993). Index species are rare. *Bangiana hanseni* n.gen. n.sp (Drobne, in press) known as ex *Protelphidium* sp. (Drobne *et al.* 1988, Pl. 25, figs. 8-11) occurs in samples described as Čeb 1b - 85 (Pl. 9, figs. 16 - 20). Sporadically *Kayseriella decastroi* Sirel occurs, too. In those overlying layers with more marine character *K. decastroi* and *Haymanella paleocenica* Sirel are frequent (Pl. 9, figs. 1 - 6).

Succession of sediments above K/T boundary described as samples Čeb 5 to 65 contain *Aeolisaccus* barattoloi De Castro (Pl. 8, fig. 5), and *Parkerella* sp. in its whole lenght, while *Thaumatoporella* sp. specimens are confined to lower part. *A. barattoloi* (Cyanophyta) might be considered as a K/T survivor. The species is characterized by thinner wall tubes and smaller sizes than its Cretaceous relative *A. kotori* Radoičić.

Dasycladaceans are present in the samples from Čeb 33 to 134 (Fig. 10). At the beginning of algal-bearing succession *Decastroporella tergestina* Barattolo and *Drobnella slovenica* Barattolo (Pl.8, figs. 1 - 3) are rare. Towards the top of the section they are common among *Hamulusella liburnica* (Buser et Radoičić). Samples described as Čeb 110 and higher contain *Microsporangiella buseri* Barattolo (Pl.8, fig.4), *Cymopolia mayaense* Johnson et Kaska and *C. paronai* Ranieri (Pl. 4, fig.3; Pl. 5, fig. 3).

Non - marine biota

Limestone samples contain numerous characean gyrogonites (Characeae) or preserved whole stems, branches or gyrogonites of Lagynophoreae. Gastropods *Stomatopsis* Stache, *Cosinia* Stache and *Kallomastoma* Stache (Stache, 1889, Pls. 1 - 6; Knez, 1996) occur, too.

Owing to its easy recognition *Lagynophora liburnica* Stache is chosen as index fossil for Early Paleocene. Known data on Late Maastrichtian and Paleocene of Kras (Hamrla 1959, 1960), and Stache's works (1889, p. 86) allow us to conclude that the occurrence of *Lagynophora* Stache and *Kallomastoma* Stache indicates the Paleocene age of sediments. These species are present in the studied section up to samples Čeb 128 (Pl. 3, figs. 1, 2; Pl. 8, fig. 6; Figs. 10, 11).

Sediments from intertidal setting contain microcodium (*Paronipora* sp., Pl. 1, fig. 2; Pl. 5, fig. 2). A. Košir (1998; 2001 - under review) deals with appearance, genesis and diagenesis of Microcodium from sediments in SW Slovenia.

Age

The occurrence of algae *Aeolisaccus barattoloi* and *Bangiana hanseni* implies Danian age (SBZ 1) of sediments that contain them. Selandian (SBZ 2) age is determined after frequently occurrence of *Drobnella slovenica, Decastroporella tergestina, Kayseriella decastroi* and *Haymanella paleocenica*. Consequently, characean-bearing limestones (*Lagynophora* sp.) are of Paleocene age with regard to marine fossils. Additional microfossil associations are represented on the Plates 8, 9 and Figs. 10, 11.

Overlying limestones

We were able to recognise 4 limestones successions separated by faults (Fig.10). In the first interval (samples Čeb 136-138) numerous specimens of *Miscellanea juliettae villattae* Leppig, *Periloculina* sp., *Idalina* sp., *Coskinon rajkae* Hottinger et Drobne and *Assilina* sp. occur, indicating Thanetian age (SBZ 3) (Pl. 10, figs. 1- 5, 7).

The second and the third limestones interval (samples Čeb 140-143) both contain, along with miscellaniids, numerous specimens of *Ass. yvettae* Schaub, *Ass. azilensis* (Tambareau), *Pseudolacazina donatae* Drobne, *Lacazina blumenthali* Reichel et Sigal, first orthophragminids, rotaliids and algae *Distichoplax biserialis* Dietrich (Pl. 7, fig. 1; Pl. 11, figs. 1-4). Fossil content indicates SBZ 4 (Late Thanetian). Boundstones are composed of coral debris encrusted by corallinaceans, colonial corals (*Astrocoenia lobato - rotundata* (Michelin, 1842), *Goniopora* sp. and *Acropora* sp.) and foraminifera scattered among them (Pl. 7, fig. 2).

The fourth limestone interval is a alveolinid-nummulitic limestone. Sphaerical alveolinids, *Alveolina daniensis* Drobne along with less numerous *Ranikothalia* sp. are scattered throughout micritic matrix. Early Ilerdian, SBZ 6 (Serra - Kiel *et al.*, 1998), is identified (Pl.7, fig.3).

Upper Paleocene sediments from Čebulovica section testify open marine influence. These trends continued through Eocene, alveolinid-nummulitic limestones overlie Paleocene ones. Additional microfossils are represented on Plates 7, 10, 11 and Fig. 10.

Characean bearing beds

Lamarck and his collaborators in 1804 for the first time described characeans from Paris and Pyrenean basins. The first written record on fossil characeans is from 1740 (Soldani, cf. Ercegovac, 1981). Characeans constitute a good biostratigraphical tool in non-marine deposits (Riveline *et al.*, 1996, fig. 4). The Creta-

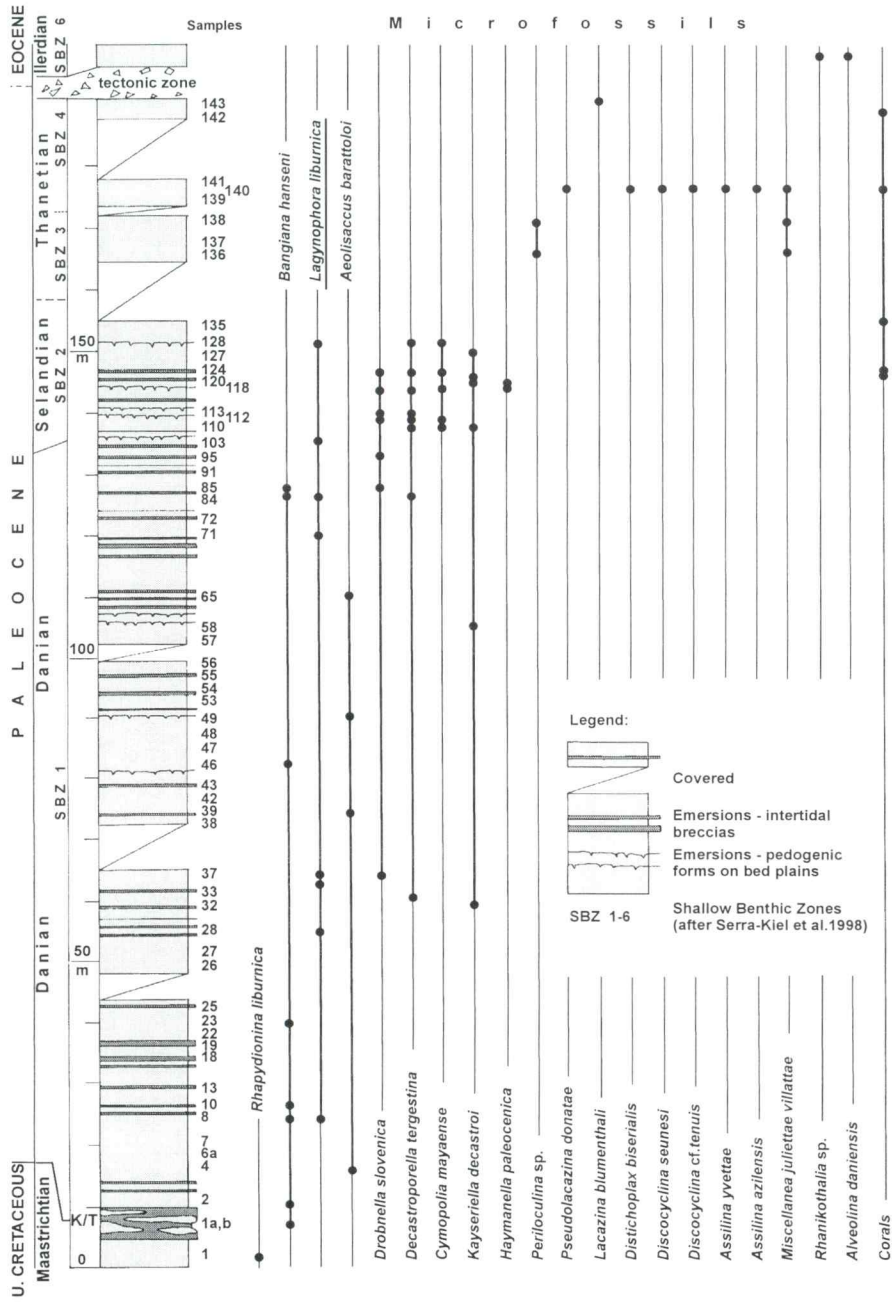


Fig. 10. Section Čebulovica: position of samples, emersions, (Fig.3), and selected biota from top of Maastrichtian to overlying Eocene beds.
Biota reflect the alternation of intertidal to shallow-marine sedimentation. Besides it is on interest the relationship among lagynophora and dasycladals as well as among smaller to larger foraminifera (r- : K- strategists).

Sl. 10. Profil Čebulovica: pozicija vzorcev, emerzije (sl. 3) in pojavljanje izbranih taksonov od maastrichtijske podlage do eocenskih krovnih plasti.
Spremembe v sedimentaciji reflektira biota, značilna za plasti medplimskega okolja in zaprtega šelfa na eni in odprtega šelfa na drugi strani. Zanimivo je razmerje med laginoforami in dasikladacejami ter malimi in velikimi foraminiferami (r- : K- strategi).

ceous to Paleocene characean biozones from Mediterranean realm and western Europe are based on determination of calcified fructifications, so-called gyrogonites (Grambast, 1971; Massieux *et al.*, 1989; Mebrouk *et al.*, 1996; Riveline *et al.*, 1996, 455). Classic ground for such studies are also nowadays next to Algeria (Mebrouk & Feist, 1999) the Pyrenees. Their abundance, one kg of sediments from Can Casadessus section, bay of Lyon, contain several hundreds of isolated gyrogonites (Martin - Closas *et al.*, 1999), makes them valuable markers for correlation between marine and non-marine realms. From this study area, derived the larger foraminifera - Charophyta correlation for the Early Lutetian to Late Bartonian time (SBZ 13 - 20; *ibidem* 1999).

In Kras, SW Slovenia, the nucleus of Liburnia formation is a coal basin that stretches over 15 km from Vremski Britof to Opicina, while its smaller branch stretches towards Rodik (Hamrla, 1959; figs. 1, 6; 1985/86). Cretaceous coal, constituent of lower part of the Liburnia deposits, was exploited for years. It is overlain by shallow-marine Paleocene sediments larger exposure. Liburnia deposits composed of both, Cretaceous and Paleocene sediments, where characean and gastropod remains are prevailing. G. Stache (1880, 1889) described 7 genera and 18 species, 17 species and subspecies were new, of Lagynophoreae and Characeae families from these deposits. His species description contains biology of algae, their growth patterns, reproduction cycles, fossilisation, synonymy, and is accompanied with good drawings (1889, 122-130), (Fig. 11). In order to shed more light on specific sedimentologic conditions during the formation of the Liburnia deposits, G. Stache (1889, p. 125) gave the lists of detailed descriptions of areas with living characeans from the South America, Africa and Mediterranean.

Grambast (1971) and later researchers studied Characeans from Pyrenean basin, Paris basin and Liburnia deposits resulted in new taxonomy and biostratigraphic evaluation. But, Stache's genera *Lagynophora* and *Kosmogyra* are still valid (Bignot, 1972; Ercegovac, 1981; Knez, 1996).

We chose to re-print Stache's drawings (Pl. 4, figs. 10, 11, 2, 3) of *Lagynophora liburnica* Stache, *Kosmogyra superba* Stache and *K. perarmata* Stache from the monograph titled "Die liburnische Stufe ....", Wien, 1889., to honour his pioneer work on characean taxonomy, biostratigraphy and paleoecology. Reproductive bodies and vegetative elements are well preserved, implying fossilisation settings to be quite, low-energy environment with short transport mechanism. It is a real rarity to find such well perserved *Lagynophora* "bouquet" of gyrogonites in sediments from the Adriatic platform (Pl. 3, fig. 2; Pl. 8, fig. 6; Fig. 11).

Intraregional correlation in Kras

The sedimentologic characteristics and thickness allows us to correlate sections of Čebulovica with Padriciano (Kras of Trieste). Both stratigraphic sequences show alternation of shallow-marine carbonates with lagoonal and palustrine deposits. Emersions recognised by microcodium (*Paronipora* sp.) occurrences and sedimentologic features are present in both sections. Similarity is better observable in lower part of the sections (SBZ 1, SBZ 2). Foraminiferal associations from Thanetian beds (SBZ 3, SBZ 4) might be correlated, too (Drobne *et al.* 1988; Pugliese *et al.* 1995; Brazzatti *et al.* 1996; Turnšek & Drobne, 1998, fig.3). We have to note that today Čebulovica and Padriciano sections are parts of different geostrucural units separated by the Divača fault (Jurkovšek *et al.*, 1996a).

SW along the main road towards Divača, 2.5 km away from Čebulovica section, characean-bearing deposits, once described by Stache (1880, 1889), have been re-collecetd by M. Knez (1996). The high-way construction in 1996 destroyed the characean sites. The Divača section, according to Knez (1996), total thickness is about 25 m, is composed of 4 limestone types: A-type consists of *Lagynophora* sp. stems; B-type contains only Chara gyrogonites; C-type is mixture between A- and B-types with gastropods; D-type is made up of gastropods (Knez, 1996, Figs. 10, 11, 12). Carbon and oxygen isotope data (Herlec, pers. data)

G. Stache, Die Liburnische Stufe und deren Grenzhorizonte. I. Abtheilung.

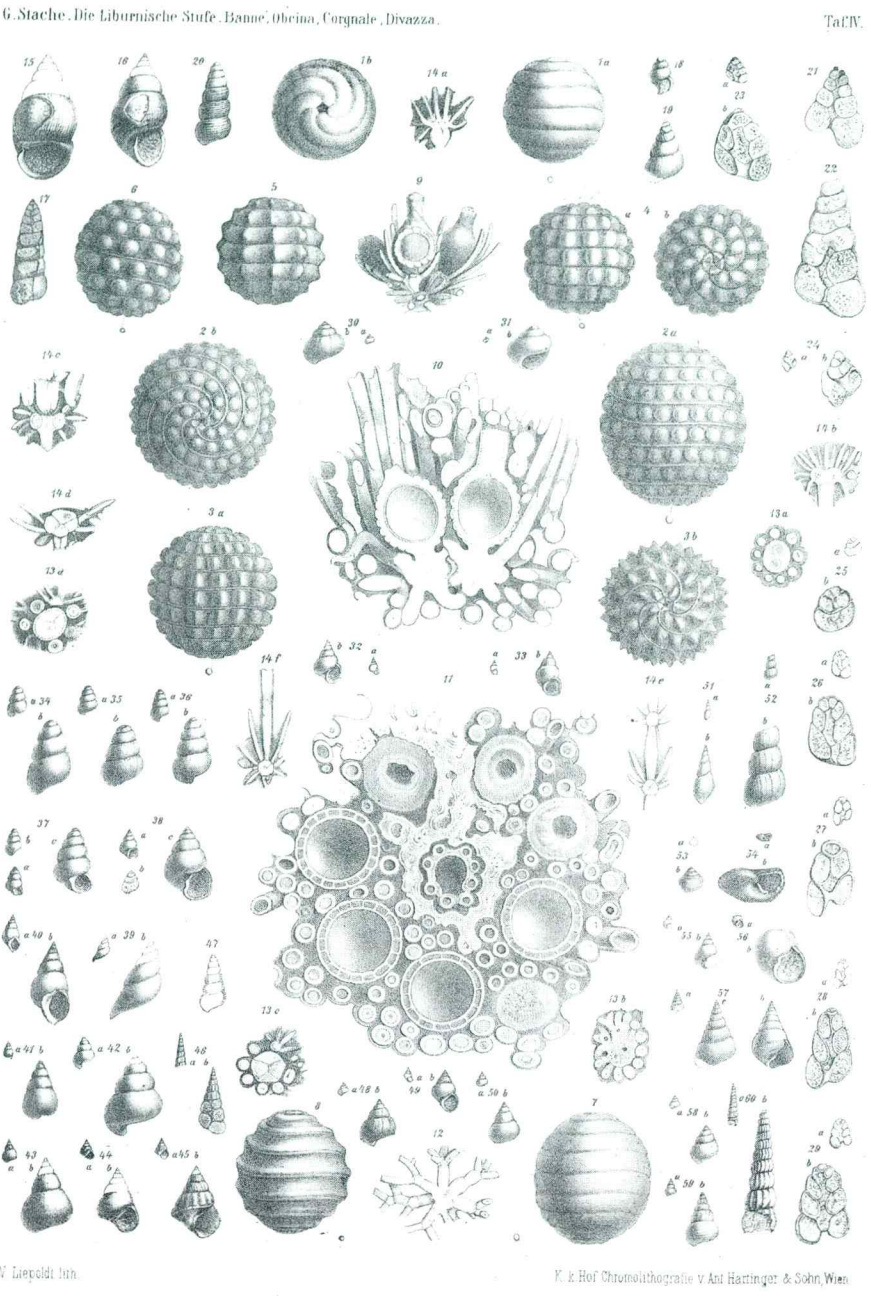
Krainisch-nordistrisches Verbreitungs-Gebiet.

Taf. IV.

Faunen- und Floren-Reste des Characeen-Kalksteins.

Fig. 11. Faximile of the Plate IV, from G. S t a c h e' s work "Die Liburnische Stufe" (1889), see the species of genera *Kosmogyra* (figs 2 - 6) and *Lagynophora* (figs 9 -16).

Sl. 11. Reprodukcija table IV iz dela G. S t a c h e j a, "Die Liburnische Stufe" (1889). Poudarek je na slikah vrst iz rodu *Kosmogyra* (2 - 6) in *Lagynophora* (9 - 16).


G. Stache. Die Liburnische Stufe. Banne, Obcina, Corgnale, Divazza.
Taf. IV.
W. Liepoldt lith.
K. k. Hof Chromolithographie v. Ant. Hartinger & Sohn, Wien

indicate repeated freshwater incursions during the sedimentation of limestones. It is interesting to note that sediments from Divača section are more rich in characean remains than sediments from Čebulovica. The characean adundances might be interpreted as results of close position to basin axis. Correlation between Čebulovica and Divača sections demostrates an abrupt lateral change in sedimentation of Liburnia deposits.

In relation to the section Dolenja vas, 5 km north of Čebulovica, the marine development prevails from K/T boundary till Thanetian beds, what indicates the closer position to the open sea in the northern direction (Drobne *et al*,. 1988, 1989, 1996; Turnšek & Drobne, 1998, fig. 3).

Interregional correlation of Paleocene in Central Tethys

Lithologic and paleoecologic features of Danian and Selandian sediments from the Čebulovica section indicate rare marine incursions. Peritidal environments with palustrine conditions provoked sporadic occurrences of foraminifera and dasycladal algae, but very offten characean beds with alternation of about 60 emersions (Figs. 3, 10). Similar developments of Paleocene beds were selected for comparison with ours in the central Tethys, its west and its east parts.

In the north part of Pyrenees occurs foraminifera *Bangiana hanseni* in profile La Cassino in Danian beds and in similar depositional conditions as in the Čebulovica profile (Cavagnetto & Tambareau, 1998, 239). In this profile also the same pollen species were found as in Slovenia in profiles Dolenja vas and Padriciano (*ibidem*; Kedves, 1998, 60, 61). More possibilities for comparison are offered by Thanetian benthic foraminifers as *Periloculina slovenica, Kathina* aff. *selveri* from profiles of east as well as Atlantic part of northern Pyrenees (*ibidem*; Peybernés *et al.*, 2000).

On the Adriatic-dinaric platform similar Paleocene sedimentation conditions are known from east part of Hercegovina from Podveležje to Metković. Also here algae *Lagynophora* in Danian beds are predominant, and dasycladaceans along with foraminifera in younger beds (Sliškowić *et al.*, 1978; Drobne *et al.*, 2000; Trutin *et al.*, 2000).

Geographically closest to NW part of our platform are Paleogene and Neogene sediments of Maiella region (Pignatti, 1994; Vecsei *et al.*, 1996; Vecsei & Moussavian, 1997). According to data in Pignatti's paper (1994), the oldest sediments with larger benthic foraminifera are of Thanetian age (in Danian emersion took place). Reef organisms, colonial corals in particular (determination by D. Turnšek), show similarity in Adriatic and Apulian platforms. More interesting are coeval stress events on both platforms. However, it seems that reefs collapsed in Thanetian or just after it (Pl. 7, fig. 2). It is known that reefs from Maiella region were reconstructed on the base of resedimented blocks found in breccias deposited on the platform margin (Vecsei & Moussavian, 1997, Fig. 2). Unfortunately, data on Paleocene fossil associations from Gargano peninsula (cf. Pignatti, 1994) were not available for correlation.

Sediments from 13 studied sections, focusing on the Upper Cretaceous and Paleogene succession of the island of Cephalonia, 6 with Paleocene sediments, indicate deposition on inner and middle carbonate ramp (Accordi *et al.*, 1998; Figs. 18, 19). Upper Maastrichtian sediments can be correlated due to occurrence of *Rhapydionina liburnica* (Stache). Younger sediments, identified in the Čebulovica section as SBZ 1 and SBZ 2, contain same species of dasyladacean algae (*ibidem*, Pl. 10), same miliolids (genus *Kayseriella* Sirel is determined in Cephalonia sections as *Paraspirolina* sp., *ibidem*, cf. Pignatti, *ibidem*, Pl. 11). Overlying sediments from both regions, SBZ 3 - SBZ 6, show similar composition of larger foraminifera association (*Periloculina* sp., *Lacazina* sp., *Alveolina* sp.). Similarity in fossil associations could be explained by existence of gyre (current stream) pattern in Maastrichtian and Paleocene (Hottinger, 1990, paleobiogeographic map).

The Maastrichtian sediments from Gavrovo (External Hellenids) and from Peloponesus peninsula contain *R. liburnica*, and they continuously pass into Paleocene sedi-

ments with textulariids, valvulinids, complex miliolids, and glomalveolinids (Tsaila - Monoplis, 1977; Fleury, 1980; Zambatakis - Lekka, 1988; Maurikas, 1993).

E. Sirel (1998) made the Atlas of Upper Cretaceous to Paleogene larger foraminifera from Turkey with taxonomic descriptions and biostratigraphic data. Some foraminifera from the Čebulovica section are described in this Atlas, like *H. paleocenica* and *K. decastroi* from Danian to Selandian, *Pseudolacazina donatae, L. blumenthali* from Paleocene to Ilerdian.

ISOTOPIC COMPOSITION OF $\delta^{18}O$ AND $\delta^{13}C$ IN THE LIMESTONE

Isotopic composition of $\delta^{18}O$ and $\delta^{13}C$ (Fig. 12) was determined for 24 limestone samples, which were chosen according to their microfacies characteristics. They were subdivided into three groups. The first group (A) includes samples influenced by fresh water and biomicrites of mudstone-wackestone type with characean gyrogonites and lagynophoras, and those samples which indicate supratidal depositional environment (i.e. Čeb 45 with gravitational cement). The second group (B) is characterised by dark coloured biomicrites, deposited in shallow lagoons and restricted shelf. They are enriched in organic matter. The third group (C) includes lightly coloured algal sparites, biomicrites and biosparites of packstone-grainstone type. They were deposited in more turbulent environment of the open shelf subtidal. Samples of the C group belong to the upper part of the Kozina limestone (Čeb 111 to 134).

The samples were analysed in the Jožef Stefan Institute after the method of Mc Crea (1950). Limestone was treated with phosphoric acid (H_3PO_4) at the temperature of 50±5°C. The CO_2 gas released during the reaction was analysed with the Varian MAT 250 mass spectrometer. All data of $\delta^{13}C$ and $\delta^{18}O$ are given in ‰ with respect to the PDB and SMOW standards.

For the majority of the analysed samples their isotopic compostion ranges between 25,3 and 27,6 ‰, and averages to about 25,5 ‰ (SMOW). The analysed values are somewhat lower than in recent marine limestones which are characterised by the $\delta^{18}O$ values ranging from +28 to +30 ‰ (Faure, 1977). We do not know the reason for the observed enrichment with the light oxygene isotope. We suppose that it could be isotopi-

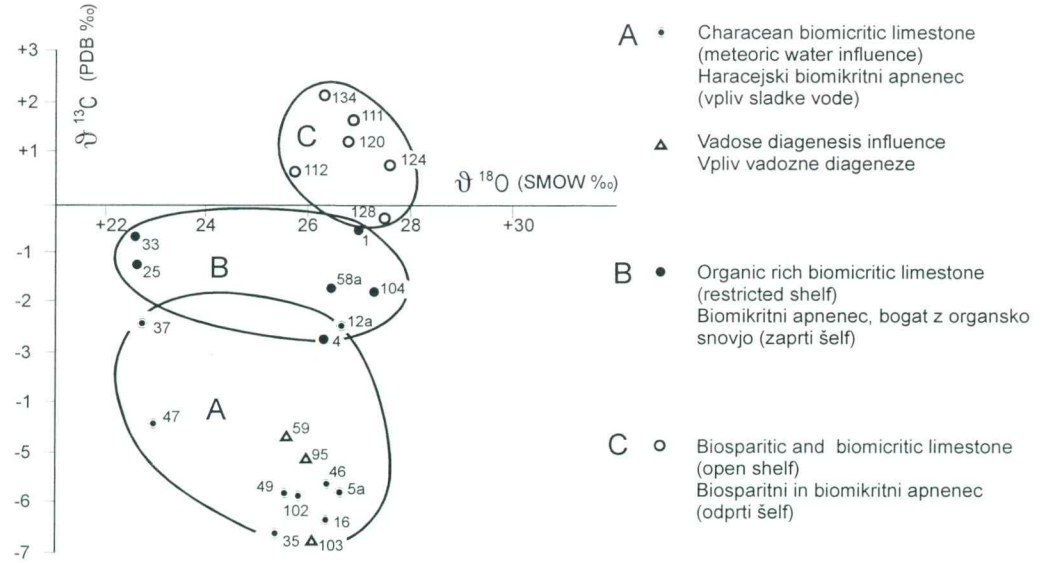


Fig. 12. Isotopic composition of $\delta^{18}O$ and $\delta^{13}C$ in investigated samples of Paleocene limestone at Čebulovica

Sl. 12. Izotopska sestava $\delta^{18}O$ in $\delta^{13}C$ izbranih vzorcev paleocenskega apnenca iz profila pri Čebulovici

cally lighter marine water influenced by meteoric water, and also, episodic warming of the sea to 27-30°C (particularly in lagoons and in some parts of the littoral where gypsum precipitation occurred).

The situation is much different with the isotopic composition of carbon. The $\delta^{13}C$ values correlate with the structural type of the limestone, particularly with the content of organic matter and the extension of fresh water influence. Consequently, the samples of A group (characean limestone) are enriched with the light ^{12}C isotope ranging from -2,5 to -6,5 (PDB) and averaging to about -5 ‰ (Fig. 12). Dark coloured biomicritic lagoonal limestone (group B) is enriched with the light $\delta^{12}C$ (-0,4 to -2,7 ‰) with respect to the limestone of open shelf environment. The reason for observed enrichments is in somewhat higher content of organic matter. After decomposition of organic matter, the isotopically lighter CO_2, as involved in the calcite exsolution, was released. Biosparitic limestone varieties from the open shelf subtidal (the C group) show "normal" $\delta^{13}C$ values from +2,3 to +0,1 ‰ and they are comparable with the values observed in marine limestone.

RECOGNITION OF LIBURNIA FORMATION IN NEIGHBOURING AREAS

The emersion phasis in Upper Campanian is one of the greatest changes on Dinaric carbonate platform which influenced the sedimentation of the Liburnia Formation. It can be recognised in all areas of the Adriatic-Dinaric platform. In Maastrichtian, sedimentation processes were recovered everywhere, but the beds were termed differently owing to the limestone facies and local changes of sedimentary environment.

In the Trieste-Komen plateau, J u r k o v š e k *et al.* (1996a, Figs. 6, 10) joined the shallow marine subtidal, intratidal and supratidal sediments from the Maastrichtian to Thanetian time interval into the Liburnia Formation. In the Trieste Karst, equivalent strata are termed the member of Monte Grisa (C u c c h i *et al.*, 1989, Pl. 1, 2), which is further subdivided into the upper and lower intervals. The upper interval is an equivalent of the Slivje limestone. In the Soča Karst area, T e n t o r *et al.* (1994) subdivided the whole succession into the Liburnia group (Gruppo Liburnico) and miliolidal limestone (Calcari a miliolidi). The Liburnia

PLATE 1 - TABLA 1

Fig. 1. Biomicritic mudstone with *Rhapydionina liburnica* (Stache). Maastrichtian, Čeb 1/ 66466, 30 x

Sl. 1. Biomikritni apnenec (mudstone) s presekom foraminifere *Rhapydionina liburnica* (Stache). Maastrichtij, Čeb 1/ 66466, 30 x

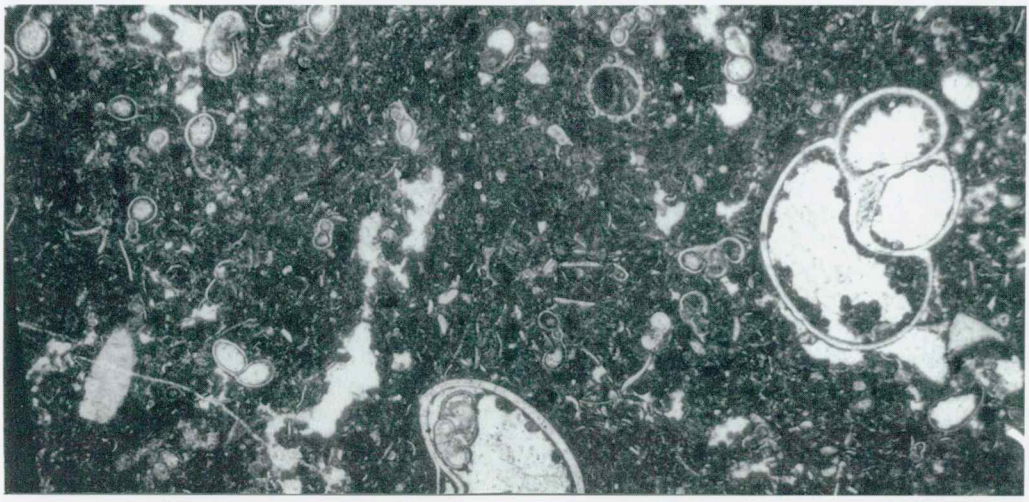
Fig. 2. Rosette type colony of Microcodium in micritic matrix. K/T boundary, Čeb 1a/ 64219, 30 x

Sl. 2. Kolonija mikrokodijev rozetnega tipa v mikritni osnovi. K/T meja, Čeb 1a / 64219, 30 x

Fig. 3. Biomicritic mudstone with small foraminifera *Bangiana hanseni* and some gastropods. Danian, Čeb 2/ 61995), 30 x

Sl. 3. Biomikritni apnenec (mudstone) z drobnimi foraminiferami *Bangiana hanseni* in gastropodi. Danij, Čeb 2/ 61995, 30 x

Photos shown on Plates 1 - 6 are taken on the Leitz microscope and they are arranged in the sample order.
Slike na tablah 1 - 6 so posnete na mikroskopu Leitz in si slede po zaporedju vzorcev.



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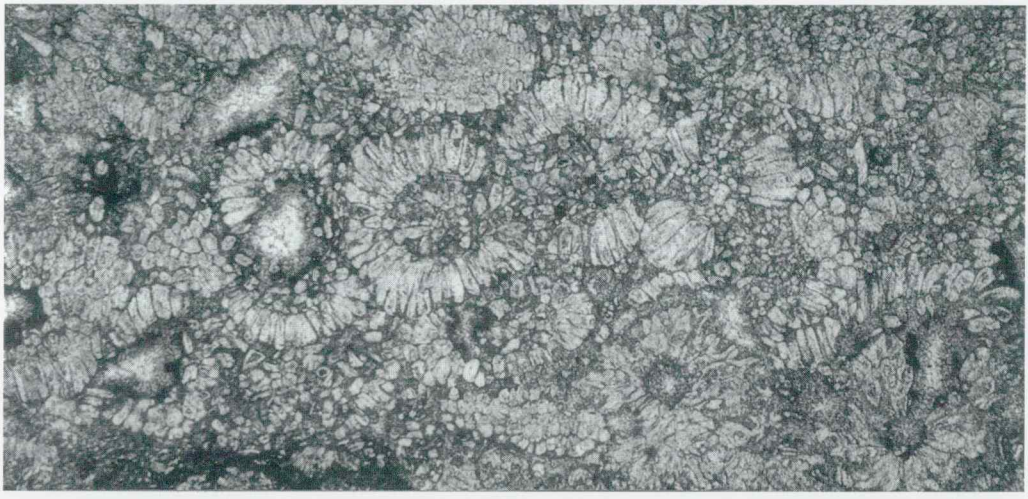

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group is further subdivided into Upper Maastrichtian Vreme beds (Strati di Vreme) and Kozina beds (Strati di Cosina) of Danian age, which are separated with an emersion boundary. Miliolidal limestone (Calcari a miliolidi) is equivalent to the Slivje limestone, and to the upper interval of the member Monte Grisa of the Liburnia Formation in the Trieste Karst. On the island of Brač (Croatia), sedimentary rocks above the Campanian-Maastrichtian emersion are joined into the Sumartin Formation which represents the lower, mainly Cretaceous equivalent of the Liburnia Formation (Gušić & Jelaska, 1990, Pl. 1).

In the Trieste-Komen plateau, the Liburnia Formation is overlain by the succession of alveolinid-numulitid limestone (Drobne, 1977; Jurkovšek *et al.*, 1996a, Fig.10), which was developed under gradual transgression on the carbonate platform. The subsidence of environement progressed from northwest to southeast. In the Trieste Karst, the equivalent strata were termed the Opicina member (Cucchi *et al.*, 1989, Pl. 1, 2), and nummulitic-alveolinal limestone in the Soča Karst (Calcari a nummuliti e alveoline, Tentor *et al.*, 1994). In all mentioned areas, their lower boundary is of the Lower Eocene age, but in the island of Brač, where rocks are termed alveolina-nummulitic limestone, it is placed into the upper part of Lower Eocene.

The last important geologic event in Kras is the disintegration of carbonate platform in upper part of Ilerdian, at the start of flysch deposition. In the Čebulovica area the boundary between limestones and flysch beds is mainly erosional.

DISCUSSION

The studies on fossils from the Čebulovica section reveal the already known reduction in occurrences of foraminifera after K/T boundary. First foraminiferas that followed K/T events were r-strategists related to meso- to eutrophic shallow-water settings, and they were dominant over 5 millions years. K-strategists appeared at the end of Paleocene, independently of physical or chemical gradients. Their new life strategy allowed them to occupy oligotrophic environments. Their advantages were the following: large tests, complex inner structures, dimorphism, reproductive cycles in accordance with seasonal food enrichments, "readiness" for speciations, increased diversity over a short period, seen through phylogenetic flourishment of few genera with many species (Hottinger & Drobne, 1988; Hottinger, 1997).

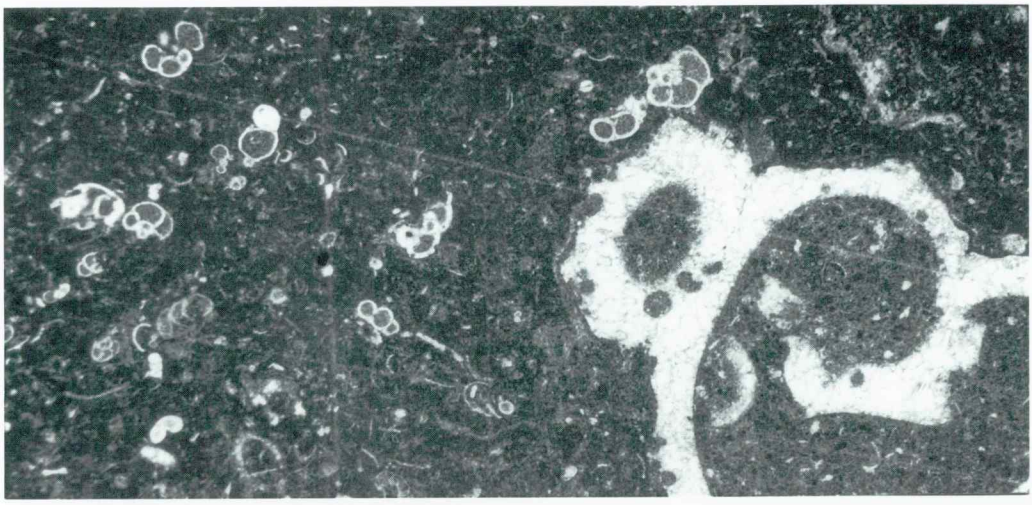
The dasycladaceans suggest once more to be the tie during the growth on shallow-water coastal lagoons and ramp. The same species occur in diachronic horizons. We can correlate the restricted shelf environment (with periodical dasycladals) of the Čebulovica section with open shelf environments (with dasycladaceans) recognised in the Dolenja vas section (Pleničar *et al.*, 1992; Barattolo, 1998; Turnšek & Drobne, 1998).

PLATE 2 - TABLA 2

Fig. 1. Poorly washed pelmicritic packstone. Danian, Čeb 4/ 62004, 30 x
Sl. 1. Izpran pelmikritni apnenec (packstone). Danij, Čeb 4/ 62004, 30 x

Fig. 2. Biointramicritic limestone with shrinkage pores (loferite). Danian, Čeb 22/ 61973, 30 x
Sl. 2. Biointramikritni apnenec z izsušitvenimi porami (loferit). Danij, Čeb 22/ 61973, 30 x

Fig. 3. Biomicritic limestone with discorbids. Gastropod shell is affected by endolithization. Danian, Čeb 14/ 62021, 30 x
Sl. 3. Biomikritni apnenec s številnimi diskorbidami. Na lupini polža je opazna endolitizacija. Danij, Čeb 14/ 62021, 30 x



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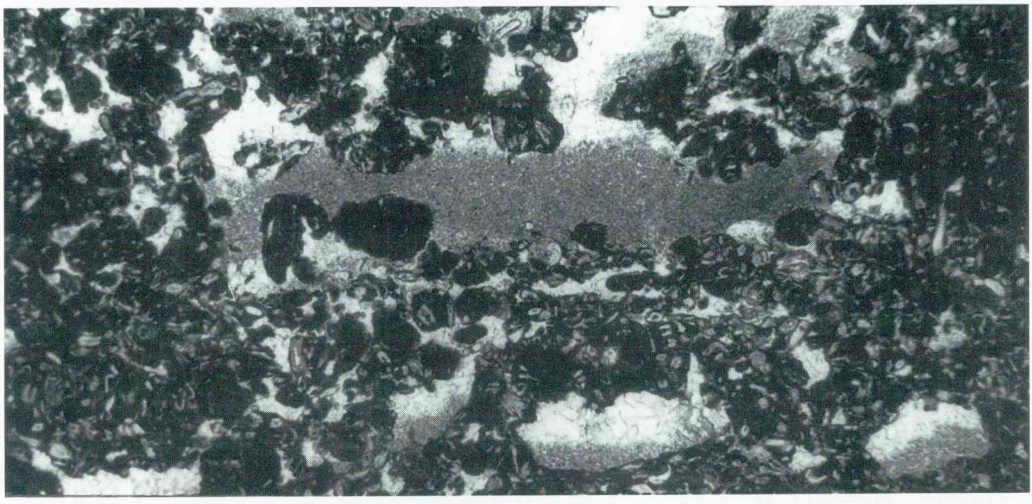

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The accurate biostratigraphic attribution of Liburnia deposits needs more paleontologic data. The author who had stimulated and recognised the importance of palentological data was Hamrla (1958, p. 212; 1985). The studied sediments ask for accurate chronostratigraphic definition where planktic foraminifera, nannoplankton, larger benthic foraminifera, Charophyta will be integrated. Based on recognised fossils we defined deposits according to the zonation recommended by the International Subcommission on Paleogene Stratigraphy. This zonation with some discrepancies around Paleocene/Eocene boundary is applied in Shallow Benthic Zonation of Paleogene (SBZ 1 - SBZ 20, Serra - Kiel *et al.*, 1998).

The stable isotope analysis on $\delta^{13}C$ and $\delta^{18}O$ indicate water temperature in environments where sedimentation took place, up to 27° and 30°C. The same values today have subtropic seas, like water in the gulf of Aqaba (Reiss & Hottinger, 1984). We can assume that the coal basin in SW Slovenia suggests here once existed characean meadows where in depressions numerous gyrogonites were accumulated.

Still we do not know the mechanisms that had caused the sinking of the coal basin in Kras. We presumed that the coal basin stretched from Vremski Britrof through Lokev and Lipice to Padriciano. Today, this coal depression is segmented into several parts. The Cretaceous and Paleocene deposits within the coal represent sedimentary core of the Liburnia Formation in NW part of the Adriatic-Dinaridic carbonate platform.

The future studies on characeans within Cretaceous and Paleogene sediments, based on biostratigraphy for Mesozoic and Tertiary (Riveline *et al.*, 1996) could shed more light on development of shallow-water environments on the Adriatic-Dinaridic carbonate platform.

CONCLUSIONS

1. The profile in road cut of the new highway at Čebulovica permitted to study the development of Paleocene limestones of the Liburnia Formation in the central part of the Kras region. The more than 150 m thick succession displays in its lower part a rather monotonous development within the shallow shelf (ramp) with lagoons and frequent inter- and supratidal conditions. The marine depositional environment alternates with brackish environment which is confirmed also by $\delta^{13}C$ isotopic analyses. With respect to microfacies most limestones belong to SMF 16-20 (restricted circulation with silty sea bottom), and the Slivje limestone as the terminal part of Liburnia Formation to SMF 16-18 (algal biosparites). In the profile more than 60 short emersion phases were established.

2. The monotonous carbonate succession where intertidal sediments alternate with emersion surfaces, represents according to biota about 5 million years. The Late Paleocene transgression, or the global sea level-rise, covered platform in SW Slovenia.

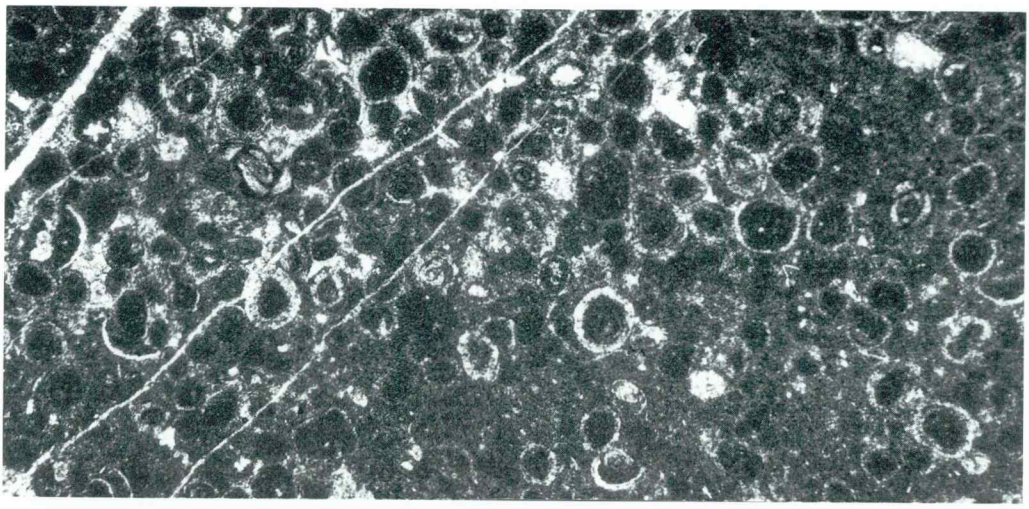
3. For the first time biostratigraphic correlation of different facies associations of

PLATE 3 - TABLA 3

Fig. 1. Gyrogonites in biomicritic matrix (characean limestone). Danian, Čeb 5a/ 62005, 12 x
Sl. 1. Številni girogoniti v mikritni osnovi (haracejski apnenec). Danij, Čeb 5a/ 62005, 12 x

Fig. 2. Bushes of lagynophora in micritic matrix. Danian, Čeb 37/ 62018, 12 x
Sl. 2. Šopki laginofor v mikritni osnovi. Danij, Čeb 27/ 62018, 12 x

Fig. 3. Pelmicirtic limestone with some ooids. Danian, Čeb 57/ 61966, 30 x
Sl. 3. Posamezni naplavljeni ooidi v izpranem pelmikritnem apnencu. Danij, Čeb 57/ 61966, 30 x



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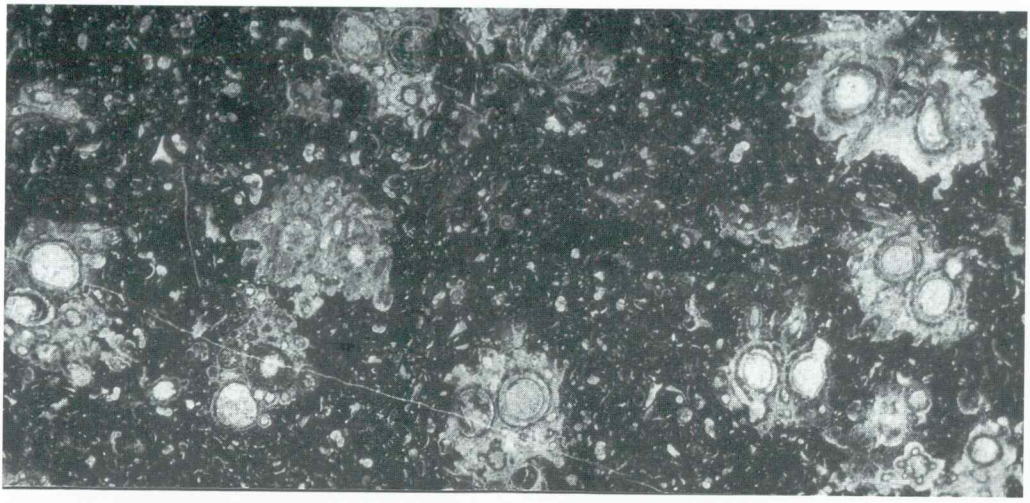

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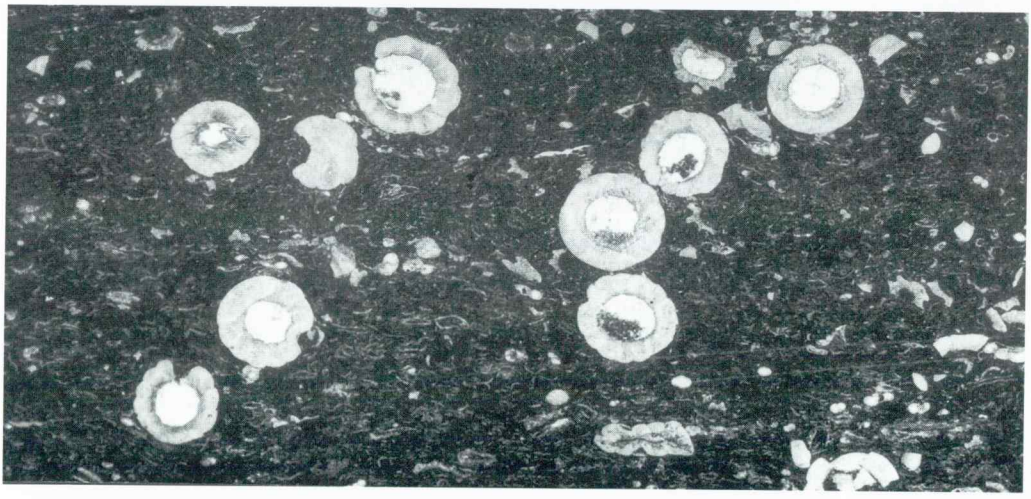

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the Liburnia Formation, based on characeans on the one hand and foraminifera and dasycladaceans on the other hand, was done in the Kras area. The Danian and Selandian (SBZ 1, SBZ 2) ages have been proved in the Čebulovica section. Applying new methods, we confirmed the hypothesis by G. Stache and M. Hamrla about Paleocene occurrences of *Lagynophora* genus.

4. We proposed that term Liburnia Formation refers to lithologic members, facies and facies associations that have to be attributed to adequate biostratigraphic zones and chronostratigraphic units of Cretaceous and Paleogene age. This will allow biostratigraphic interpretation of the Liburnia Formation in Kras, Istria and along the eastern Adriatic coast.

5. We suggest that term the Liburnia Formation and named lithologic members, together Cretaceous and Paleogene in age, can be kept in geologic mapping.

6. Index fossils for Danian in the Čebulovica section are dasycladaceans *Decastroporella tergestina, Drobnella slovenica,* cyanophyta *Aeolisaccus barattoloi* and foraminifera *Bangiana hanseni.* Selandian is characterised by numerous occurrences of previous dasycladaceans, *Hamulusella liburnica, Microsporangiella buseri, Cymopolia* spp. and by foraminifera *Kayseriella decastroi* and *Haymanella paleocenica.* The advantage of rare marine intercalations recognised by biota is determination of Paleocene age (Danian and Selandian) of characeans and *Lagynophora* in brackish limestones and non-marine sediments studied in the Čebulovica section.

7. The correlation between marine and non-marine limestones could be used throughout the central Tethyan realm. The characean/foraminifera-bearing succession could be correlated with northern Pyrenean development. The marine succession with dasycladaceans and foraminifera is similar to those found in eastern part of the Tethys, in Turkey, Greece, Cephalonia Island, Apulia and Herzegovina.

ACKNOWLEDGEMENTS

Our special thanks to Prof. Dr. Filippo Barattolo, University of Naples, for his help in dasycladacean determination. His monography (1998) has appeared to be useful in identifying Paleocene sediments in Mediterranean region. We are thankful to Acad. Dr. Dragica Turnšek for coral recognition. In addition, we thank Doc. Dr. Vlasta Ćosović for providing special literature on charophyta, for discocylinid identifying and for translation in English a biostratigraphic part of the paper. A part of the manuscript was translated by Prof. Dr. Simon Pirc, we express our thanks to them.

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PLATE 4 - TABLA 4

Fig. 1. Laminated biomicritic wackestone with debris of fossils. Danian, Čeb 76/ 63674, 30 x

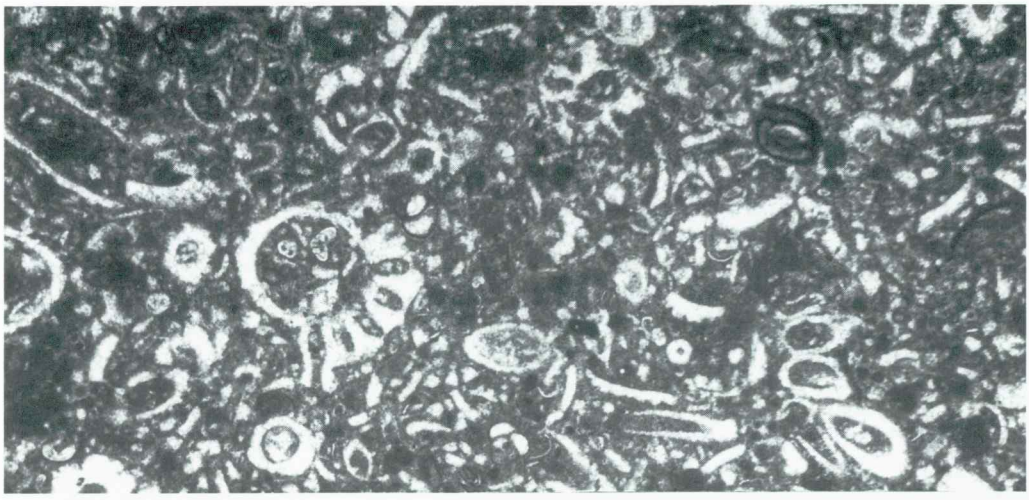
Sl. 1. Rahlo laminiran biomikritni apnenec (wackestone) z drobirjem fosilnih skeletov. Danij, Čeb 76/ 63674, 30 x

Fig. 2. Shrinkage pore with gravitational cement in biopelmicritic matrix. Meteoric diagenesis influence. Danian, Čeb 90/ 63684, 30 x

Sl. 2. Izsušitvena pora z gravitacijskim cementom v biopelmikritni osnovi. Vpliv meteorske diageneze. Danij, Čeb 90/ 63684, 30 x

Fig. 3. Biomicritic packstone with dasycladal algae. Danian, Čeb 95a/ 63692, 30 x

Sl. 3. Biomikritni algni apnenec (packstone) z dasikladacejami. Danij, Čeb 95a/ 63692, 30 x



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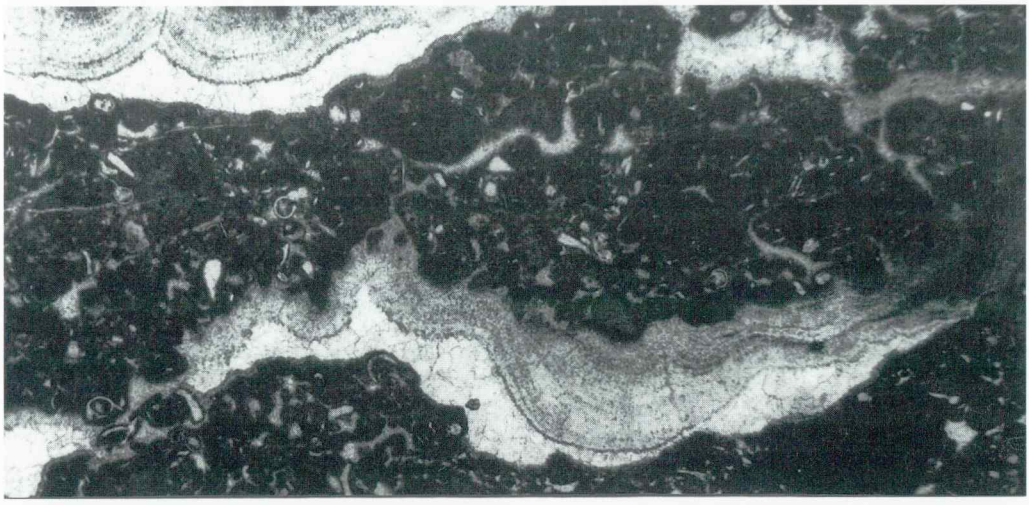

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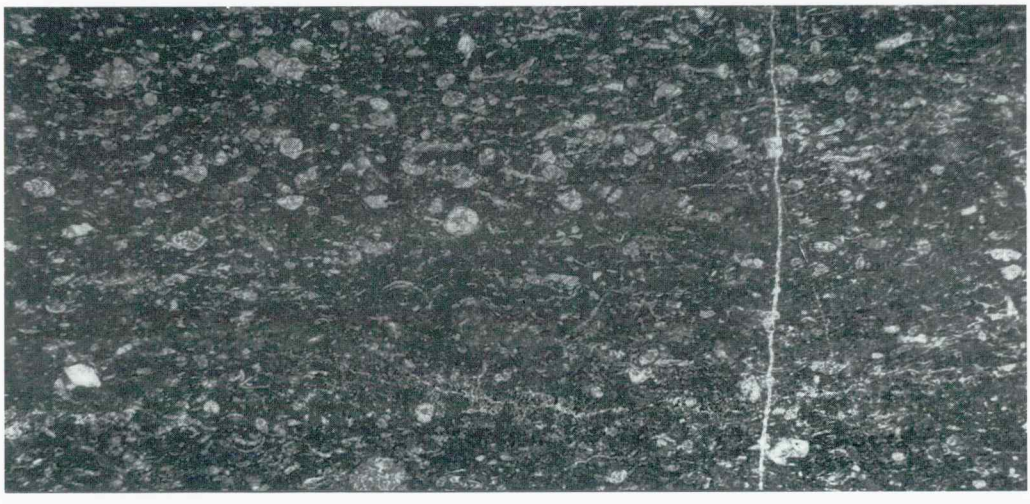

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PALEOCENSKE PLASTI LIBURNIJSKE FORMACIJE V PROFILU ČEBULOVICA (NW JADRANSKO - DINARSKA PLATFORMA)

UVOD

Z izgradnjo avtoceste med Postojno in Trstom se nam je ponudila priložnost, da ponovno raziskujemo liburnijske plasti paleocenske starosti. Le-te je podrobno opisoval že G. Stache v letih med 1859 in 1920. Predstavljajo skladovnico med rudistnimi in alveolinsko-numulitnimi apnenci, ki le s krajšim hiatusom prehajajo krizno obdobje kredno/terciarne meje v intralitoralnem okolju Jadransko - dinarske karbonatne platforme. Danes se za njih uporablja oznaka Liburnijska formacija (Jurkovšek *et al.*, 1996a).

Zaradi pestre sedimentologije so v rabi oznake mnogih litoloških in stratigrafskih členov. Le - te ne vodijo k prepoznavnosti in korelaciji med njimi v stilu sedanjega poimenovanja stratigrafskih krednih in paleocenskih členov Liburnijske formacije (Jurkovšek *et al.*, 1996a, sl. 6, 10). S fosili določena starost plasti je še nepopolna in je predmet podrobnih študij (Drobne *et al.*, 1988, 1989, 1996; Pugliese *et al.*, 1995; Knez, 1996, Brazzatti *et al.*, 1996; Barattolo, 1998; Turnšek & Drobne, 1998).

V profilu Čebulovica, ki se nahaja med Senožečami in Divačo (sl. 1, 2) izdanjajo starejše paleocenske plasti, ki so del srednjega dela Liburnijske formacije. Sedimentna sekvenca je primerna za litološke in facialne analize. Še posebnega pomena pa je biostratigrafska korelacija plasti brakičnega izvora z morskim razvojem, dokumentirana z abiotskimi raziskavami.

Biostratigrafski in litološki podatki iz paleocenskih plasti na Krasu omogočajo primerjavo z istodobnimi plastmi širšega mediteranskega prostora, od Turčije (Sirel, 1998) in Grčije (Fleury, 1980; Mavrikas, 1993), otoka Krfa (Accordi *et al.*, 1998), preko pogorja Maiella v Abruzzih (Pignatti, 1994; Vecsei *et al.*, 1996) in vzdolž Jadranskega morja (Bignot, 1972; Tari - Kovačić *et al.*, 1998; Marjanac, T. *et al.*, 1998; Marjanac T. & Ćosović, 2000), Hercegovine (Sliškowić *et al.*, 1978; Drobne *et al.*, 2000) do Istre (Sakač & Gabrić, 2000). Več skupnih rodov in vrst pa ugotavljamo tudi z razvojem paleocena v severnih Pirenejih (Tambareau, 1972; Massi eux *et al.*, 1989; Peybernés *et al.*, 2000).

Problematika analize flore in favne iz karbonatnih plasti pri Čebulovici je v tem, da so možne raziskave le v preparatih, kar otežkoča prepoznavanje notranjih struktur foraminifer, determinacija haracej pa je nezanesljiva.

Terenske raziskave pri Čebulovici sta opravila B. Jurkovšek in M. Toman, snemanje profila B. Ogorelec in M. Toman ter v začetni fazi tudi Luka Šribar. K. Drobne je določila mikrofosile in pripravila biostratigrafska poglavja ter del zaključnih poglavij, izotopske analize $\delta^{18}O$ in $\delta^{13}C$ so delo T. Dolenca, mikrofacialne analize in litološka in-

PLATE 5 - TABLA 5

Fig. 1. Biomicritic mudstone with thin wall gastropods. Danian, Čeb 105/ 64217, 30 x

Sl. 1. Biomikritni apnenec (mudstone) s tankolupinskimi polži. Danij, Čeb 105/ 64217, 30 x

Fig. 2. Microcodium colonies and isolated prisms in micritic matrix with some solution cavities. Selandij, Čeb 113/ 64293, 30 x

Sl. 2. Preseki mikrokodijev in njihovih prizem v mikritni osnovi z izsušitvenimi porami. Selandij, Čeb 113/ 64293, 30 x

Fig. 3. Biointrasparitic limestone with algal skeletons and miliolids. Selandian, Čeb 112/ 64244), 30 x

Sl. 3. Biointrasparitni apnenec (packstone) z algami in miliolidami. Selandij, Čeb 112/ 64244, 30 x

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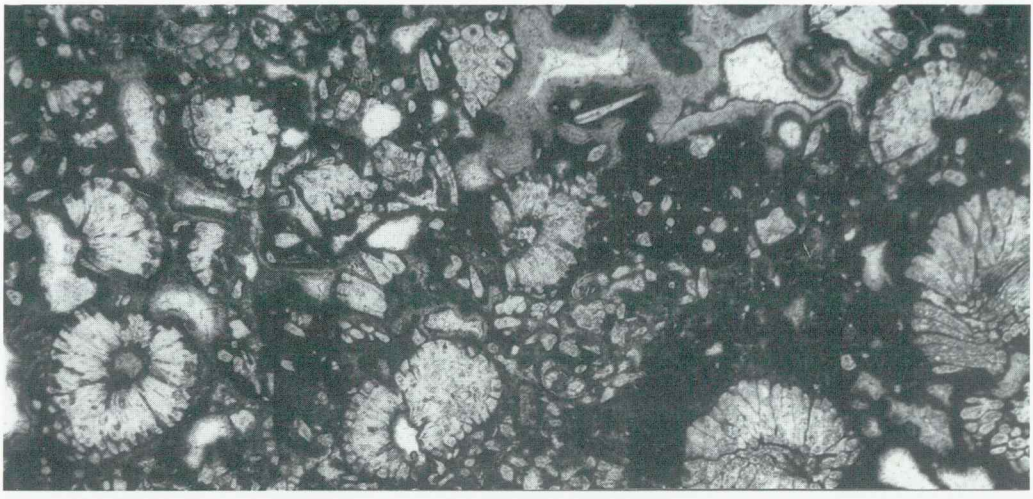

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terpretacija preiskanih vzorcev ter grafične priloge pa so prispevek B. Ogorelca. Terenski vzorci in preparati so dokumentirani v arhivu Geološkega zavoda Slovenije.

DOSEDANJE RAZISKAVE

Prvi je plasti Liburnijske formacije preučeval Stache (1889) in jih združil v "liburnijsko stopnjo" (Liburnische Stufe), imenovano po pokrajini Liburnija ob jadranski obali, med rekama Rašo in Krko. Razdelil jih je v tri dele: spodnji foraminiferni apnenec, zgornji foraminiferni apnenec in vmesne plasti, ki jih je imenoval kozinske plasti.

Za posamezne člene Liburnijske formacije so bila kasneje uvedena še druga imena. Spodnje foraminiferne apnence je Pavlovec (1963, tab.1) poimenoval vremske plasti, združene zgornje foraminiferne in operkulinske apnence pa trsteljske plasti, imenovane po kraju Trstelj na severnem robu Kraške planote. Na osnovi značilnih in številnih alg (Buser & Radoičić, 1987) in drugih značilnosti sta Delvalle in Buser (1990) uvedla za zgornje foraminiferne ali miliolidne apnence novo ime - Slivska formacija, ki sta jo poimenovala po vasici Slivje na jugozahodnih obronkih Brkinov. V današnji literaturi se uporablja Slivski apnenec kot člen Liburnijske formacije (Jurkovšek *et al.*, 1996a, 55, sl. 10).

Že Stache (1889) je ugotovil, da so meje med posameznimi enotami Liburnijske formacije, t.j. med spodnjimi in zgornjimi foraminifernimi apnenci in vmesnimi kozinskimi plastmi, nestalne. Hamrla (1959, 1960) jim je tako kot Stache v pretežni meri pripisal facialni pomen. Litološko je marsikje težko ločiti vremske plasti od kozinskih, saj te prehajajo ene v druge tako lateralno kot vertikalno. Zato so jih avtorji Formacijske geološke karte južnega dela Tržaško-komenske planote 1:50.000 (Jurkovšek *et al.*, 1969a) združili v enotno Liburnijsko formacijo, ki zajema več različnih faciesov.

Debelina Liburnijske formacije je na raziskanem ozemlju Krasa zelo različna. Po Hamrli (1959, sl. 6., 1960) znaša njena skupna debelina pri Lipici okoli 260 m, proti Lokvam pa naraste do blizu 400 m. Debelina zgornjih foraminifernih apnencev (Slivski apnenec) znaša na tem prostoru od 50 do 150 m. Precej manjša je debelina apnenca vremskega in kozinskega faciesa na pobočjih doline Raše. V Dolenji vasi in pri vasi Bogo so ti apnenci celo tanjši od 50 m. Da je debelina Liburnijske formacije spremenljiva, kaže tudi primerjava s podatki z italijanske strani (Masoli *et al.*, 1979). Medtem ko je njena debelina v profilu Padriče pri Bazovici blizu mejnega prehoda Lipica preko 300 m (Pugliese *et al.* 1995, Brazzatti *et al.*, 1996), naraste zahodno od Opčin na več kot 450 m. V nadaljevanju proti Nabrežini se tanjša, dokler se pri Devinu povsem ne izklini. Izrazito stanjšanje plasti Liburnijske formacije v smeri od severa proti jugu (od 360 na 200 m) je bilo ugotovljeno tudi ob izgradnji avtoceste na razmeroma kratkem odseku med Divačo in Kozino (Jurkovšek *et al.*, 1997).

Prostor zahodnega dela slovenskih Dina-

PLATE 6 - TABLA 6

Fig. 1. Micritic limestone with gastropods. Selandian, Čeb 128/ 64292, 30 x

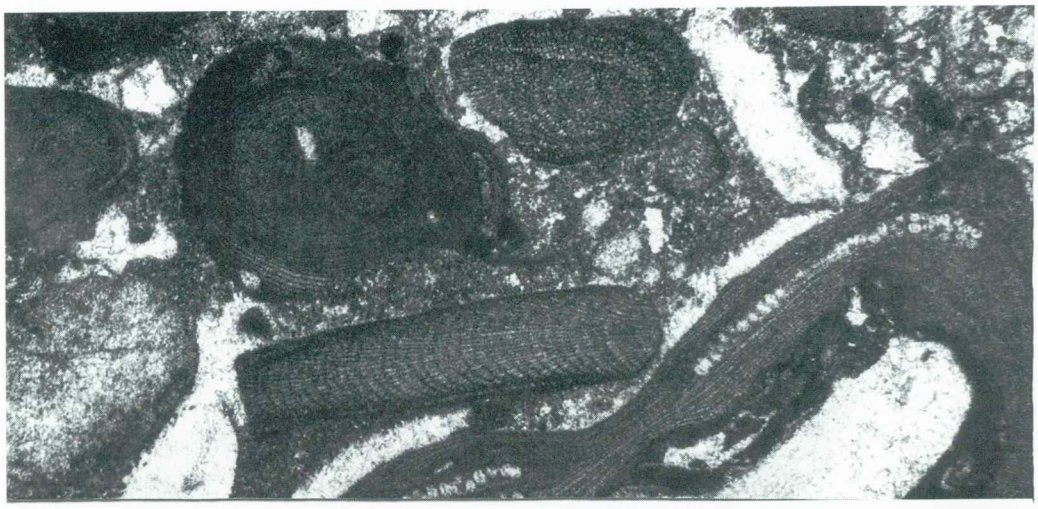
Sl. 1. Mikritni apnenec s preseki gastropodov. Selandij, Čeb 128 / 64292, 30 x

Fig. 2. Washed biopelmicritic packstone with miliolids. Selandian, Čeb 138, 30 x

Sl. 2. Izpran biopelmikritni apnenec (packstone) z miliolidami. Selandij, Čeb 138, 30 x

Fig. 3. Biosparitic grainstone with numerous coralinacean algae. Detail of Alveolinid-nummulitid limestone. Thanetian, Čeb 142/ 66458, 30 x

Sl. 3. Biosparitni apnenec s številnimi fragmenti koralinacejskih alg (grainstone). Detajl alveolinsko-numulitnega apneneca. Thanetij, Čeb 142/ 66458, 30 x



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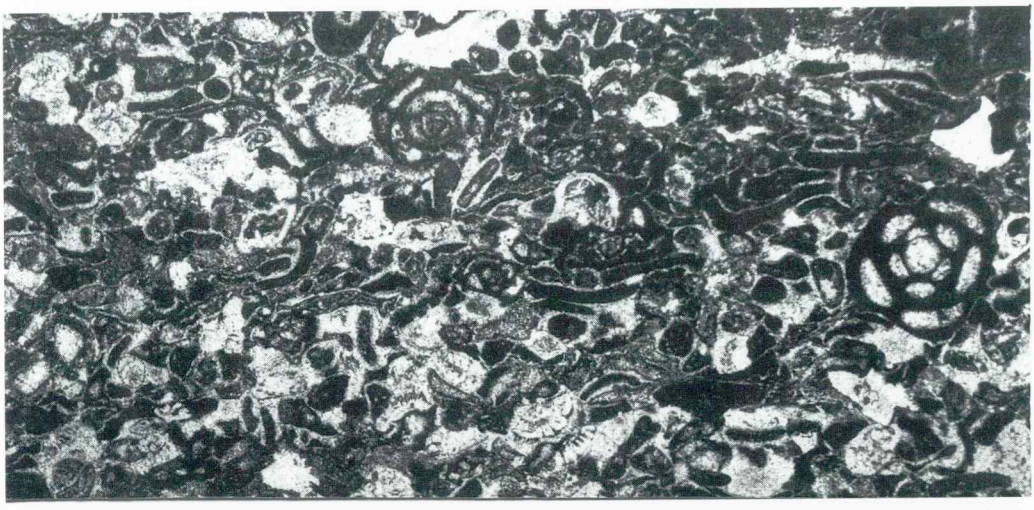

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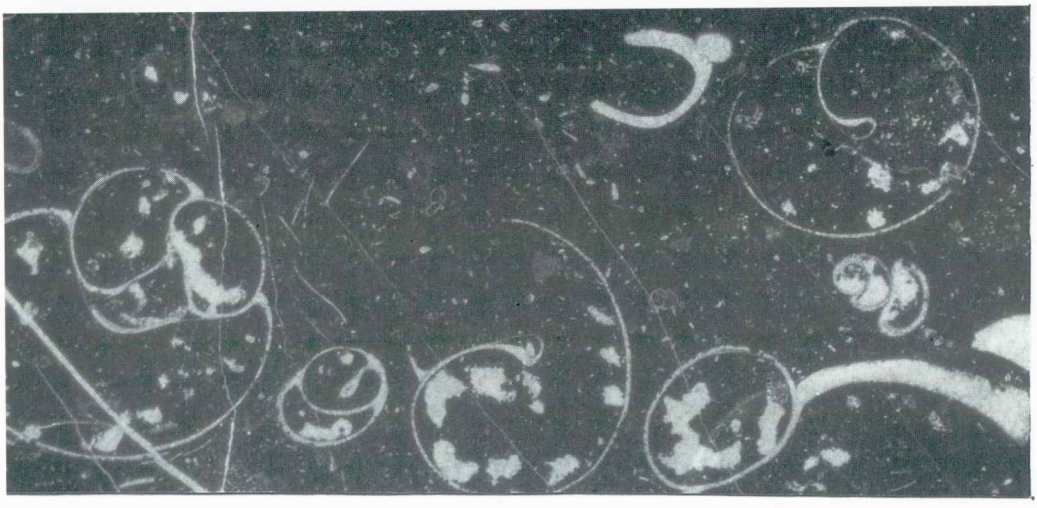

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ridov, točneje širše območje Tržaško-komenske planote, je bil v zadnjih petnajstih letih predmet številnih terenskih raziskav ter študija biote in abiote. To velja predvsem za prehodne plasti na meji kreda/terciar, saj so te posebno zanimive, ker so razvite v plitvomorskem karbonatnem faciesu. To je velika redkost v celotnem mediteranskem prostoru. Biostratigrafsko, paleontološko in sedimentološko so te plasti raziskovali: Drobne *et al.*, 1988, 1989, 1994, 1995, 1996; Pugliese *et al.*, 1995; Jurkovšek *et al.*, 1996a,b; Knez, 1994, 1996; Knez & Pavlovec, 1990; De Castro *et al.*, 1994; Caffau *et al.*, 1995; Otoničar & Košir, 1998. Dasikladaceje je obdelal Barattolo (1998), korale Turnškova (v Turnšek & Drobne, 1998), podatke o raziskavah abiote pa najdemo v delih: Delvalle & Buser, 1990; Hansen *et al.*, 1995, 1996; Dolenec *et al.*, 1995; Ogorelec *et al.*, 1995; Marton *et al.*, 1995 ter Palinkaš *et al.*, 1996. V zgornjekrednih paleokraških sedimentih na meji med Lipiško in Liburnijsko formacijo je bila pri Kozini najdena tudi raznolika fosilna združba kopenskih vretenčarjev (Debeljak *et al.*, 1999). Vsa geološka literatura s slovenskega in italijanskega dela Krasa do leta 1989 je zbrana v delih Palovca in sodelavcev (1989) ter Martinisa (1989).

GEOLOŠKA LEGA PROFILA

Vzporedno s traso stare magistralne ceste proti Kopru se v jugovzhodno pobočje Čebulovice globoko zarezuje trasa nove avtoceste. Ob njeni izgradnji med leti 1996 in 1997 se nam je ponudila priložnost podrobnega vzorčevanja in študija plasti Liburnijske formacije.

Profil Čebulovica leži v ozki coni na ozemlju med dvema najpomembnejšima dinarsko usmerjenima prelomoma Tržaško-komenske planote, Raškim prelomom na severu in Divaškim na jugu (Buser, 1968, 1973).

Raziskani profil je bil posnet na dolžini 650 metrov. Spodnjih 120 debelinskih metrov smo vzorčevali ob novi avtocesti (vzorci od 1 do 71), vrhnjih 40 metrov (vzorci od 72 do 135) pa ob stari cesti (sl.2a,b). Plasti v profilu vpadajo z naklonom 15° do 25° proti jugozahodu. Sicer idealno situacijo za stratigrafsko snemanje motita dva manjša lokalna preloma v spodnjem delu profila, ki pa plasti premakneta le za nekaj metrov.

PLATE 7 - TABLA 7

Fig. 1. Limestone with foraminifera *Lacazina blumenthali* Reichel et Sigal (A), *Kathina subsphaerica* Sirel (B), *Assilina yvettae* Schaub (C), Ass. *azilensis* (Tambareau) (D), orthophragminids (E) and others. Čeb 140/ 65611, Thanetian, SBZ 4.

Sl. 1. Apnenec s foraminiferami: *Lacazina blumenthali* Reichel et Sigal (A), *Kathina subsphaerica* Sirel (B), *Assilina yvettae* Schaub (C), *Ass. azilensis* (Tambareau) (D), orthophragminide (E) in druge. Čeb1 40/ 65611, thanetij, SBZ 4

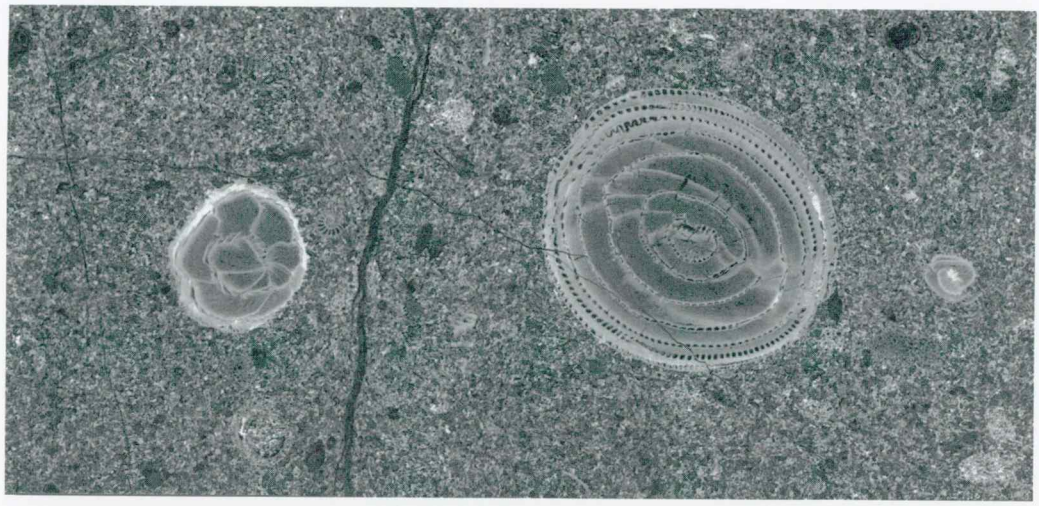
Fig. 2. Limestone with red algae and corals: *Astrocoenia lobato - rotundata* (Michelin) (A), *Goniopora* sp. (B). Čeb 142/ 66458, (det. D. Turnšek). Thanetian, SBZ 4

Sl. 2. Apnenec z rdečimi algami in koralami: *Astrocoenia lobato - rotundata* (Michelin) (A), *Goniopora* sp. (B). Čeb 142/ 66458, (det. D. Turnšek), thanetij, SBZ 4

Fig. 3. Alveolina - nummulitic limestone with foraminifera *Alveolina daniensis* Drobne, axial section. Čeb s.n./ 66479, Lower Ilerdian, SBZ 6

Sl. 3. Alveolinsko - numulitni apnenec s foraminifero *Alveolina daniensis* Drobne, aksialni prerez. Čeb s.n./ 66479, spodnji ilerdij, SBZ 6.

All enlarged 10 x, incident light
Vse povečano 10 x, odbojna svetloba



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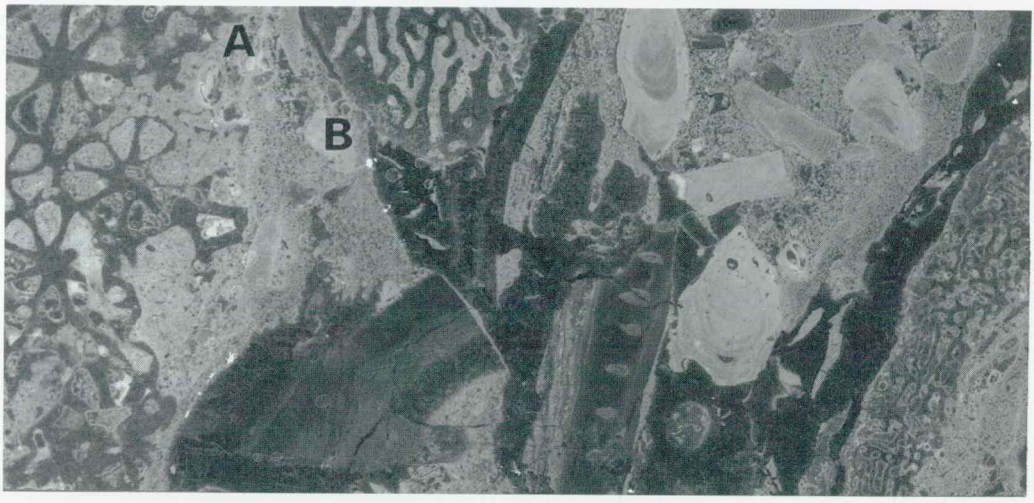

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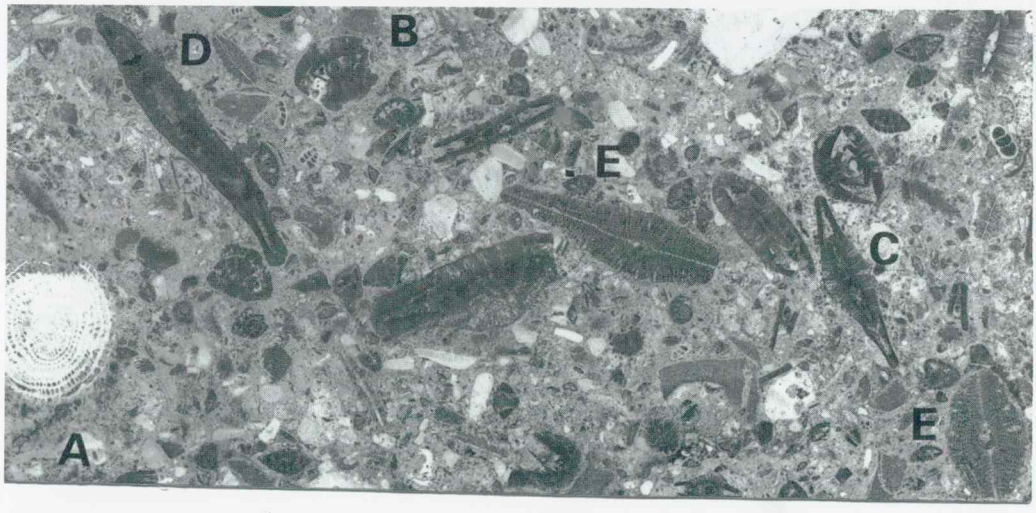

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Odkritost profila je odlična, razen v njegovem najnižjem delu ob kredno-terciarni meji, kjer je ta rahlo tektoniziran in na dolžini nekaj metrov pokrit. Profil na vrhu končuje ob močnejši prelomni coni znotraj alveolinsko-numulitnega apnenca.

Za mikrofacialne in paleontološke analize je bilo odvzetih preko 160 vzorcev, glede na spremembe facialnih asociacij.

Večji del plasti v profilu pripada Liburnijski formaciji z značilno menjavo morskega, brakičnega in sladkovodnega sedimentacijskega okolja.

Profil Čebulovica je litološko navidezno dokaj monoton, predvsem v spodnjem delu, čeprav se v zaporedju plasti menjavajo številni litološki tipi apnenca. To kaže na dolgotrajne in enotne sedimentacijske razmere v plitvem in mirnem morju. Občasno je bilo okolje izpostavljeno kratkotrajnim okopnitvam ter pogostnim sladkovodnim vplivom. Z okopnitvami so povezane tanke emerzijske breče ter znaki paleozakrasevanja. Skupno je v profilu opaznih več kot 60 prekinitev sedimentacije.

LITOLOGIJA IN MIKROFACIES

Na profilu Čebulovica so prve vzorčevane plasti apnenci tik pod kredno/terciarno mejo. Tem slede apnenci danijske starosti, profil pa končuje s slivskim apnencem thanetijske starosti ter alveolinsko-numulitnim apnencem ilerdijske starosti (sl. 3 in 10).

Maastrichtij: Plasti pod kredno/terciarno mejo pripadajo sivemu, rahlo bituminoznemu in biomikritnemu apnencu. Njegovo

PLATE 8 - TABLA 8

Fig. 1. *Decastroporella tergestina* Barattolo, transversal section across the head of dasycladal algae, perfectly fossilized with thin calcified wall. Internal micrite and sparitic cement. Čeb 124A/ 64250, Selandian, SBZ 2, 40 x

Sl. 1. *Decastroporella tergestina* Barattolo. Prečni prerez preko glave dasikladacejske alge. Interni mikrit in sparitni cement. Čeb 124A/ 64250, selandij, SBZ 2, 40 x

Fig. 2,3. *Drobnella slovenica* Barattolo. Danian, Selandian, (SBZ 1, SBZ 2), 40 x
1. Oblique section of the central stem. Čeb 124A/ 64250
2. Central stem and part of the whorl of branches. Čeb 95/ 63683

Sl. 2,3. *Drobnella slovenica* Barattolo. Danij, selandij, (SBZ 1, SBZ 2), 40 x
1. prerez preko osrednjega stebla. Čeb 124A/ 64250
2. steblo z razplodnimi poganjki. Čeb 95/ 63683

Fig. 4. *Microsporangiella buseri* Barattolo. Part of the stem. Čeb 124A/ 64250, Selandian, SBZ 2, 40 x

Sl. 4. *Microsporangiella buseri* Barattolo. Del stebelca. Čeb 124A/ 64250, selandij, SBZ 2, 40 x

Fig. 5. *Aeolisaccus barattoloi* De Castro, Cyanophyta. Various sections of tubular segments, microfacies. Čeb 49/ 61968, Danian, SBZ 1, 60 x

Sl. 5. *Aeolisaccus barattoloi* De Castro, Cyanophyta. Paličasti in okrogli prerezi. Čeb 49/ 61968, danij, SBZ 1, 60 x

Fig. 6. *Lagynophora liburnica* Stache. Green algae with reproductive structures, perfectly fossilized, part of the "bouquet" with organic and anorganic parts. Čeb 46/ 61985, Danian, SBZ 1, 20 x

Sl. 6. *Lagynophora liburnica* Stache. Zelena alga z razmnoževalnimi strukturami, fosilizirani organski in anorganski deli "šopka". Čeb 46/ 61985, danij, SBZ 1, 20 x

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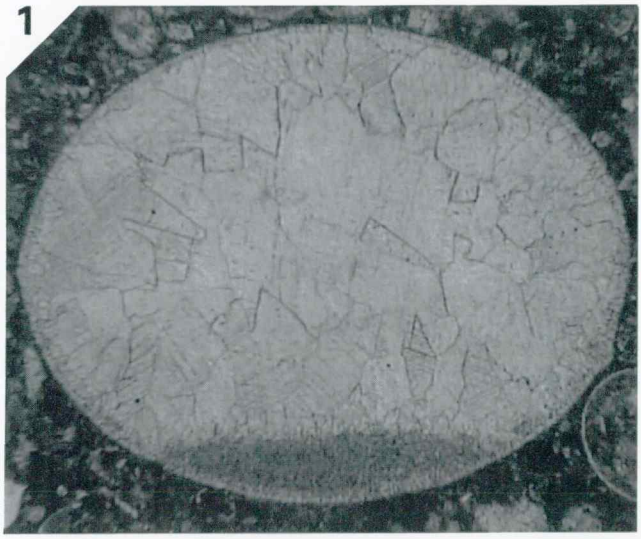
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PLATE 9 - TABLA 9

Fig. 1-3. *Haymanella paleocenica* Sirel. Danian, Selandian, (SBZ 1, SBZ 2), 40 x
1. Planispiral and 4 uniserial chambers. Čeb 124/ 64249
2. Lumen of one chamber with two apertures on the sections below and above it. Čeb 124/ 64249
3. Periembryonic chambers, two of them uniserial. Čeb 58A/ 61975

Sl. 1-3. *Haymanella paleocenica* Sirel. Danij, selandij, (SBZ 1, SBZ 2), 40 x
1. planispiralne in 4 uniserialne kamre. Čeb 124/ 64249
2. lumen kamre in dva prereza ustja. Čeb 124/ 64249
3. periembrionalne kamre in dve uniserialni. Čeb 58A/ 61975

Fig. 4-7. *Kayseriella decastroi* Sirel. Danian, Selandian, (SBZ 1, SBZ 2), 40 x
4. Axial section, large specimen. Čeb 114/ 64241
5. Axial section of the specimen of smaller size. Čeb 58A/ 61975
6. Axial section. Čeb 58 A/61975
7. Periembryonic chambers, equatorial section. Čeb 124 A/ 64250

Sl. 4-7. *Kayseriella decastroi* Sirel. Danij, selandij, (SBZ 1, SBZ 2), 40 x
4. aksialni prerez, večji primerek. Čeb 114/ 64241
5. aksialni prerez manjših dimenzij. Čeb 58 A/ 61975
6. aksialni prerez. Čeb 58 A/61975
7. periembrionalne kamre, ekvatorialni prerez. Čeb 124 A/ 64250

Fig. 8-11. *Kayseriella* sp., specimens of smaller sizes. Danian, Selandian, (SBZ 1, SBZ 2), 40 x
8. Axial section. Čeb 58 A/61975
9. Axial section. Čeb 124/ 64249
10. Longitudinal section of embryonic and adult chambers. Čeb 124/ 64249
11. Equatorial section of embryonic shell. Čeb 124/ 64249

Sl. 8-11. *Kayseriella* sp., primerki majhnih dimenzij. Danij, selandij, (SBZ 1, SBZ 2), 40 x
8. aksialni prerez. Čeb 58 A/ 61975
9. aksialni prerez. Čeb 124/ 64249
10. ekvatorialni prerez in uniserialne kamre. Čeb 124/ 64249
11. ekvatorialni prerez. Čeb 124/ 64249

Fig. 12-14. Polymorphinidae, *genera indet.* Danian, SBZ 1, 40 x
12, 13. Specimens of larger size. Čeb 85/ 63685
14. Specimen of smaller size. Čeb 85/ 63685

Sl. 12-14. Polymorphinidae, *genera indet.* Danij, SBZ 1, 40 x
12, 13. primerki večjih dimenzij. Čeb 85/ 63685
14. primerek majhnih dimenzij. Čeb 85/ 63685

Fig. 15. *Epistomaria* sp. Čeb 10/ 62015, Danian, SBZ 1, 40 x

Sl. 15. *Epistomaria* sp. Čeb 10/ 62015, danij, SBZ 1, 40 x

Fig. 16-20. *Bangiana hanseni*, (ex *Protelphidium*), (in print, *n.gen. n.sp.*). Danian, SBZ 1, 80 x
16. Equatorial section, rather perfectly. Čeb 85/ 63685
17. Oblique sections of two specimens. Čeb 85/ 63685
18. Axial section with all stadies of the growths. Čeb 10/ 62015
19. Equatorial section of broken shell. Čeb 85/ 63685
20. Oblique section of adult stage of the growth, two gyrogonites of Charophytes. Čeb 85/ 63685

Sl. 16-20. *Bangiana hanseni*, (ex *Protelphidium*), (v tisku *n.gen. n.sp.*). Danij, SBZ 1, 80 x
16. ekvatorialni prerez, dokaj popolen. Čeb 85/ 63685,
17. poševna prereza dveh primerkov. Čeb 85/ 63685
18. aksialni prerez, vsi stadiji rasti. Čeb 10/ 62015
19. aksialni prerez poškodovane hišice. Čeb 85/ 63685
20. poševen prerez, adultni stadij, dva girogonita haracej. Čeb 85/ 63685

Fig. 21. Specimen of the ostracod. Čeb 85/ 63685, Danian, SBZ 1, 40 x

Sl. 21. Ostrakod. Čeb 85/ 63685, danij, SBZ 1, 40 x

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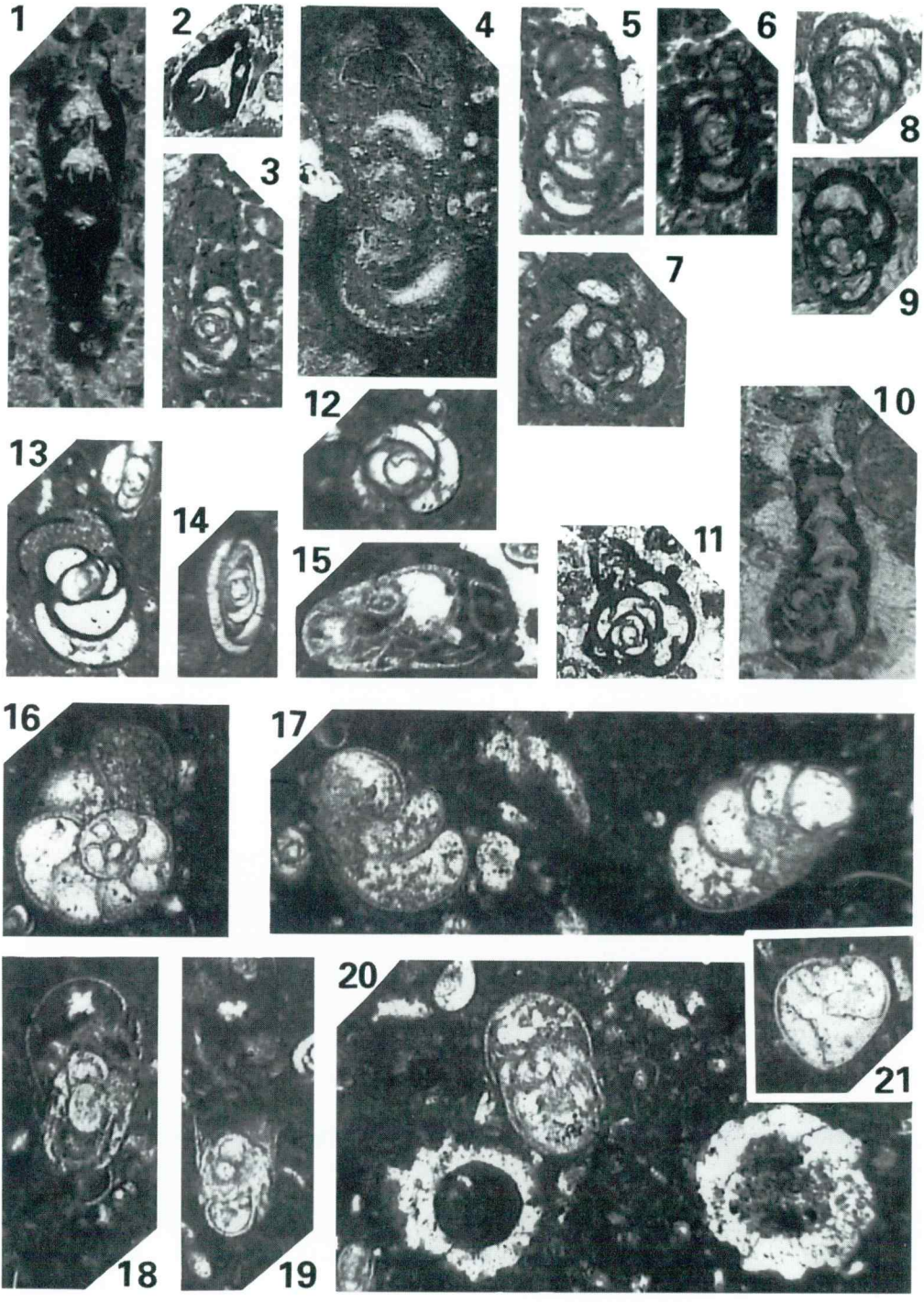
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zgornjekredno, maastrichtijsko starost določajo redke foraminifere *Rhapydionina liburnica* (Stache), ki pa so zaradi tektonizacije apnenca precej deformirane (tab. 1, sl. 1). Poleg rapidionin nastopajo še druge drobne foraminifere, lupine tankih školjk ter posamezni primerki alge *Thaumatoporella parvovesiculifera* (Raineri). Po strukturi je apnenec "mudstone do wackestone". Plasti so debele 5 do 20 cm in večkat kažejo neizrazito laminacijo. Apnenec se je odlagal v plitvem, zaprtem delu šelfa z redukcijskimi pogoji, na katere sklepamo po razpršenem piritnem pigmentu in organski snovi.

K/T meja: Sam K/T kontakt v debelini okrog 5 m poteka v manjši kotanji, ki je bila ob izgradnji avtoceste v času naših raziskav že zasuta. Golice v bližini kažejo, da je ta meja razvita podobno kot v Dolenji vasi (Drobne et al. 1988, 1995, 1996), na Sopadi (Jurkovšek *et al.*, 1996a; Ogorelec *et al.*, 1995) ter v Padričah pri Bazovici na italijanski strani meje (Pugliese *et al.*, 1995; Brazzatti *et al.*, 1996). Emerzijsko apnenčevo brečo, debelo do tri metre, sestavljajo nekaj cm veliki karbonatni drobci, ki so bili v času sedimentacije še plastični. Na lokalne in občasne okopnitve ter na kasnejše paleozakrasevanje kažejo v kamnini korozijske votline, izsušitvene pore ter strukture rizokodijev (sl. 3; tab. 1, sl. 2). Sama osnova apnenca je gost biomikrit s posameznimi girogoniti haracej, foraminiferami in drobnimi polži. V kamnini opazujemo tudi številne bioturbacijske teksture.

Paleocen: Celotni spodnji del profila v debelini okrog 120 metrov, ki smo ga posneli v useku avtoceste (sl. 1, 2), grade 10 do 30 cm debele plasti srednjesivih in temnejših apnencev, v katerih se menjava več litoloških in strukturnih tipov (sl. 3). Najpogostnejši je biomikritni apnenec tipa "wackestone", v katerem kot fosili v večji meri nastopajo drobne foraminifere, ostrakodi, girogoniti haracej in laginofore, v nekaterih vzorcih pa še drobni polži in školjčne lupine (tab. 1, sl. 3; tab. 2, sl. 3). Tipa "mudstone in packstone" sta precej redkejša. V posameznih plasteh so girogoniti haracej tako številni, da lahko govorimo kar o haracejskem apnencu (tab. 3, sl. 1 in 2). Temnejšo barvo kamnini dajeta pigment piritnih framboi-

PLATE 10 - TABLA 10

Fig. 1-5. *Miscellanea juliettae villattae* Leppig. Thanetian, SBZ 3, 30 x
1, 2. Megalospheric specimens, axial sections. Čeb 136/ 65613
3. Equatorial section, non-centered ? B form. Čeb 136/ 65613
4. Subaxial section, microspheric generation. Čeb 136/ 65612
5. Oblique section, B form. Čeb 136/ 65613

Sl. 1-5. *Miscellanea juliettae villattae* Leppig. Thanetij, SBZ 3, 30 x
1, 2. megalosferična oblika (A), aksialni prerezi. Čeb 136/ 65613
3. ekvatorialni prerez, necentriran ?oblika B. Čeb 136/ 65613
4. subaksialni prerez, mikrosferična oblika (B). Čeb 136/ 65612
5. poševni prerez, oblika B. Čeb 136/ 65613

Fig. 6. *Goesella* sp. Čeb 114/ 64241, Selandian, SBZ 2, 30 x

Sl. 6. Goesella sp. Čeb 114/ 64241, selandij, SBZ 2, 30 x

Fig. 7. *Coskinon rajkae* Hottinger et Drobne, oblique section. Čeb 137/ 65070, Thanetian, SBZ 3, 30 x

Sl. 7. *Coskinon rajkae* Hottinger et Drobne, poševen prerez. Čeb 137/ 65070, thanetij, SBZ 3, 30 x

Fig. 8. *Plumokathina* sp., oblique section at umbilical side. Čeb 141/ 65616, Thanetian, SBZ 4, 30 x

Sl. 8. *Plumokathina* sp. Čeb 141 / 65616, thanetij, SBZ 4, 30 x

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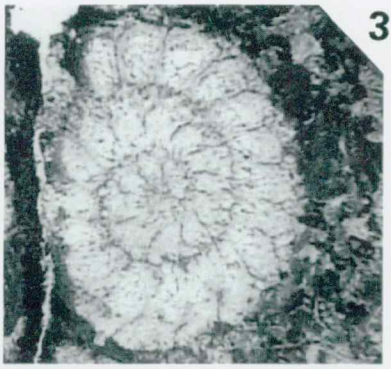
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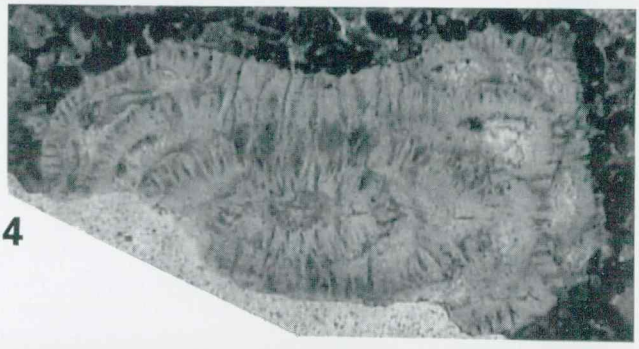
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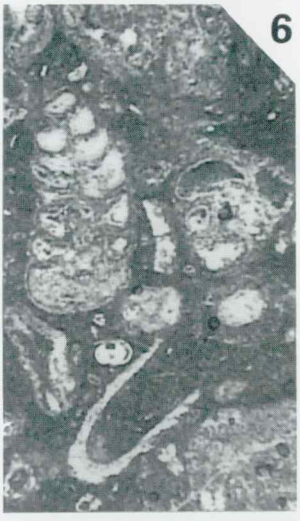
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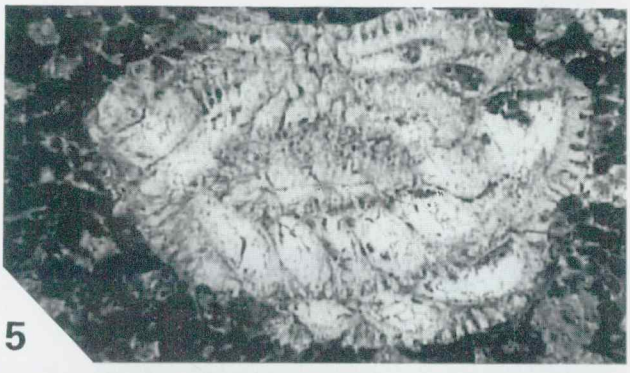
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dov in organska snov. Večkrat apnenec kaže neizrazito laminacijo milimetrskih dimenzij (tab. 1, 2, 3).

Biomikritni apnenec prekinjajo pogosto plasti, ki kažejo medplimske in emerzijske teksture ter pedogene tvorbe (sl. 4 do 6). Med te uvrščamo drobnozrnat nadplimski konglomerat ("flat pebble conglomerate"), izsušitvene pore (loferitni apnenec), plasti z izsušitvenimi razpokami, stromatolite in kopuče neskeletnih alg ter predvsem emerzijske breče in pojave mikrokodijev. Mikrokodiji (*Paronipora*) so razen v plasteh na K/T meji pogostni v vzorcih Čeb 19-22, okrog št. 35 ter med vzorci Čeb 55 in 63. Javljajo se v mnogih variacijah, največkrat kot obročaste inkrustacijske tvorbe, večkrat pa so njihove kalcitne prizme popolnoma razsute. V plasteh s pedogenimi tvorbami nastopa večkrat fosfatni mineral kolofan, nekatere plasti pa je zajela tudi kasnodiagenetska silicizacija. Ta se kaže tako v drobnih avtigenih kristalih kremena kot tudi v obliki mikrokristalnega in drobnozrnatega kremena, ki zapolnjuje medprostore in izsušitvene pore kot cement več generacij (tab. 1, sl. 2; tab. 5, sl. 2).

Apnenec spodnjega dela profila Čebulovica (vzorci Čeb 1-71) se je odlagal kot karbonatno blato v zelo plitvem in mirnem energijskem okolju zatišnega šelfa in lagun. Nadplimska breča in pedogene tvorbe pa kažejo na občasne in kratkotrajne okopnitve raziskanega ozemlja. Do 120. metra profila ugotavljamo 38 takih emerzijskih faz. Po haracejah in laginoforah sklepamo tudi

PLATE 11 - TABLA 11

Fig. 1. *Glomalveolina dachelensis* Schwager, axial section, *Lacazina blumenthali* Reichel et Sigal, section across trematophorid pole. Čeb 143/ 66576, Thanetian, SBZ 4, 30 x

Sl. 1. *Glomalveolina dachelensis* Schwager, aksialni prerez, *Lacazina blumenthali* Reichel et Sigal, prerez skozi trematoforni pol. Čeb 143/ 66576, thanetij, SBZ 4, 30 x

Fig. 2-4. *Lacazina blumenthali* Reichel et Sigal. Čeb 143/ 66576, Thanetian, SBZ 4, 30 x
2. longitudinal section near equatorial plane, showing uniserial chambers with subepidermal elements, microspherical form
3. section across one mega-proloculus, at first uniserial chambers
4. section across proloculus of smaller size, A form, first bi- and than uniserial chambers (A)
Pseudolacazina donatae (Drobne), axial section, bi-serial whorl, section across the pole (B)

Sl. 2-4. *Lacazina blumenthali* Reichel et Sigal. Čeb 143/ 66576, thanetij, SBZ 4, 30 x
2. vzporeden prerez z ekvatorialno ravnino, vidne uniserialne kamre in ornamentacija osnovne plasti, oblika B
3. prerez skozi prolokul izjemnih dimenzij, oblika A, prvi zavoj uniserialen
4. prerez skozi prolokul manjših dimenzij, oblika A, prvi bi-, drugi uniserialni zavoj (A)
Pseudolacazina donatae (Drobne), aksialen prerez, biserialni zavoji, prerez skozi pol (B)

Fig. 5. *Periloculina* sp., subaxial section. Čeb 119/ 66418, Selandian, SBZ 2, 30 x

Sl. 5. *Periloculina* sp., poševen aksialni prerez. Čeb 119/ 66418, selandij, SBZ 2, 30 x

Fig. 6. ? *Scandonea* sp., planispiral shell, observable part of trematophorid aperture on upper chamber and the other one at embryonic whorls. Čeb 121/ 66464, Selandian, SBZ 2, 30 x

Sl. 6. ? *Scandonea* sp., planspiralna hišica, viden del trematofornega ustja v zgornji kamri ter sifonalna ustja v embrionalnih zavojih. Čeb 121/ 66464, selandij, SBZ 2, 30 x

Fig. 7. *Idalina* sp., lingitudinal, equatorial section, Aform, Čeb 36/ 61987, Danian, SBZ 1, 30 x

Sl. 7. *Idalina* sp., vzdolžni ekvatorialni prerez, oblika A. Čeb 36/ 61987, danij, SBZ 1, 30 x

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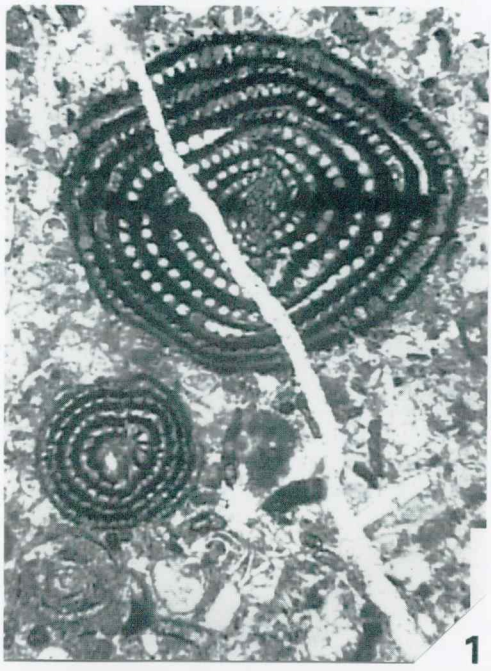
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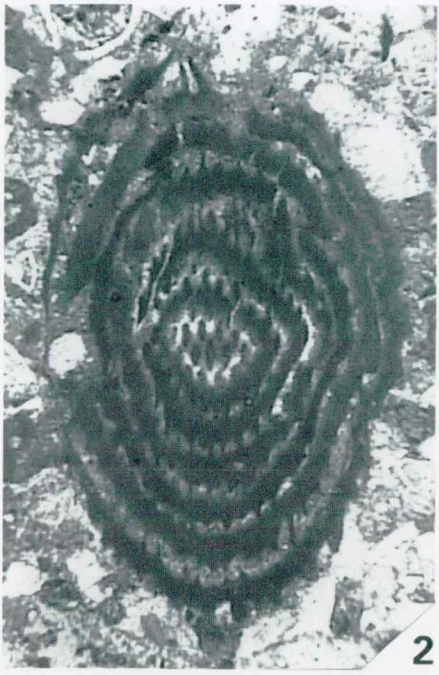
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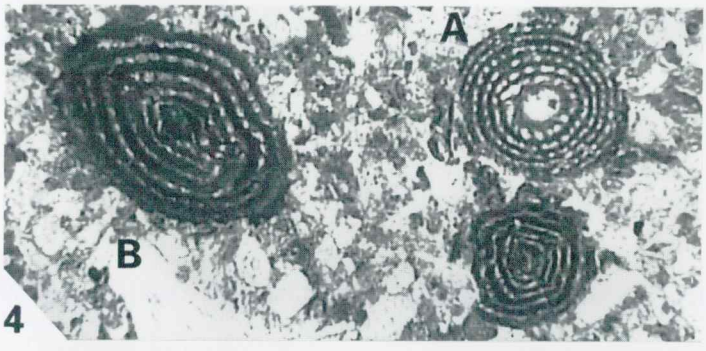
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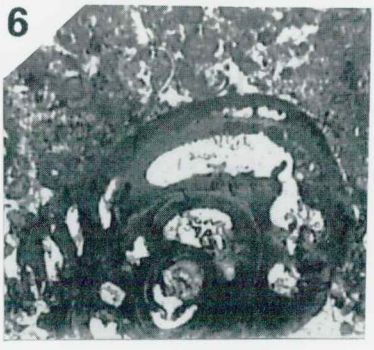
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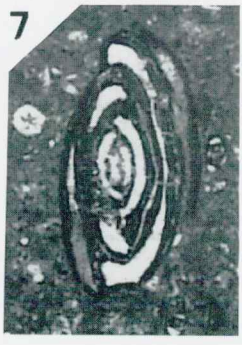
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na občasno zaslajevanje morske vode oziroma na menjavanje morskega in brakičnega ali celo sladkovodnega okolja. V literaturi se je za tak tip karbonatne sedimentacije uveljavilo ime "palustrine environment" oziroma palustrinski apnenec. Zelo zanimive primere takega razvoja prikazujeta Freytet (1964) ter Freytet in Plaziat (1982), ki sta raziskovala zgornjekredne in paleogenske plasti v južni Franciji. Palustrinsko okolje sedimentacije v času nastajanja Liburnijske formacije na prostoru jugozahodne Slovenije interpretirata Otoničar in Košir (1998), (Košir, 1998). Vpliv sladke vode pri sedimentaciji haracejskega apnenca v profilu Čebulovica ter meteorske pogoje v času zgodnje diageneze potrjuje tudi lahka izotopska sestava ^{12}C v nekaterih raziskanih vzorcih apnenca (sl.12, ta članek).

Po standardni klasifikaciji mikrofaciesa (SMF - Standard microfacies, Wilson, 1975) uvrščamo apnence spodnjega dela profila Čubulovica, ki so danijske starosti, v SMF 16-20, za katerega sta značilna omejena cirkulacija vode ter zamuljeno morsko dno. Prevladujejo strukturni tipi apnenca "mudstone in wackestone". Facialno okolje (facies zones) FZ 7-8 ustreza sedimentacijskim pogojem zaprtega šelfa, lagun in medplimskega pasu. Tanke emerzijske breče pa sovpadajo s SMF 24.

Da so bile lahko razmere v lagunah večkrat namesto brakične tudi hipersaline, sklepamo po redkih stromatolitnih plasteh ter po psevdomorfozi kalcita po kristalih sadre v redkih vzorcih (npr. Čeb 28). Na občasno višji energijski indeks pa nas opozarjajo tudi ooidi v vzorcih Čeb 56 in 58. Ti so bili ob neurjih naplavljeni iz odprtega dela šelfa (tab. 3, sl. 3). Zelo redko in v majhnem obsegu je posamezne plasti apnenca zajela zgodnjediagenetska dolomitizacija. Dolomitizirani so le tisti horizonti, ki so bili izpostavljeni nadplimskim pogojem, delež mikritnega dolomita pa ne presega 10 %.

Za apnenec vrhnjih 35 metrov profila (vzorci Čeb 72 do 135), ki je bil posnet v useku ob stari cesti (sl. 1), je značilno, da je svetlejši in nekoliko bolj debeloplastovit. Sicer je še vedno biomikriten ali biopelmikriten, zaradi večjega števila fosilov pa po strukturi prevladujeta tipa "wackestone in packstone". Med fosili so še vedno najbolj pogostne foraminifere, predvsem miliolide. Tem se pridružujejo še ostrakodi, v več plasteh pa tudi haraceje, laginofore in skeletne alge iz skupine dasikladacej (tab. 4, sl. 3; tab. 5, sl. 3). Slednje so posebno številne v plasteh med vzorci Čeb 95 in 124. Večkrat se omenjenim fosilom pridružujejo še polži (tab. 5, sl. 1; tab. 6, sl. 1; sl. 8).

Apnenec vrhnjega dela profila lahko po mikrofaciesu (Wilson, 1975) uvrščamo v SMF 8-10 (tip "bioklastični wackestone") ter SMF 16-18 (biosparit in algni "grainstone") oziroma FZ 2 in 7 (lagune in podplimsko okolje s cirkulacijo odprtega morja ter povišano energijo).

Tudi v zgornjem delu profila je bila sedimentacija prekinjana s številnimi kratkotrajnimi okopnitvami. V 30 debelinskih metrih plasti naštejemo kar 22 emerzijskih faz. Te so nakazane s tanjšimi filmi ali žepi laporne gline, predvsem pa s pedogenimi teksturami, kot so mikrokodijske tvorbe, z izsušitvenimi razpokami, loferitnimi plastmi, stromatoliti in nadplimskimi brečami. V številnih plasteh opazujemo tudi kolofonski pigment. Gravitacijski cement v korozijskih votlinah kaže na občasno vadozno okolje diageneze (tab. 4, sl. 2).

V vrhnjih desetih metrih profila, (nad vzorcem Čeb 118), ki pripadajo zaključnemu členu Liburnijske formacije, postane apnenec že svetlejši in kaže še višji energijski indeks. Po strukturi je to "packstone do grainstone" oziroma intrabiomikrit do biokalkarenit, ki se je odlagal na plitvem odprtem šelfu. Znaki litoralnega faciesa (emerzijske breče, pedogene tvorbe, kalkrete, stromatoliti in izsušitvene pore) ter haraceje se javljajo le še v sledovih, značilne pa so dasikladaceje, foraminifere s porcelansko steno hišic ter redke solitarne korale (Čeb 120-124 ter 134), (tab. 6, sl. 2).

Nad profilom Čebulovica smo orientacijsko odvzeli v 50 debelinskih metrih še 7 vzorcev apnenca (Čeb 137-143). Teh vzorcev zaradi nekontinuiranosti in prevelike pokritosti terena nismo več zajeli v profil, shematsko pa je ta karbonatni paket prikazan na sl.10 (tab. 7, sl. 1, 2). Zanimiv je predvsem zaradi velikih foraminifer in druge biote ter mikrofaciesa. Po vzorcu Čeb 143 sledi širša tektonska cona, na drugi strani le-te pa se nadaljuje profil z alveolinskim apnencem (tab. 7, sl. 3).

Po strukturi je ta apnenec packstone do grainstone oziroma biokalkarenit (tab. 7, sl. 1 in 2). Razen numulitin in alveolin so od biote prisotne še rdeče koralinacijske alge (tab. 6, sl. 3), ploščice ehinodermov, miliolide in redke korale. Apnenec se je odlagal na plitvem šelfu z dokaj visoko energijo. Po standardni klasifikaciji faciesa ga uvrščamo v cono FZ 6.

BIOSTRATIGRAFIJA

Pri biostratigrafski interpetaciji plasti smo se poslužili razčlenitve za bentične foraminifere plitvomorskega okolja, SBZ 1 - SBZ 20. Te cone upoštevajo pojavljanje vodilnih vrst (index species) v izbranih reprezentativnih profilih Tetide, od Pirenejev do Indije, v času od kredno-terciarne meje do oligocena (Serra - Kiel *et al.*, 1998). Biocone velikih foraminifer so usklajene, z manjšimi odstopanji na meji paleocen-eocen, z nanoplanktonskimi in planktonskimi conami, magnetostratigrafsko skalo in absolutno starostjo. Za opredelitev con so upoštevane tudi foraminifere iz profilov SW Slovenije in Istre: Dolenja vas, Veliko Gradišče, Golež, Pićan in Raganzini - Lišani (Drobne & Pavlovec, 1991). Razčlenitev paleogena v "Shallow Benthic Zones" SBZ 1 - SBZ 20 upošteva predloge mednarodne podkomisije za paleogensko stratigrafijo za kronostratigrafske enote (Jenkins & Luterbacher, 1992; Odin & Luterbacher, 1992).

Vzorčevane plasti v profilu Čebulovica so paleocenske, točneje danijske in selandijske starosti. V podlagi se nahajajao plasti vrhnjega dela maastrichtija, v krovnini pa apnenci thanetijske in ilerdijske starosti. Zanimivost profila so pogoste izmenjave morskega, lagunskega okolja z brakičnim oz. povezava morske vode z oslajenimi vodami priobalnega območja. Značilnosti medplimskega in nadplimskega okolja se zrcalijo v emerzijah, ki jih je okrog 60. Izmenjava faciesov v debelini skoraj 150 m omogoča datacijo "brakičnih" plasti s pomočjo morskih organizmov. Na sliki 10 ta korelacija različnih facialnih asociacij jasno izstopa na podlagi determiniranih izbranih taksonov. Dobro je definirana poznopaleocenska, thanetijska transgresija oz. dvig morske gladine, ki je po 5 milijonih let prekrila celotni prostor sedanje SW Slovenije (tab. 1, 3, 4, 5, 7; sl. 3, 10).

Flora in favna iz morskega okolja

Plasti, sedimentirane v plitvomorskem okolju, vsebujejo dasikladacejske alge ter male bentične foraminifere. Sodijo med tipične r - strategе, ki hitro poseljujejo mezo-, eutrofno okolje. Imajo kratko življensko dobo in hišice majhnih dimenzij. Mednje uvrščamo diskorbide, polymorphinide, miliolide brez notranje strukture - še nedefiniranih rodov, konične oblike kot tekstulariine, valvulinine, poleg drugih redkih rotaliidnih hišic (Hohenegger *et. al.*, 1989; 1993). V seriji tovrstnih kamnin so indeksne vrste redke. Med pomembnejše sodi *Bangiana hanseni* n.gen. n.sp., (Drobne, v tisku), doslej znana kot ex *Protelphidium* (Drobne *et al.*, 1988, tab. 25, sl. 8 - 11). Vrsta je bila ugotovljena v plasteh Čeb 1b do 85 (tab. 9, sl. 16 - 20). Kot redko v tem faciesu velja omeniti foraminifero *Kayseriella decastroi* Sirel. Le-ta se v mlajših, bolj morskih plasteh, pojavlja pogosteje. Nastopajo še *Haymanella paleocenica* Sirel, miliolide iz skupine pseudonumolokulin in rotaliide (tab. 9, sl. 1 - 6).

Nad kredno / terciarno mejo, od vzorca Čeb 5 do 65, se pojavlja alga *Aeolisaccus barattoloi* De Castro (tab. 8, sl. 5). Je preživela kredna oblika, iz skupine Cyanophyta. Tubuse ima kratke, votle in tanjše stene kot njena sorodna vrsta večjih dimenzij *Aeolisaccus kotori* Radoičić iz zgornje krede. Tudi kredni rod alge *Thaumatoporella* je še prisoten v spodnjih plasteh. Zelo pogostni so ostanki rodu parkerelit (*Parkerella* sp.) v vsej sekvenci.

V zaporedju plasti do vzorca Čeb 134 se pojavljajo dasikladacejske alge. Dokaj redki sta v starejših plasteh vrsti *Decastroporella tergestina* Barattolo in *Drobnella slovenica* Barattolo (tab. 8, sl. 1 - 3). V plasteh nad vzorcem Čeb 85 postajata številčnejši ob vrsti *Hamulusella liburnica* (Buser et Radoičić). Nad vzorcem Čeb 110 najdemo primerke alg *Microsporangiella buseri* Barattolo (tab. 8, sl. 4), *Cymopolia mayaense* Johnson et Kaska in *C. paronai* Raineri (tab. 4, sl. 3; tab. 5, sl. 3).

Ne-morska flora in favna

Plasti vsebujejo številne bodisi girogonite haracej iz družine Characeae, bodisi še cele rastline z girogoniti, talusom, dolgimi internodiji iz družine Lagynophoreae Stache. Med njimi je neredko tudi makrofavna, predvsem polži *Stomatopsis* Stache in *Cosinia* Stache ter polž, majhnih dimenzij *Kallomastoma* Stache (tab. 1- 6, Stache 1889; Knez, 1996).

Lagynophora liburnica Stache je edina haraceja, ki smo jo zaradi lažje prepoznavnosti izbrali kot indeksni fosil za starejši paleocen. Iz dosedanjih študij vrhnjega dela maastrichtija in paleocena na Krasu (Hamrla 1959, 1960) in ob razumevanju G. Stacheja (1889, 86) je mogoče prvo pojavljanje rodu *Lagynophora* Stache in polža *Kallomastoma* Stache opaziti v paleocenu. Izbrana vrsta se pojavlja v profilu vse do vzorca Čeb 128, v vertikalni menjavi z morskimi sedimenti (tab. 3, sl. 1, 2; tab. 8, sl. 6; sl. 10, 11).

Tovrstne sedimentne sekvence v medplimskem okolju kot po pravilu spremlja pojavljanje mikrokodija (*Paronipora*) (tab. 1, sl. 2; tab. 5, sl. 2). Pojavljanje in genezo mikrokodijev v sedimentih južnozahodne Slovenije obravnava A. Košir (1998; 2001, v recenziji).

Starost plasti v profilu

Po naših raziskavah sta za danijsko starost (SBZ 1) v profilu Čeublovica vodilna alga *Aeolisaccus barattoloi* De Castro in foraminifera *Bangiana hanseni*. Za opredelitev selandija (SBZ 2) bi navedli pogostnost dasikladacej *Decastroporella tergestina* in *Drobnella slovenica* ob foraminiferah *Kayseriella decastroi* in *Haymanella paleocenica*. Glede na navedeno morsko združbo fosilov je mogoče sklepati na paleocensko starost haracejskega apnenca, ki vsebuje ostanke alg *Lagynophora* (sl.10,11). Spremljevalna združba je predstavljena na sl. 10, 11 ter tablah 8 in 9.

Krovne plasti nad profilom

Nad sklenjenim profilom smo analizirali fosilni inventar še v štirih paketih apnenca (sl.10). V prvem (Čeb 136 - 138) nastopajo dokaj pogoste hišice *Miscellanea juliettae villattea* Leppig, med porcelanskimi *Periloculina* sp. in *Idalina* sp., dalje *Coskinon rajkae* Hottinger et Drobne ter *Assilina* sp. Po ugotovljeni združbi bi mogli sklepati na njihovo thanetijsko starost v coni SBZ 3 (tab. 10, sl. 1 - 5, 7).

V drugem in tretjem paketu (Čeb 140 - 143) le nekaj metrov debelih skladov, se pojavljajo še miscelaneje, številne asiline kot *Assilina yvettae* Schaub, *Assilina azilensis* (Tambareau), *Pseudolacazina donatae* (Drobne), *Lacazina blumenthali* Reichel et Sigal, prve diskocikline, poleg pogostejših rotaliid pa tudi alga *Distichoplax biserialis* Dietrich (tab. 7, sl. 1; tab. 11, sl. 1 - 4). Kar nekaj foraminifer sodi med vodilne vrste v coni SBZ 4. V biolititnem apnencu so okruški koral obraščeni z rdečimi algami, kolonijskimi koralami, v medprostorih pa najdemo foraminifere. Določena je vrsta *Astrocoenia lobato - rotundata* (Michelin, 1842), ter rodova *Acropora* in *Goniopora*, vse kolonijske korale (tab. 7, sl. 2).

Najvišji paket raziskanih kamnin že sodi v mlajšo sedimentno sekvenco alveolinsko-numulitnega apnenca. V mikritnem apnencu se pojavljajo kroglaste hišice alveolin, med njimi *Alveolina daniensis* Drobne ter redki fragmenti hišice *Ranikothalia* sp. (tab. 7, sl. 3). Po foraminiferni združbi bi sklepali že na ilerdijsko starost, cono SBZ 6 po Serra - Kielu in 16 sodelavcih (1998). Mikrofosilna združba je predstavljena na tablah 7, 10, 11.

Mlajše paleocenske plasti pri Čebulovici že kažejo vplive povezave z odprtim morjem. Te se nadaljujejo še v eocenu, saj alveolinsko-numulitni apnenci prekrivajo paleocenske. V profilu je sklenjeno nadaljevanje iz paleocena v eocen prekinjeno s tektonskimi dislokacijami.

O haracejskih plasteh

Iz Pariške kotline in Pirenejev so o raziskavah haracej poročali že v letih 1804, (Lamarck in nasledniki), prvi podatki o fosilnih haracejah pa segajo v leto 1780 (Soldani, cf. Ercegovac, 1981). Biostratgrafska conacija temelji na determinaciji izoliranih giro-

gonitov (Grambast, 1971; Wray, 1977; Ercegovac, 1981; Massieux *et al.*, 1989; in drugi). Ker so haraceje v splošnem številne, z vertikalno razširjenostjo od paleozoika do danes, s kozmopolitskimi vrstami ter nastopajo v okolju sladkih do brakičnih voda, v menjavi tudi z morskimi sedimenti, so po mnenju raziskovalcev (Riveline *et al.*, 1996, 455; Grambast, 1971; Massieux *et al.*, 1989; Mebrouk *et al.*, 1996;) dobro "orodje" za biostratigrafsko conacijo (Riveline *et al.*, 1996, sl.4). Klasično ozemlje za tovrstne raziskave so ob Alžiriji (Mebrouk & Feist, 1999) še danes Pireneji. Kot primer naj navedemo, da so v južno - vzhodnem delu Pirenejev, v profilu Can Casadessus, v srednje eocenskih plasteh izolirali več sto primerkov girogonitov iz 1 kg sedimenta. S korelacijo velikih foraminifer iz morskih plasti in harofit iz ne-morskih plasti so bile ugotovljene biocone SBZ 13 - SBZ 18 (Martin - Closas *et al.*, 1999).

Na Krasu se premogovna kadunja razteza, kot jedro Liburnijske formacije, v dolžini okoli 15 km med Vremskim Britofom in Opčinami oz. Bazovico. En krak se širi tudi proti Rodiku (Hamrla 1959, sl. 1, 6; 1985/86, glej Dosedanje raziskave, v tem članku). Izkoriščali so premog kredne starosti spodnjih delov liburnijskih plasti, ki jih prekrivajo v precej večjem obsegu paleocenske plasti, tudi plitvovodnega nastanka. V obeh sekvencah so haraceje dominantna fosilna skupina ob makrofavni, zlasti gastropodih. S tega področja izhajajo tudi študije G. Stachejа o prvih opisih rodov in vrst iz družine "Characeae" in družine Lagynophoreae (1880, 1889). V SW Sloveniji je iz 7 rodov in podrodov opisal 18 vrst, od tega 17 novih vrst in podvrst. Odlično jih je upodobil tudi na risbah v 15 - ali 20 kratnih povečavah (1889) (sl.11). Dodaja obsežno razlago bioloških podatkov o haracejah, njih rasti, vegetativnih delih rastlin, reproduktivnih organih in fosilizaciji, vse tudi v latinskem izrazoslovju. G. Stache kaže skrbnost raziskovalca pri uvajanju nove skupine v paleontologijo in stratigrafijo ter pri interpretaciji poselitvenega okolja (1889, 122 -130). Prav glede na specifične razmere pri sedimentaciji liburnijskih plasti navede kar nekaj "recentnih" rastišč ob Mediteranu, iz rokavov reke Nil, province Oran v Alžiriji, zaliva pri Valenciji, iz beneške lagune ter celo primere iz Angole in jezera Valle pri Caracosu v Braziliji (1889, 125).

Daljša navedba Stachejevih raziskav se nam zdi umestna, ker je dosedaj edina s tega prostora in v strokovni literaturi malo poznana. Družina Charophyceae ima več fosilnih kot recentnih predstavnikov. Ob tej reviziji je kar nekaj Stachejevih taksonov prešlo v sinonimiko. Rodova *Lagynophora* in *Kosmogyra* sta v rabi še danes (Bignot, 1972; Ercegovac, 1981; Knez, 1996).

V spomin na pionirsko izdajo prvega dela monografije o liburnijski stopnji (Die Liburnische Stufe, Wien, Stache, 1889) objavljamo reprodukcijo njegovih risb vrste *Lagynophora liburnica* St., *Kosmogyra superba* St. in *K. perarmata* St. iz table 4, slike 10, 11 in 2, 3 med drugimi haracejami in gastropodi (sl. 11). Primerki so zanimivi zaradi odlične fosilizacije vegetativnih in razmnoževalnih elementov (oosporangijev). Zato nas veseli, da imamo priložnost ponovno osvetliti biostratigrafsko problematiko haracejskih apnencev in to prvič pri nas v korelaciji z morskimi organizmi (tab. 3, sl. 2; tab. 8, sl. 6; sl. 10, 11).

Primerjava med profili na Krasu

Profil Padriče (Padriciano) na Tržaškem Krasu moremo glede na debelino skladov in litološke značilnosti primerjati s profilom Čebulovica. Obe skladovnici kamnin kažeta pogosto menjavanje plitvomorskih karbonatnih sedimentov z lagunskimi in celo s palustrinskimi. Slednje imajo večjo vsebnost organske primesi. V obeh profilih so opazne tudi pogostne okopnitve z znaki mikrokodijev, emerzijskih breč in drugih litoralnih značilnosti. Podobnosti veljajo predvsem za starejši del plasti (SBZ 1, SBZ 2) v debelini cca 150 m. Primerljivosti so ugotovljive prav tako v foraminiferni združbi thanetijskih plasti (SBZ 3, SBZ 4), kjer v obeh profilih že prevlada morska sedimentacija (Drobne *et al.*, 1988, Pugliese *et al.*, 1995; Brazzatti *et al.*,1996, sl. 2,3; Turnšek & Drobne, 1998; sl.3). Sicer pa profila Čebulovica in Padriče ležita danes v različnih geotektonskih enotah, razmaknjenih ob Divaškem prelomu (Jurkovšek *et al.*, 1996a).

Južnozahodno po glavni cesti proti Divači, 2,5 km, so se pred izkopom za avtocesto nahajale plasti haracejskega apnenca, opisovanega že v delih G. Stacheja. Kot zadnji jih je še vzorčeval in obdeloval K n e z (1996). V 25 m debelem profilu je prepoznal štiri tipe apnencev: A: samo z rastlinskimi ostanki *Lagynophora*, B: samo z girogoniti haracej, C: mešane primerke tipa A in B s polži, D: samo s polži (K n e z , 1996; sl.10 - 12). Po analizah U . H e r l e c a izotopska sestava ogljika in kisika kaže na večkratne vplive sladke vode pri sedimentaciji.

Koncentracija haracejske flore je pri Divači precej večja kot pri Čebulovici. V slednjem profilu, smo tudi v daljši sinhroni sekvenci apnenca kozinskega faciesa, ugotovili vse navedene tipe. Nismo pa jih sistematično klasificirali, še zlasti ne zaradi pogostnih emerzijskih dogodkov. Le - ti niso omenjani v profilu Divača. Morda niso tako izraziti in pogostni, ker leži profil bliže jedru kadunje kot pa plasti pri Čebulovici. Primerjava obeh profilov pa le kaže na izredno hitre lateralne spremembe pri sedimentaciji liburnijskih plasti.

V nasprotju z lagunskim razvojem plasti pri Čebulovici pa izstopa prevladujoč morski razvoj, od K/T meje do thanetija, v profilu Dolenja vas, cca 5 km severno od tod, kar kaže na bližino odprtega morja (D r o b n e *et al.*, 1988, 1989, 1996; T u r n š e k & D r o b n e , 1998, sl.3).

Regionalna primerjava paleocenskih združb v centralnem Tetisu

V plasteh danijske in selandijske starosti na profilu Čebulovica ugotavljamo morske ingresije dokaj redko. V pretežno intertidalnem okolju se sporadično pojavljajo dasikladaceje in foraminifere, zelo pogosto plasti s haracejami, med vsemi pa okoli 60 emerzijskih prekinitev (sl. 10). Podobne razvoje paleocenskih plasti smo izbrali za primerjavo z našimi v centralnem Tetisu, njegovem zahodnem in vzhodnem delu.

Na severni strani Pirenejev nastopa foraminifera *Bangiana hanseni* v profilu La Cassino v danijskih plasteh in v podobnih sedimentacijskih pogojih kot v profilu Čebulovica (C a v a g n e t t o & T a m b a r e a u , 1998, 239). V istem profilu so najdene tudi enake pelodne vrste kot pri nas v profilu Dolenja vas in Padriče (*ibidem*, K e d v e s , 1998, 60, 61). Več možnosti primerjav nudijo thanetijske bentične foraminifere (kot n.pr. *Periloculina slovenica*, *Kathina* aff. *selveri*, rotaliidae) iz profilov vzhodnega kot tudi atlantskega dela severnih Pirenejev (*ibidem*, P e y b e r n é s *et al.*, 2000).

Na Jadransko-dinarski platformi so podobni paleocenski pogoji sedimentacije znani iz vzhodnega dela Hercegovine od Podveležja do Metkovića. Tudi tod dominirajo alge *Lagynophora* v danijskih plasteh ter dasikladaceje ob foraminiferah v mlajših (S l i š k o v i ć *et al.*, 1978; D r o b n e *et al.*, 2000; T r u t i n *et al.*, 2000)

Ob Jadranu je najbližje NW delu naše platforme obsežno območje paleogenskih in neogenskih apnencev na robu platforme Maiella (P i g n a t t i , 1994; V e c s e i *et al.*, 1996; V e c s e i & M o u s s a v i a n , 1997). Po datacijah J . P i g n a t t i j a (1994) je v času danija še hiatus in so citirane velike foraminifere šele iz thanetijskih plasti. Korelacija z grebenskimi organizmi, to je kolonijskimi koralami (det. D. Turnšek) kaže sorodno združbo na obeh platformah (tab. 7, sl. 2). Še bolj zanimiv pa je lahko sinhron stresni dogodek, kolaps grebena na obeh straneh v času thanetija ali kmalu po njem. Znano je, da je greben na Maielli rekonstruiran iz resedimentiranih blokov v breči na robu platforme (V e c s e i & M o u s s a v i a n , 1997, sl. 2).

Z otoka Krfa imamo podatke za 13 profilov. Od teh jih 6 delno ali v celoti obsega paleocenske plasti, odložene na notranjem in srednjem delu rampe, še v plitvem podplimskem pasu (A c c o r d i *et al.*, 1998, sl. 18 in 19). Korelacija fosilne združbe dasikladacej in foraminifer je možna že v zgornjem maastrichtiju z vrsto *Rhapydionina liburnica* (Stache). Nadaljuje se z dasikladacejami istih rodov in vrst kot na profilu v Čebulovici v conah SBZ 1 - SBZ 2 (*ibidem*,1998, tab. 10). Med foraminiferami so prepoznavne velike miliolide iz rodu *Kayseriella* Sirel, navedene kot *Paraspirolina* sp. (cf. P i g n a t t i , v *ibidem*, tab. 11). Tod na Krfu, tudi krovne plasti SBZ 3 - SBZ 6 kažejo sličnosti z združbo velikih foraminifer v okolici Čebulovice (kot: *Periloculina, Lacazina, Alveolina*). Podobnost združbe si lahko razlagamo z lego v istem morskem toku na Ja-

dranski oz. Dinarski platformi v času maastrichtija in paleocena (Hottinger 1990, paleobiogeografska karta).

Iz sosledja plasti maastrichtijske in paleocenske starosti na platformi Gavrovo v zunanjih Helenidih ter na zahodnem delu Peloponeza že *Rhapydionina liburnica* kaže na sinhronost plasti. Ta se nadaljuje v paleocen z rodovi iz skupine textulariin, valvulinid, velikih miliolid, glomalveolin in drugih (Tsaila - Monopolis, 1977; Fleury, 1980; Zambatakis - Lekkas, 1988; Maurikas, 1993).

Iz Turčije je E. Sirel (1998) objavil atlas velikih foraminifer zgornje krede in predvsem starejšega paleogena, z biostratigrafskimi podatki in opisi taksonov. V njem smo našli skupne oblike tudi na profilu v Čebulovici. To so *Haymanella paleocenica, Kayseriella decastroi* v daniju in selandiju ter *Lacazina blumenthali , Pseudolacazina donatae* v thanetijskih plasteh.

IZOTOPSKA SESTAVA $\delta^{18}O$ IN $\delta^{13}C$ V APNENCU

Izotopsko sestavo $\delta^{18}O$ in $\delta^{13}C$ smo določili v 24 vzorcih apnenca (sl. 12). Vzorci za analize so bili izbrani glede na njihov značilni mikrofacies in bili razdeljeni v tri skupine. Prvo skupino (A) sestavljajo apnenci, pri katerih opazujemo vpliv sladke vode (meteorsko-vadozna diageneza). To so biomikritni apnenci tipa "mudstone - wackestone" s številnimi girogoniti haracej ali z laginoforami in pa vzorci, ki kažejo znake sedimentacije v litoralnem nadplimskem okolju (npr. Čeb 95 z gravitacijskim cementom). V drugo skupino (B) uvrščamo temen biomikritni apnenec, ki se je odlagal v plitvih lagunah in ima rahlo povišano vsebnost organske snovi. Tretji skupini (C) prištevamo svetlejše različke apnenca; po strukturi so to algalni sparit, biomikrit in biosparit ("packstone-grainstone"), ki so se odlagali v bolj razgibanem morskem okolju na odprtem šelfu. Vzorci zadnje skupine so vsi iz vrhnjega dela profila (Čeb 111 do 134) in pripadajo kozinskemu apnencu.

Vzorci so bili analizirani na Inštitutu Jožef Stefan po modificirani metodi McCrea (1950). Apnenec je bil obdelan s fosforno kislino (H_3PO_4) pri temperaturi 50 ± 0,5°C. CO_2 plin, ki je nastal pri reakciji, je bil analiziran z masnim spektrometrom Varian MAT 250. Vse vrednosti za $\delta^{13}C$ in $\delta^{18}O$ so podane v ‰ glede na PDB in na SMOW standarde.

Vrednost izotopske sestave $\delta^{18}O$ je pri veliki večini vzorcev v ozkem intervalu med 25,3 in 27,6 ‰, s poprečjem okrog 25,5 ‰ (SMOW). Te vrednosti so nekoliko nižje kot pri recentnih apnencih morskega okolja, v katerih $\delta^{18}O$ niha večinoma od +28 do +30 ‰ (Faure, 1977). Kaj je vzrok za delno obogatitev z lahkim kisikom izotopom ne vemo, predpostavljamo pa, da je posledica izotopsko lažje morske vode zaradi vpliva meteorske vode in občasno toplega morja s temperaturo med 27 in 30°C (posebno predeli zaprtih lagun in litorala, v katerih se je mestoma izločala tudi sadra).

Drugačna pa je situacija z izotopsko sestavo ogljika. Pri tem vsebnosti $\delta^{13}C$ sovpadajo s strukturnim tipom apnenca, predvsem z deležem organske snovi v njem ter z vplivom sladke vode. Tako so vzorci skupine A (haracejski apnenci) obogateni z lahkim ogljikom 12C, ki se giblje v razponu med -2,5 in -6,5 ‰ (PDB) s povprečjem okrog -5 ‰ (sl.12). Vzorci skupine B (temni biomikriti lagunskega okolja) so glede na apnenec odprtega šelfa tudi obogateni z lahkim $\delta^{12}C$ (-0,4 do -2,7 ‰). To je rezultat povišane vsebnosti organske snovi. Pri razkroju organskih snovi se je namreč sprostil izotopsko lažji CO_2, ki je sodeloval pri izločanju kalcita. Biosparitni različki apnenca odprtega morja (skupina C) pa kažejo "normalne" vsebnosti $\delta^{13}C$ za apnence morskega okolja in sicer od +2,3 do + 0,1 ‰.

PREPOZNAVNOST LIBURNIJSKE FORMACIJE NA SOSEDNJIH OBMOČJIH

Med velike spremembe na Dinarski karbonatni platformi, ki so vplivale na sedimentacijo plasti Liburnijske formacije, spada emerzija v zgornjem delu campanija. Omenjena kopna faza je dobro prepoznavna na vseh stabilnih delih Dinarske karbonatne plošče. V maastrichtiju se je sedimentacija marsikje obnovila, vendar so bile te plasti zaradi bolj ali manj lokalno pogojenih razlik v sedimentacijskem okolju različno poimenovane.

Na Tržaško - komenski planoti so

Jurkovšek in sodelavci (1996a, sl.6,10) plitvomorske podplimske, medplimske in nadplimske sedimente združili v Liburnijsko formacijo, na Tržaškem krasu pa imenujejo ekvivalentne plasti člen Monte Grisa (Cucchi *et al.*, 1989, tab. 1, 2), ki ga delijo na spodnji in zgornji interval. Zgornji interval je ekvivalenten slivskemu apnencu. Na ozemlju Soškega krasa pa so Tentor in sodelavci (1994) celotno zaporedje plasti razdelili na Liburnijsko skupino (Grupo "Liburnico") in na miliolidne apnence (Calcari a miliolidi). Liburnijsko skupino so nadalje razdelili na zgornjemaastrichtijske vremske (Strati di Vreme) in danijske kozinske plasti (Strati di Cosina), med katerima opazujejo emerzijsko mejo. Miliolidni apnenci (Calcari a miliolidi) so ekvivalentni Slivskemu apnencu in zgornjemu intervalu člena Monte Grisa Liburnijske formacije na Tržaškem krasu. Na otoku Braču predstavlja sedimentne kamnine nad campanijskomaastrichtijsko emerzijo formacija Sumartin, v kateri je zastopan spodnji (predvsem kredni) del Liburnijske formacije (Gušić & Jelaska, 1990, tab. 1).

Liburnijski formaciji sledi na Tržaško-komenski planoti zaporedje plasti alveolinsko-numulitnega apnenca (Drobne, 1977; Jurkovšek *et al.*, 1996a, sl. 10), ki je nastala kot posledica progresivne transgresije na karbonatno platformo. Poglabljanje okolja je napredovalo v smeri od severozahoda proti jugovzhodu. Na Tržaškem krasu so ekvivalentne plasti poimenovali kot člen Opčine (Opicina member, v Cucchi *et al.*, 1989, tab. 1, 2), na Soškem krasu pa numulitno-alveolinski apnenec (Calcari a nummuliti e alveoline, Tentor *et al.*, 1994). Povsod na teh območjih sega njihova spodnja meja v spodnji eocen, na otoku Braču, kjer ga imenujejo alveolinsko-numulitni apnenec, pa v zgornji del spodnjega eocena.

Zadnji pomemben geološki dogodek na Krasu predstavlja razpad karbonatne platforme v zgornjem delu ilerdija, ko se je začela sedimentacija fliša. Na prostoru okrog Čebulovice je meja med apnenci in flišem večinoma erozijska.

DISKUSIJA

Analiza združbe na profilu Čebulovica potrjuje že večkrat ugotovljeno redukcijo v pojavljanju foraminifer po kredno / terciarni meji. Prve, ki se pojavijo so r - strategi kot populacija mezo- in eutrofnih plitvin, dominantnih več kot 5 milijonov let. K - strategi nastopijo še pred koncem paleocena, ne glede na fizikalno - kemične gradiente. Okupirajo oligotrofno okolje z novo strategijo preživetja. Ta se kaže s hišicami večjih dimenzij, A in B generacijami, kompleksno notranjo morfostrukturo, s prilagojenim ciklom razmnoževanja glede na povečan sezonski delež hranil, primerno podlago za "nastanitev" v konkurenci z drugimi organizmi itd. V sorazmerno kratkem času je ugotovljeno povečanje raznolikosti in filogenetski "razcvet" malo rodov z mnogimi vrstami (Hottinger & Drobne, 1988; Hottinger, 1997).

Pojavljanje dasikladacej ponovno potrjuje, da so te ozko vezane na morsko okolje plitve rampe ali obrežnih lagun. To sklepamo glede na pojavljanje istih vrst v diahronih horizontih. Za primerjavo služijo spremenljivi pogoji sedimentacije v profilu Čebulovica - zaprti šelf (občasno z dasikladacejami) in na profilu Dolenja vas - odprti šelf (z dasikladacejami) (Pleničar *et al.*, 1992; Barattolo, 1998; Turnšek (Drobne, 1998, sl.3).

Za biostratigrafsko umestitev plasti je potrebno nadaljevati s paleontološkim študijem fosilnega inventarja. To je spodbujal že pokojni raziskovalec premogov M. Hamrla (1958, 212), ki je paleontološke rezultate tudi s pridom uporabljal (1985/86). Le - te pa je potrebno dalje umestiti v kronostratigrafske cone, ki so na voljo za planktonske foraminifere, nanoplankton, plitvomorski bentos in tudi za Charophyta. Z determinacijo fosilov bi bila mogoča prepoznavnost plasti po predlogu " International Subcommission on Paleogene Stratigraphy". Le-te upošteva, s pridržkom meje paleocen / eocen, tudi nova razčlenitev paleogena, s pomočjo velikih foraminifer iz plitvomorskega bentičnega okolja, v obsegu SBZ 1 - SBZ 20, za paleocen SBZ 1 - SBZ 4 (Serra - Kiel *et al.*, 1998).

Po analizah izotopske sestave $\delta^{18}O$ in $\delta^{13}C$ bi na rastiščih haracej temperatura vode lahko dosegla 27° do 30°C, kar je dobro primerljivo z današjim subtropskim okoljem v zalivu Aqaba (Reiss Hottinger,

1984). Glede na to bi lahko sklepali na občasno bližino haracejskih travnikov in na akumulacijske depresije z množicami girogonitov v kraški premogovni kadunji.

Med nerešene probleme na Krasu sodi še nepojasnjen mehanizem tonjenja premoške kadunje. Omejimo jo lahko na smer med Vremskim Britofom, preko Lokev in Lipice do Padrič. Danes je pretrgana in razcepljena na več krakov. Kadunja s svojimi krednimi in paleocenskimi plastmi predstavlja sedimentacijsko jedro Liburnijske formacije na NW delu Jadransko - dinarske platforme.

Glede na stopnjo raziskanosti harofit in njih bioconacije v mezozoiku in terciarju (R i v e l i n e *et al.*, 1996) bi paleontološka obdelava girogonitov v krednih in paleogenskih plasteh lahko dala jasnejšo sliko razvoja plitvomorskih območij na Jadransko - dinarski karbonatni platformi.

ZAKLJUČKI

1. Profil v useku nove avtoceste pri Čebulovici nam omogoča, da študiramo razvoj paleocenskih apnencev Liburnijske formacije na osrednjem delu Krasa. Preko 150 m debela skladovnica kaže v spodnjem delu na dokaj monoton razvoj znotraj plitvega šelfa ("rampe") z lagunami in pogostnimi med- in nadplimskimi pogoji. Morsko okolje sedimentacije se menjava z brakičnim, kar potrjujejo tudi izotopske analize $\delta^{13}C$. Po mikrofaciesu pripada večina apnencev v SMF 16-20 (omejena cirkulacija vode z zamuljenim morskim dnom), v slivskem apnencu kot zaključnem delu Liburnijske formacije pa v SMF 16-18 (algalni biospariti). V profilu ugotavljamo preko 60 kratkotrajnih emerzijskih faz.

2. Monotona sekvenca plasti z menjavo plitvovodnih sedimentov in emerzijskih površin obsega čas nad 5 milijonov let, glede na ugotovljeno bioto. V poznem paleocenu je morska transgresija oziroma globalen dvig morske gladine prekril platformo južnozahodne Slovenije.

3. Biostratigrafska korelacija različnih facialnih asociacij v plasteh Liburnijske formacije, haracej na eni strani ter dasikladacej in foraminifer na drugi, je na Krasu izvedena prvič. Na profilu Čebulovica je ugotovljena danijska in selandijska starost plasti (SBZ 1, SBZ 2). Z novimi metodami, smo potrdili stare hipoteze G. S t a c h e j a in M. H a m r l e o pojavljanju rodu Lagynophora v paleocenu.

4. Za Liburnijsko formacijo predlagamo dosledno rabo litoloških členov, faciesa in "facies association" ter njih umestitev v cone in kronostratigrafske enote kredne in paleogenske starosti. Ta bi omogočila sodobno biostratigrafsko interpretacijo ugotovljenih plasti Liburnijske formacije na Krasu kakor tudi v Istri in vzdolž Jadrana.

5. Mnenja smo, da bi za potrebe geološkega kartiranja zadržali kot uporaben inštrument izraz Liburnijska formacija z poimenovanimi litološkimi členi kredne in paleogenske starosti.

6. Biota v profilu Čebulovica kaže na pojavljanje vodilnih vrst v daniju kot so dasikladaceje *Decastroporella tergestina*, *Drobnella slovenica*, cyanophyta *Aeolisaccus barattoloi* ter foraminifera *Bangiana hanseni*. Za selandij so značilne še iste dasikladaceje, številčnejše, poleg drugih kot sta *Hamulusella liburnica*, *Microsporangiella buseri* in *Cymopolia* spp. ter foraminiferi *Kayseriella decastroi* in *Haymanella paleocenica*.

Morska flora in favna nam omogočata starostno definiranje apnencev s haracejami in laginoforami, ki so danijske in selandijske starosti in so se odlagali v brakičnem okolju in ne-morskih sedimentih.

7. Korelacija biote v morskih in ne-morskih apnencih nam nudi primerjavo v širšem prostoru centralnega Tetisa. Razvoj s haracejami in foraminiferami je mogoče korelirati z razvojem v severnih Pirenejih. Medtem ko je morski razvoj z dasikladacejami in foraminiferami skoraj identičen s tistim na vzhodni strani Tetisa, vključno z Hercegovino, Apulijo, otokom Krfom, zahodno Grčijo in Turčijo.

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