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Changes of Depositional Environment as Causal Factors in Development of Facial Variability: An Example from the Late Senonian Limestones on the Island of Brač (Yugoslavia)

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The sediments of the uppermost Senonian on the island of Brač represent shoaling phase of restricted platform carbonates showing emergence features. The two profiles considered, would be the most representative of the main facial characteristics of the uppermost Senonian succession on the island of Brač.

Sedimenti najvišeg senona otoka Brača predstavljaju fazu oplićavanja zaštićene karbonatne platforme. Uz to, sadržavaju i emerzijska obilježja. Odabrani profili (Splitska i Sutivan) mogu poslužiti kao reprezentativni kada je u pitanju razmatranje glavnih facijelnih karakteristika slijeda senonskih naslaga otoka Brača.

INTRODUCTION

The sediments of the uppermost Senonian on the island of Brač represent shoaling phase of restricted platform carbonates showing emergence features. These sediments also draw our attention because of the problem of dividing them from Palaeogene sediments. This problem has been actual for a long time in the West Dinarides. Stache (1889) was one of the first to study this problem. He separated the layers between underlaying rudistid limestones and overlaying limestones with alveolinids/nummulitids under the name Liburnian sediments. This formation corresponds partly to the Senonian and partly to the Palaeogene but its stratigraphic range has been differently treated. Stache (1889), Pleničar (1961) and Bignot (1972) consider them as the Senonian, while Pavlovec (1963) defines the equivalent sediments in south Slovenia (under the name Vreme beds) as the Tertiary. Hötzl and Pavlovec (1979) had consequently defined the layers with gyropleuras near Vremski Britof in south Slovenia as a part of Vreme beds, considering them an equivalent to the lower part of Liburnian deposits (Maastrichtian). According to recent explorations carried out by Pavlovec and Pleničar (1981) the boundary between the Cretaceous and Tertiary is placed within or above the so called Vreme beds. Jelaska and Ogorelec (1983), considering the upper cretaceous depositional environments on the island of Brač, recognized beds which are comparable with so called Vreme beds.

FACIAL VARIABILITY

The two profiles (Splitska and Sutivan) considered, would be the most representative of the main facial characteristics of the uppermost Senonian succession on the island of Brač. According to Jelaska and Ogorelec (1983), the profiles mentioned comprise sediments Maastrichtian in age, based on the microfossil assemblage as well as rudistid species.

a) Types of Sediments on the Profile of Splitska

There are several types of limestone in alternation. We can distinguish:

— White to brownishgrey sparse biomicrite and biopelmicrite (wackestone). This type of limestone can be poorly-washed in some places and they differ from the previous one having a grain supported: packed biopelmicrite (packstone).

— White, massive, thick-bedded pure lime mudstone.

— Fenestral, sparse biomicrite (wackestone). Fenestrae have irregular shape and are cemented with sparite. They rarely have geopetal filling with lime-mud which fills the lower part and sparry calcite filling the upper part.

— Fenestral, sparse and packed pelmicrites and biopelmicrites (wackestone — packstone). Rocks are white, pale pink and light brown coloured. Concentration of fenestrae in particular levels makes the sediment look laminated. Micritic matrix is sporadically recrystallized into microsparite and sparite. Fenestrae in this type of limestone are mostly minute, but slightly bigger than the space between grains. They are filled with mosaic sparry cement.

— Fenestral and fossiliferous intramicrite to intrasparite (skeletal intraclastic packstone to grainstone). Fenestrae are equal to or slightly larger than the space between grains. They are cemented with mosaic sparry calcite, but the larger ones are partly filled with lime-mud.

— Algal biolithite (horizontal stromatolites, boundstone). Laminae vary in colour from dark grey to black. Numerous fenestrae are different in shape and size. They are mostly cemented with mosaic sparite.

— Poorly sorted and partly washed biosparite contains rudist and/or rudist fragments. The textures of these rocks vary from biostromes to floatstones depending whether rudist shells are self-supported or float in the matrix.

Previously described types of limestone are very often dolomitized. The process of dolomitization was of different intensity, so the dolomite content varies from 30—79%. It is characteristic for the whole group of dolomitic rocks on this profile that their previous structure was more or less recognizable. Dolomite crystals differ in dimension: larger one up to 0,1 mm and smaller grains up to 0,03 mm. The dolomitization of bound-

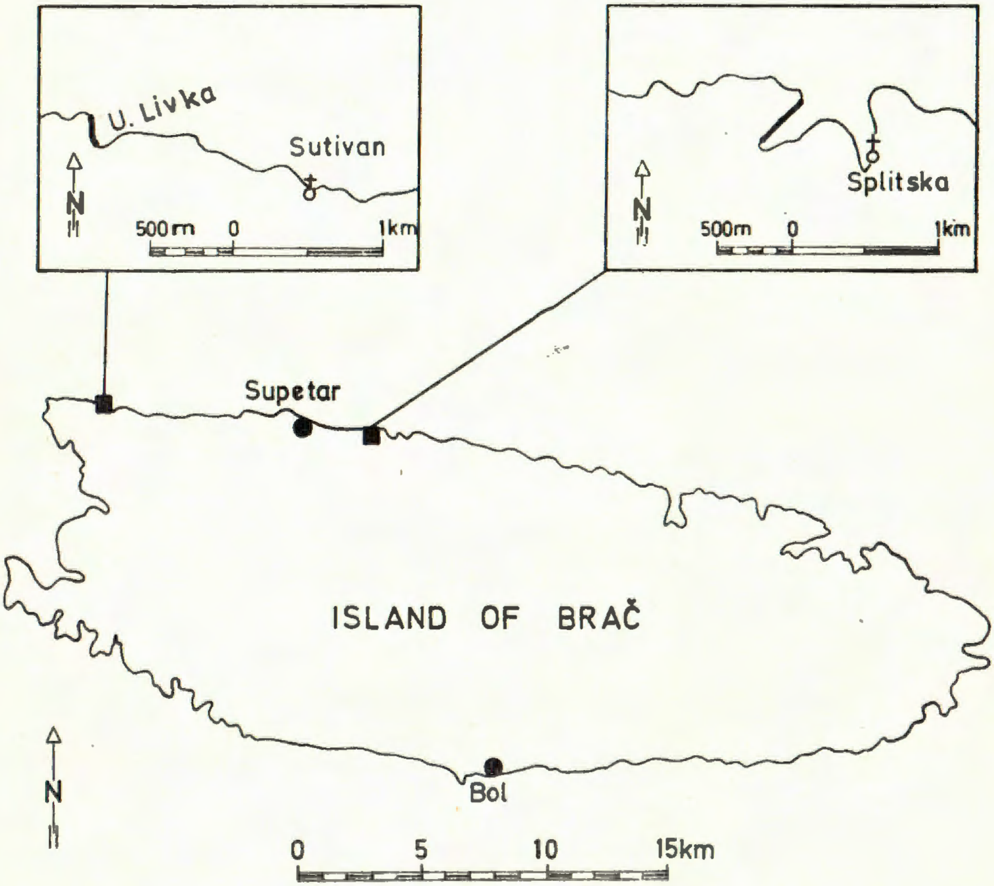

Fig. 1 Index map showing location of the profiles considered

Slika 1 Smještajna karta

stones as well as skeletal-pelletal wackestones and packstones is considered to be early diagenetic. This process continued later on and probably in rocks already lithified as well.

The considered sediments represent a hundred meters thick sequence. This succession comprises several meters thick repetitive units (cycles), which consists of rudist floatstone and/or skeletal-pelletal wackestone-packstone alternating with various types of fenestral limestones and/or, but rarely, algal boundstone.

b) Types of Sediments on the Profile in Livka Cove (West of Sutivan)

The profile in Livka cove consists of three distinguishable parts, as follows:

— The basal part comprises rudistid limestones — wackestones. Skeletal grains include: rudistid fragments (predominate in composition), foraminifers (*Dicyclina schlumbergeri* Munier-Chalmas, *Rhapydionina liburnica* (Stache), *Miliolidae, Ophtalmidiidae, Valvulinidae*), algae (*Thaumatoporella*) and echinoderms. These grains can make up to 20 % of the rock. Its mud matrix is partly recrystallized.

— The middle part of profile is represented by several types of limestones in alternation:

— Well-bedded microsparite with poorly recognizable primary structure. Primary micrite recrystallized into microsparite (average grain size 20—30 μm). Shell fragments and foraminifers are rare.

— Thin-bedded laminated micrite to biomicrite. Laminae are inorganic in origin. The numerous milimetre-size parallel stylolites are red coloured by clayey substance.

— Thin-bedded cryptalgal limestone (boundstone).

— Thick-bedded biopelmicrite (pelletal-foraminiferal wackestone). These layers are associated with cryptalgal limestones. Pellets predominate over the other particles. The rock is pigmented with dispersed inorganic substance.

— Fenestral wackestone, usually overlays the formerly described deposits. Cementation of fenestrae with sparite occured very early and rapidly.

— Packstone layers consisting an abundance of foraminifers, particularly miliolids, so that they can be called miliolidal packstones. These packstones are in alternation with coquina limestones containing numerous thin-shelled molluscs, probably genus Gyropleura. Both types are more or less dolomitized (probably late-diagenetic dolomitization). This part of the profile considered can be comparable with the so called Vreme beds which Hötzl and Pavlovec (1979) defined as the Maastrichtian. The fossils found here also indicate the Maastrichtian: *Monchar-*

montia apenninica (De Castro), *Laffitteina marsicana* (Farinacci), *Discorbis* (sensu Bignot, 1972), *Bolivinopsis* sp., *Ataxophragmium* sp., *Miscellanea* sp.

— *The topmost part* of the Livka profile is built up of mudstones and skeletal wackestones. These limestones differ from the previously mentioned ones because of their abundance of ostracods and charas, but small rotalids, miliolids, valvulinids and some algae are also found. Radoičić (1960) included these sediments into Danian. According to Jelaska & al. (1984), the boron content here is from 30 to 50 ppm., meanwhile the boron content in the underlaying packstone horizon vary from 100 to 180 ppm. in insoluble fraction respectivelly. Dolomitization is more distinct in this part of the sequence, and it is probably late-diagenetic as in packstone horizon.

Emergences features, which occasionally appear within the three parts of Livka profile, are the best seen at the end of the topmost part particularly. Emergence breccia, as the most distinct feature, seems to have been connected with the solution process of the topmost limestones (? Danian) as well as the middle part limestones (Maastrichtian). The solution could be associated, in some cases, with the penetration of red-coloured unsoluble residuum of bauxitic character.

INTERPRETATION OF ENVIRONMENTS

Having reviewed the carbonate successions of the two profiles considered we can interpret the observed facial variability in terms of depositional environments:

1. Sparse and packed, poorly washed biomicrites and biopelsparites exhibit:

— considerable amount of pellets in composition,
— fossil association with a small number of species and an abundance of individuals,
— micritization and general abundance of mud,
— no sorting, no rounding of skelletal particles.

In accordance with the above mentioned facts we can emphasize that these types of limestones had been deposited within restricted platform areas where slightly agitated water of subtidal environment directly influence the textural types. This conclusion is supportable because of biostromes being generally made up of radiolitids (it is known that the radiolitids represented more restricted environment, Polšak, 1979). Matrix of these biostromes appear to be very fine particles and/or of lime-mud. The associated limestones also exhibit abundance of mud, therefore it would be imagined a quiet water of restricted environment. Meanwhile, the higher-energy regime could have existed temporarily as indicated by the origin of poorly washed biosparites.

2. Limestones with fenestral texture could be compared with recent sediments in supratidal (Shinn, 1968, Shinn & al., 1965, Shinn &

SUCCESSION OF THE PART OF MASTRICHTIAN CARBONATES AT SPLITSKA SHOWING TRANSGRESSIVE-REGRESSIVE CYCLES (simplified display)

Transgresivno-regresivni ciklusi mastrihta kod Splitske (detalj, pojednostavljen prikaz)

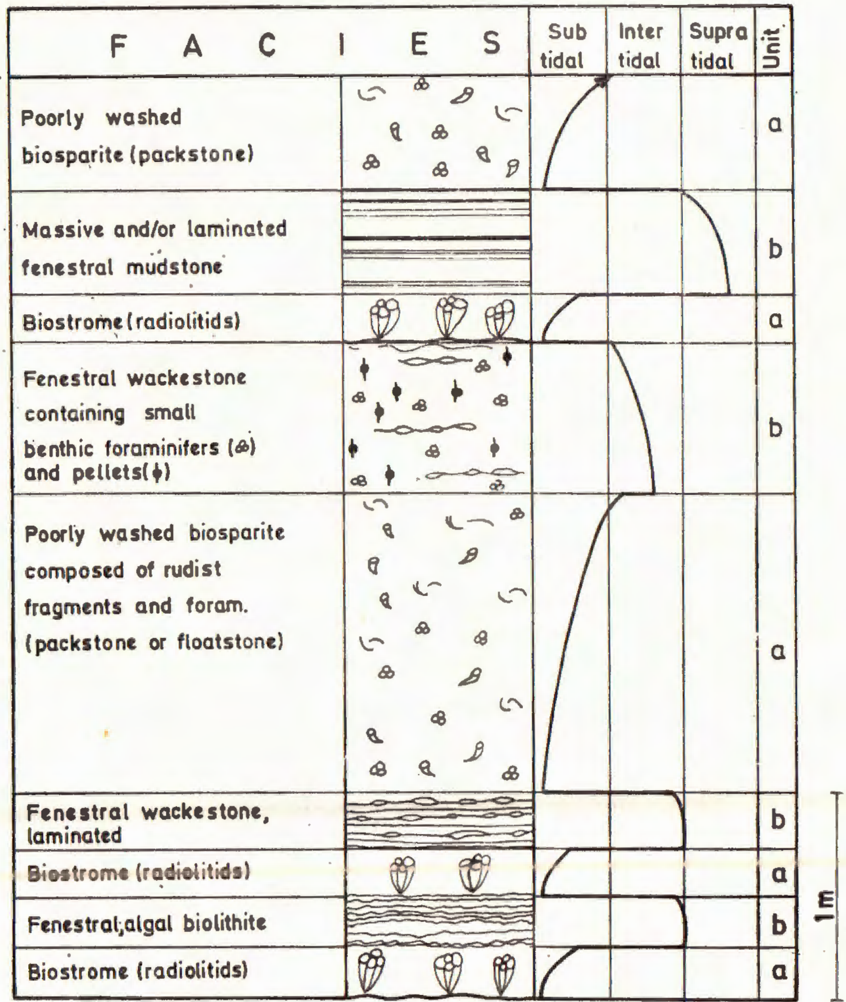

Fig. 2
Slika 2

al., 1969, Ginsburg & Hardie, 1975). In respect of their characteristics these limestones exhibit similar features as well as the described carbonates of different ages, which are considered as intertidal to supratidal (Fischer, 1964, Colacicchi, Passeri & Pialli, 1975, Castellarin & Sartori, 1973).

3. Algal boundstone respectively cryptalgal laminites, with its uneven and unconformable laminae and fenestrae are also indicators of the intertidal to supratidal environment. The laminae are dessicated forming tepee structures. Repetitive dessication and weting could have induced conditions under which calcite could be replaced by dolomite. This was happening at the same time as the stromatolite algae were growing; minute dolomite grains and well preserved depositional texture indicate the same conditions (Shinn & al., 1965).

CONCLUSION

The Upper Cretaceous carbonates of the island of Brač were deposited in two major cycles (Jelaska & Ogorelec, 1983). The first cycle comprised Cenomanian, Turonian and Lower Senonian carbonates respectively. The late Senonian, i. e. the two profiles considered, belong to the second cycle. It represents the shoaling phase showing features of subaerial exposure. Emergence climax was reached by the end of the topmost part of succession which can be comparable with the so called Vreme beds, in south Slovenia (Pavlovec & Pleničar, 1981).

The profiles observed comprise limestones forming rhythmic succession and consist of the several textural types. Nevertheless, this repetition seems to be of cyclic character. In respect of thickness, the cycles ranging from one meter to several meters. A vertical sequence shows that cycles mostly comprise the two main rock-units: unit a — various types of skeletal-pelletal packstones, associated with unit b — which consists of fenestral limestones and/or cryptalgal laminites.

Considering these phenomena in terms of depositional environments, we can conclude that they reflect the changes from (shallow) subtidal to intertidal/supratidal. Unit a corresponds to subtidal and unit b would correspond to intertidal/supratidal. In other words, a vertical sequences of the cycles show that different sedimentary environments produce distinctive variations of carbonate rocks. The repetition of these units bears out the supposition of a constant subsiding of the platform followed by sea-level oscillations. These events produced the considered carbonate succesions consisting of minor transgressive — regresive cycles.

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Mijene sedimentacijskog okoliša kao uzročni faktor u razvoju facijelne varijabilnosti: promatrano na primjeru gornjosenonskih vapnenaca otoka Brača (Jugoslavija)

V. Jelaska

Profili kod Splitske i Sutivana odabrani su kao tipični za prikaz glavnih facijelnih karakteristika visokog senona otoka Brača.

Više tipova vapnenačkih stijena moguće je razlikovati na profilu kod Splitske. To su:

— svijetli i smeđesivi biomikriti i biopelmikriti,
— svijetli, masivni, debelo uslojeni vapnenci muljevite potpore: mikriti (mudstone),
— fenestralni biomikriti (skeletni wackestone),
— fenestralni, pakirani pelmikriti i biopelmikriti (peletno-skeletni wackestone-packstone),
— fenestralni, fosiliferni intramikriti do intraspariti (skeletni, intraklastični packstone do grainstone),
— algalni biolititi (boundstone),
— slabo sortirani i djelomice isprani biospariti, razlikuju se: biostrome i tip floatstone u odnosu na uređenost rudista, odnosno njihovog kršja.

Spomenuti tipovi stijena grade približno stotinu metara debeo slijed naslaga koje karakterizira cikličko ponavljanje manjih jedinica sastavljenih od rudistnog vapnenca, odnosno skeletno-peletnih vapnenaca tipa wackestone-packstone u izmjeni s različitim varijetetima fenestralnog vapnenca i/ili, ali rjeđe, algalnog biolitita.

Promatrani profil kod Sutivana obuhvaća tri različite litološke cjeline, to su:

— bazalni dio; predstavljen rudistnim vapnencem tipa wackestone,
— srednji dio; izgrađen od više različitih tipova vapnenačkih stijena: dobro-uslojeni mikrospariti, tanko-uslojeni i laminirani mikriti i biomikriti, tanko-uslojeni kriptalgalni vapnenci (boundstone), debelo-uslojeni biopelmikriti, fenestralni wackestone, te miliolidni packstone s kojim je u izmjeni kokinitski vapnenac,
— najviši dio; izgrađuju mikriti i biomikriti koji sadržavaju brojne ostrakode, hare i sitne bentičke foraminifere.

Spomenute karbonatne stijene, podrazumjevajući i njihove facijelne varijabilnosti, moguće je interpretirati kao uzročnu posljedicu mijena sedimentacijskog okoliša:

Biomikriti i biopelspariti mogli su biti taloženi unutar zaštićene platforme. Rudistno kršje, koje izgrađuje vapnence tipa wackestone, potječe od razaranja manjih ili većih radiolitidnih biostroma koje su povremeno postojale u zatvorenim, ali mjestimice ipak dovoljno prozračenim, plićacima platforme. Pod-plimski okoliš umjereno uzburkane vode izravno je djelovao na strukturu taložina.

Vapnenci fenestralne građe usporedivi su s recentnim taložinama nad-plimskog okoliša (Shinn, 1968, Shinn & al., 1965, Shinn & al., 1969, Ginsburg & Hardie, 1975), odnosno fosilnim ekvivalentima među-plimskog i nad-plimskog okoliša različite starosti: Fisher, 1964, Colacicchi, Passeri & Pialli, 1975, Castellarin & Sartori, 1973.

Algalni biolititi odnosno kriptalgalni laminiti također su indikativni za među-plimski, odnosno nad-plimski okoliš.

ZAKLJUČAK

Gornjokredni karbonati otoka Brača taloženi su unutar dva velika ciklusa (Jelaska & Ogorelec, 1983). Prvi ciklus obuhvaća cenomanske, turonske i donjosenonske karbonatne stijene. Naslage gornjeg senona, što podrazumijeva i stijene promatrane na dva prikazana profila, pripadaju drugom ciklusu. Taj ciklus predstavlja, naime, fazu oplićavanja obilježenu emerzijskim manifestacijama. Maksimum emerzije izražen je u najvišem nivou slijeda, koji je usporediv s tzv. Vreme naslagama južne Slovenije (Pavlovec & Pleničar, 1981).

Ritmičko ponavljanje različitih tipova vapnenaca na prikazanim profilima doimlje se da je cikličkog karaktera. Vertikalni slijed pojedinog ciklusa obuhvaća dvije osnovne stijenske jedinice: Jedinicu — a, koju obilježavaju različiti tipova skeletno-peletnog wackestone-packstone vapnenca udruženog s jedinicom — b, koju, u pravilu gradi fenestralni vapnenac i/ili laminirani vapnenac kriptalgalne građe.

Ako ove pojave promatramo uzročno povezano sa sedimentacijskim okolišem, tada možemo zaključiti da su u pitanju mijene taložnog okoliša od (plićeg) pod-plimskog do međuplimskog odnosno nad-plimskog. Jedinica — a odgovarala bi pod-plimskom, a jedinica — b međuplimskom/ okolišu. Ponavljanje spomenutih jedinica potvrđuje pretpostavku o postojanom tonjenju platforme, ali koje je bilo praćeno oscilacijama morske razine. Slijed tih događaja rezultirao je slijedom karbonatnih stijena sastavljenim od manjih transgresivno-regresivnih ciklusa.

PLATE — TABLA I

1, 2 Poorly washed biopelsparites (packstones). Profile of Splitska.

3 Biopelmicrite composed largerly of miliolids mixed with the pellet grains (wackestone or packstone). The middle part of the profile in Livka cove — Sutivan.

4 Fenestral, poorly laminated pelmicrite (wackestone). Profile of Splitska.

5 Fenestral, laminated micrite (mudstone). The middle part of the profile in Livka cove — Sutivan.

6 Fenestral pelmicrite (wackestone or packstone). Profile of Splitska.

7 Algal biolithite (boundstone). Profile of Splitska.

1, 2 Slabo isprani biopelspariti (skeletni-peloidni packstone). Profil kod Splitske.

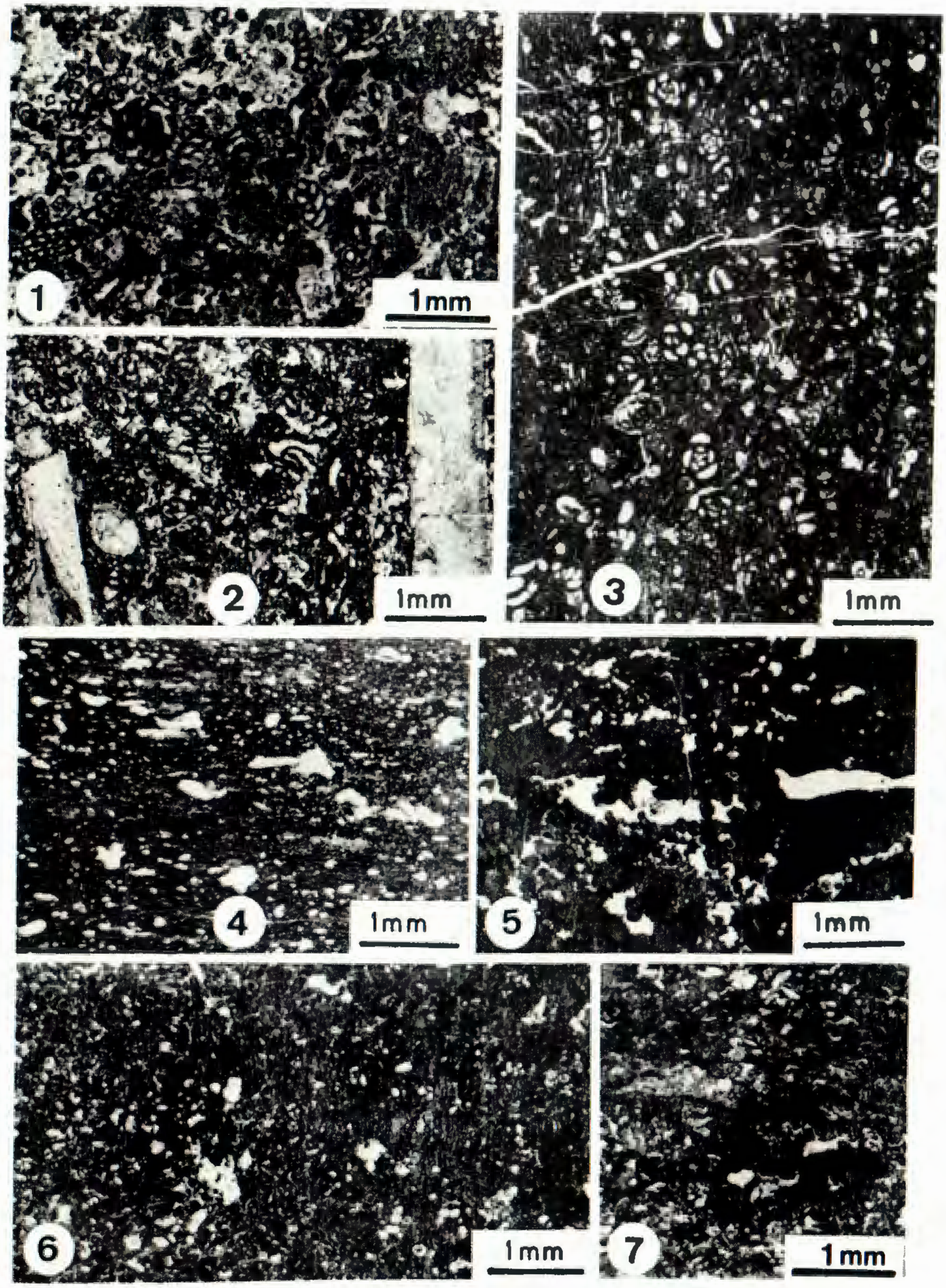
3 Biopelmikrit (foraminiferski-peloidni wackestone ili packstone). Srednji dio profila u Livka uvali kod Sutivana.

4 Neizrazito laminirani pelmikrit (wackestone). Profil kod Splitske.

5 Laminirani mikrit fenestralne građe (mudstone). Srednji dio profila u Livka uvali kod Sutivana.

6 Pelmikrit (peloidni wackestone ili packstone). Profil kod Splitske.

7 Algalni biolitit (boundstone). Profil kod Splitske.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