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CIKLIČKA SEDIMENTACIJA NA RUBOVIMA MARINSKOG ŠELFA ZA VRIJEME SREDNJEG I GORNJEG PERMA U CENTRALNOM DIJELU VELEBITA (HRVATSKA)

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Ključne riječi: Srednji/gornji perm, mikrofosili, paleookoliši, Velebit

UVOD

Gornjopermska biotička kriza izazvana najvećim pomorom u poznatoj povijesti Zemlje, dugo se smatrala jedinim događajem. Nova istraživanja više autora pokazuju da se izumiranje odvijalo u dvije faze: jednom završava srednji perm (kasnije: granica G-L) a drugom završava cijelo razdoblje paleozoika (kasnije: granica P-T). Pretpostavlja se da je Kamura zahlađenje jedan od glavnih uzroka prve od dvije faze gornjopermskog izumiranja na G-L granici (Isozaki et al., 2011).

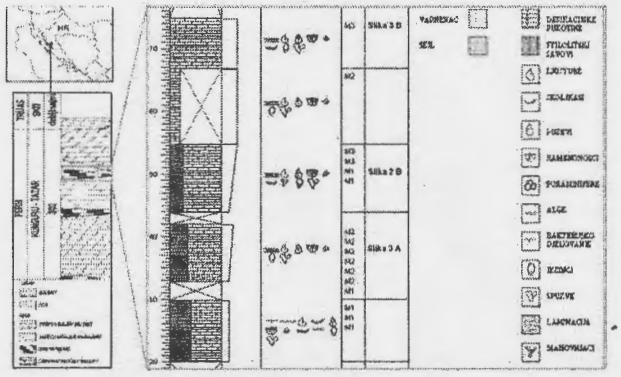
Prva značajna istraživanja naslaga srednjeg i gornjeg perma Velebita napravio je Salopek, (1942). Salopek je opisao različite litofacijalne jedinice i njihove stratigrafske odnose. Detaljne biostratigrafske analize na osnovu fuzulinidnih foraminifera objavila je Kochansky-Devidé (1965), a paleoekološki aspekti bili su predmet proučavanja više autora (npr. Sremac, 1991; Tišljar et al., 1991; Sremac & Marjanac, 2003). Kontinuirano taloženje gornjopermskih naslaga Velebita kao i P-T izumiranje istraženo je u radu Fio et al., (2010) te su opisana dva stresa na osnovu izotopnih analiza.

Naslage srednjeg i gornjeg perma započinju taloženjem krupnozrnatih Košna slojeva ili Velebitskih breča, a nastavljaju se produktima dugotrajne sedimentacije na karbonatnoj platformi (dolomiti s tri vapnenačka horizonta). Vapnenačke zone izuzetno su bogate fosilima.

Najmlađa zona vapnenaca (pv_3) odlikuje se miješanom bentičkom zajednicom fuzulinidnih foraminifera i vapnenačkih algi, a dobila je ime po najčešćoj fuzulidnoj vrsti kao Yabeina syrtalis zona (Salopek, 1942; Kochansky-Devide, 1965). Zona je dobro razvijena duž cesta Gospić-Karlobag i na području Velničke Glavice (Kalvarija). Tišljar et al. (1991) prvi su istraživali slijed naslaga duž ceste te prepoznali cikličko taloženje i opisali nekoliko mikrofacijesnih tipova vrlo plitkog šelfnog okoliša.

METODE

Za potrebe ovog istraživanja napravljen je detaljan geološki stup duž ceste Brušane-Baške Oštarije (Slika 1).



Slika 1. Područje istraživanja i shematski geološki stup naslaga srednjeg i gornjeg perma Velebita (Ramovš et al, 1990, preuzeto iz Sremac & Marjanac, 2003). Dio pripadajućeg profila te detaljan geološki stup s ceste Brušane - Baške Oštarije (M 1:250) označeni su zelenom bojom. Tri glavna tipa mikrofacijesa su: M1, M2 i M3.

Fig. 1. Research area and schematic geological column through the carbonate Middle-Upper Permian sequence in the Velebit Mt.(after Ramovš et al, 1990, from Sremac & Marjanac, 2003). Detailed geological column along

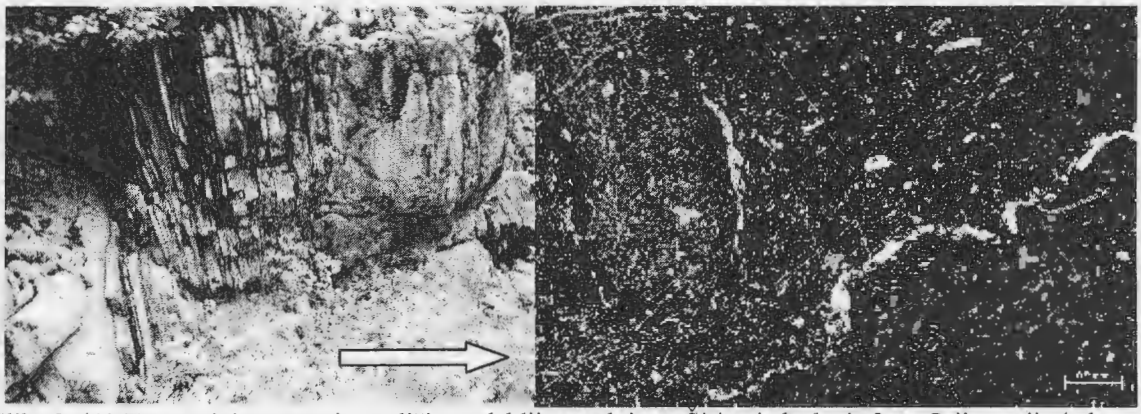
the road Brušane - Baške Oštarije M 1:250 is marked with green lines. Three main microfacies types are M1, M2 and M3.

Tamnosivi, gotovo crni vapnenci pv_3 zone bogati organskom tvari naliježu na svjetlosive dolomite s fuzulinidnim foraminiferama *Neoschwagerina.* Debljina slojeva varira od nekoliko milimetara do 60 centimetara. Slojevi su gotovo vertikalni (slika 2A) i u srži su antiklinale. Granica s naliježućim slojevima graničnog dolomita (*sensu* Salopek, 1942) nije jasno vidljiva. Totalna dužina izdanka je cca. 100metara, a za detaljnije istraživanje odabrana je sekvenca u rasponu od 20 do 75 metara. Izbrusci su pripremljeni od 30 uzoraka najbogatijih fosilnim materijalom. Na samom izdanku mogu se prepoznati dijelovi puževa, školjkaša i krinoida, a također, vidljive su i varijacije u boji te gradacija u veličini čestica. Šejlovi su prikupljani za obradu tehnikom otapanja.

REZULTATI

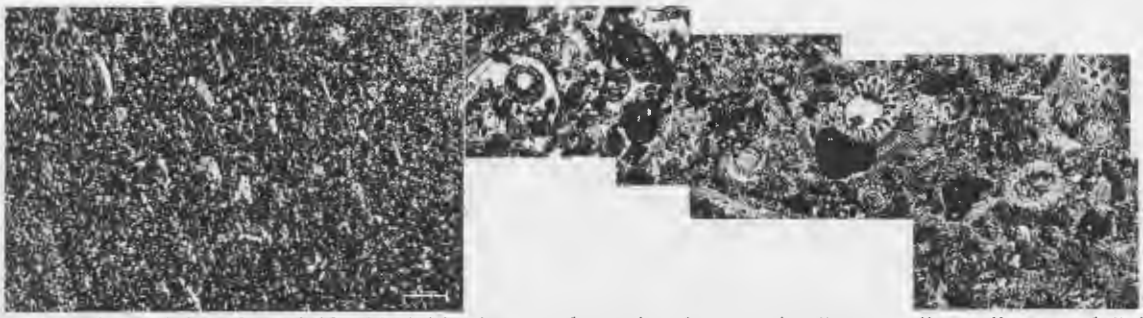
U geološkom stupu izdvojena su tri glavna facijesa s pripadajućim mikrofosilnim zajednicama (Slike 2 B, 3 A i 3 C).

M 1 - mudstone - Jednolične su strukture, na pojedinim horizontima ispresijecani desikacijskim pukotinama, karakterističnim za zone izranjanja te stilolitskim šavovima na mjestima kompakcije sedimenta (Slika 2 B). U nekoliko preparata vidljiva je cijanobakterijska aktivnost. Mirna sedimetacija omogućava rast kora *Claracrusta* oko čestica donošenih iz susjednih okoliša. Veće čestice su malobrojne i razbacane po sedimentu. Uglavnom se radi, ili o skeletima puževa nanesenim iz drugih tipova okoliša, s različitim tipom sedimenta u šupljini kućice. Fragmenti velikih školjkaša (*Shikamaia*) prisutni su samo u donjem dijelu geološkog stupa. Od sitnog kršja najčešći su komadići spužvi, ramenonožaca i ostrakoda, Prisutne su također male foraminifere (*Glomospira* , *Hemigordius*), vapnena alga *Vermiporella* i problematična *Shamovella* te "kalcisfere" koje su karakteristične za gornjopermske naslage.



Slika 2. (A) Tamnosivi vapnenci s različitom debljinom slojeva. Širina izdanka je 2 m. Orijentacija (od starijeg prema mlađem) je označena strelicom; (B) Mudstone s cijanobakterijskom grudicom i desikacijskim pukotinama. Povećanje 2,5x

Fig. 2. (A) Dark grey limestones with variable layer thickness. Width of this part of the sequence is 2 m. Orientation towards the younger sediments is marked with arrow (B) Mudstone with cyanobacterial lumps and dessication cracks. Enlargement 2,5x.



Slika 3. (A) Laminiran foraminiferski bioklastičan mudstone/wackstone s izraženom orijentacijom po dužoj osi. Povećanje 2,5x; (B) Bioklastičan algalno - foraminiferski packstone . Povećanje 2,5x

Fig. 3. (A) Laminated foraminiferal bioclastic mudstone/wackstone with parallel orientation of elongate particles Enlargement 2,5x; (B) Bioclastic algal - foraminiferal packstone. Enlargement 2,5x.

M 2 - foraminiferski bioklastičan mudstone/wackstone - Mikrofacijesi ovog tipa su nelaminirani u donjem dijelu geološkog stupa s mjestimično blago izraženom orijentacijom manjih skeletnih krhotina po dužoj osi. Naslage mlađih horizonata laminirane su s izmjenama tamnijih i svjetlijih proslojaka te su jasno orijentirane po duljoj osi (Slika 3 A). Bioklasti su, ili komadići, ili potpuno sačuvani skeleti školjkaša, spužvi, ehinodermi i brahiopoda taloženih iz suspenzije. Male porculanske foraminifere su tu najvjerojatnije autohtoni stanovnici okoliša. Od rodova određen je *Hemigordius* sp., a od vrsta *Hemigordius ovatus*. Čestice u sedimentu postaju generalno krupnije u odnosu na M1 horizonte.

M 3 - bioklastičan algalno-foraminiferski packstone - Sitnozrnati do krupnozrnati mikrofacijes sortiran je po veličini zrna s trendom okrupnjavanja prema mlađim horizontima. Čestice su velikom većinom sortirane po dužoj osi. Izražena laminacija razvijena je samo u donjem horizontu, dok su gornji horizonti karakterizirani djelomičnom zamjenom mulja sparitnim (Slika 3 B). Fosilni materijal je obilan. Javlja se u obliku donošenih komadića s okolnih krpastih grebena i kokina (gastropodi, bivalve, ehinodermi,, briozoi). ili se radi o organizmima koji su živjeli in situ (npr. alge *Vermiporella* sp., *Mizzia* sp, *Permocalculus* sp., *Gymnocodium* sp., te foraminifere *Hemigordius ovatus*, *Hemigordius* sp., *Nankinella* sp., *Globivalvulina* sp.).

DISKUSIJA I ZAKLJUČAK

Sedimentni slijed naslaga na izdanaku uz cestu Brušane-Baške Oštarije sastoji se od tri glavne litostratigrafske jedinice (po Salopek, 1942): srednjopermski neošvagerinski dolomit, treća zona crnih vapnenaca i granični dolomit. Crni vapnenci su bogati fosilima i izražene cikličnosti te su detaljno istraženi.

Naslage M 1 tipa su mudstone-i s rijetkim fosilnim nalazima. Taloženi su u plitkom i zaštićenom okolišu koji nije vrlo povoljan za život vjerojatno zbog visokog saliniteta, ili promjena u salinitetu. Također je moguć utjecaj permskog anoksičnog događaja u ovom području. Samo je otporna biota mogla preživjeti takve uvjete (cijanobakterije, *Shamovella*, *Glomospira*, *Hemigordius*, male spužve).

Situacija u subtidalnom okolišu postaje nemirnija što se može vidjeti po M2 horizontima. Ovaj mikrofacijes postaje češći u gornjim dijelovima sedimentne sekvence (Slika 1). Bakterijska aktivnost je smanjena, ali još uvijek ima dosta krhotina alohtonih puževa, spužvi, školjkaša. Male miliolide nađene su *in situ* (*Hemigordius* sp.). Uvjeti života su još uvijek nepovoljni.

Idući prema mlađim naslagama vidi se kako energija i dalje jača, a okoliš je nemirniji što kulminira sedimentima oluja mikrofacijesa M3 (Slika 1). Obilan fosilan materijal u obliku fragmenata s okolnih staništa (spužve i briozoi) miješa se s autohtonom biotom. U sedimentima su uobičajeni nalazi fuzulinidnih foraminifera (*Nankinella* sp.) i vapnenih algi (*Mizzia* sp. i gimnokodiacee). Gimnokodiacee su tolerantnije od dazikladalnih algi i kao takve su prisutne u Palaeotethys-u do P-T granice. Neke su uspjele preživjeti i u mezozoiku.

Facijesi istražene sekvence ciklički se izmjenjuju u slijedu naslaga s generalnim okrupnjavanjem čestica prema gore. Biota plitkomorskog marinskog šelfa jako je pogođena promjenama morske razine, saliniteta, oscilacijama u energiji okoliša te krizom kisika. Samo rodovi tolerantnih oportunista mogu preživljavati u takvim uvjetima U razdobljima emerzije, prisutne su samo stromatolitne kore. Iz slijeda mikrofacijesa vidljivo je kako je ritam ciklične izmjene brži u gornjem dijelu stupa.

Kao jedan od tri markera G-L granice Isozaki et al., (2011) navodi izumiranje velikih alatokonkidnih bivalvi (*Shikamaia*). Nestanak ovih školjkaša je vidljiv i u analiziranom slijedu naslaga. Ipak, opisani su depoziti rezultat nepovoljnih okoliša te bi nestanak alatoconchida u ovom području mogao biti posljedica lokalnih uvjeta.

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CYCLIC SEDIMENTATION IN MARGINAL MARINE SHELF ENVIRONMENT AT THE MIDDLE/UPPER PERMIAN BOUNDARY IN CENTRAL PART OF THE VELEBIT MT. (CROATIA)

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Key words: Middle/Upper Permian, Microfossils, Palaeoenvironments, Velebit Mt.

INTRODUCTION

Late Permian biotic crisis, the most devastating extinction event in Earth history, was for a long period considered to be unique event. New research of several authors has shown the two extinction phases: at the Guadalupian/Lopingian boundary (later: GLB) and at the Permian/Triassic boundary (later: PTB). Kamura cooling event was recognized as a possible trigger of the first extinction event at GLB (Isozaki et al., 2011 and references therein).

Middle and Late Permian deposits from the Velebit Mt. were studied in detail by M. Salopek and his research group (Salopek, 1942). Salopek described a variety of lithofacial units, and their stratigraphical relationships. More detailed biostratigraphical research on the basis of fusulinid foraminifera was performed by Kochansky-Devidé (1965), and paleoecological aspects were studied by several authors (e.g. Sremac, 1991; Tišljar et al., 1991; Sremac & Marjanac, 2003). Continuous Late Permian deposition in the Velebit Mt., with evidence of Permian/Triassic extinction was recently studied by Fio and coauthors, who described two stress events on the basis of isotope analyses (Fio et al., 2010),

During the Middle and Upper Permian, mode of deposition shifted from coarse grained clastic sedimentation (Košna beds, or Velebit breccias) towards a long-lasting carbonate platform deposition (dolomites with three limestone horizons). Limestone zones are particularly rich in fossils.

The uppermost limestone zone (pv3) is characterized wit mixed benthic community of fusulinids and calcareous algae and is named after a common fusulinid species Yabeina syrtalis zone (Salopek, 1942; Kochansky-Devide, 1965). Zone is well exposed along the regional road Gospić-Karlobag and at Velnačka glavica (Kalvarija) locality. Deposits along the road were first studied by Tišljar et al. (1991). Authors recognized a cyclic pattern of deposition and described several microfacies types, belonging to a very shallow shelf environment.

MATERIALS AND METHODS

During this study a detailed geological column was studied along the road between Brušane-Baške Oštarije (Fig. 1).

Dark grey, sometimes almost black limestones and shales of the limestone pv3 zone, rich in organic matter, overly the light grey dolomites with fusulinid *Neoschwagerina*. Layers vary in thickness from a few millimetres to 60 centimetres. Upper contact with transitional dolomite (sensu Salopek, 1942) is not clearly visible. These deposits represent a core of an anticline, and are almost in vertical position (Fig. 2). Total length of the outcrop is ca. 100 metres, and the sequence between 20 and 75 metres was chosen for a more detailed study. Thin sections were prepared from total 30 limestone samples, particularly from layers with fossil remnants. Gastropod, bivalve and crinoid fragments can be recognized on weathered surfaces in the field, as well as the variation in colour, and gradation of particle. Shales were collected for dissolving techniques.

RESULTS

Three main microfacies groups were recognized along the column (Figs. 2 B, 3 A and 3 C).

M 1 - mudstone – Some samples are characterized with uniform structure. Others exhibit desication cracks typical for emersion phases or stilolite compaction structures (Fig. 2 B). Cyanobacterial activity is visible in several samples. *Claracrusta* encrusted the particles brought in the basin from neighbouring areas. Scarce larger clasts are scattered within the micritic material. Among them gastropods are rather common, sometimes filled with darker sediment moulds. Fragments of large bivalves (*Shikamaia*) are present in lower part of the section. Sponge, brachiopod and ostracod particles are smaller in size. Small foraminifera (*Glomospira* , *Hemigordius*), calcareous alga *Vermiporella* and problematica *Shamovella* are also present, together with "calcispheres", which are also known from other localities in Upper Permian deposits.

M 2 – Foraminiferal bioclastic mudstone/wackestone – These sediments are commonly massive in lower parts, with scarcely visible parallel orientation of elongate fragments. In upper horizons they are explicitly laminated, with alternation of dark-grey and light-grey lamina and expressed sorting of elongate fragments (Fig. 3 A). Bioclasts are composed of fragmented or completely preserved bivalves, gastropods, sponges, echinoderms and brachiopods, deposited from the suspension. Small porcellaneous foraminifera are presumably autochthonous in the basin. Taxa *H. ovatus* and *Hemigordius* sp. were determined. Grain size is increased, compared with M 1.

M 3 – Bioclastic algal-foraminiferal packstone. Fine-grained to coarse-grained microfacies, with expressed coarsening upwards. Particles are in most cases sorted along the elongate axis. Lamination is prominent in lower horizon, while uppermost horizons are characterized with partial replacement of mud support with sparite Fig. 3 B). Fossils are abundant in these deposits. Some are present as particles transported from the surrounding patch reefs and coquinas (gastropods, bivalves, echinoderms, bryozoans), and others are found in situ (e.g. *Vermiporella* sp., *Mizzia* sp, *Permocalculus* sp., *Gymnocodium* sp., and foraminifers *Hemigordius ovatus*, *Hemigordius* sp., *Nankinella* sp., *Globivalvulina* sp.).

DISCUSSION AND CONCLUSION

Sedimentary sequence exposed along the road Brušane – Baške Oštarije consists of three main litostratigraphic units (sensu Salopek, 1942): Middle Permian *Neoshwagerina*-dolomite, Third zone of black limestone and Transitional dolomite. Black fossiliferous limestone zone exhibits pronounced cyclic patterns, and was studied in detail.

Deposits characterized as M 1 type are mudstones, with scarce fossils. They were deposited in shallow, sheltered environment, but unfavorable, possibly due to the high salinity, or salinity excursions. It is also possible that the Permian global anoxic event influenced this area. Only tolerant biota could survive under such conditions (cyanobacteria, *Shamovella*, *Glomospira*, *Hemigordius*, small sponges).

More agitated conditions in shallow subtidal environment resulted in deposition of M 2 type of sediment. Such deposits become more common in upper part of the sequence (Fig. 1). Bacterial activity decreased, but allochtonous fossil particles are present (e.g. gastropods, sponges and alatoconchid bivalves). Small miliolids (*Hemigordius* sp.) are found in situ. Life conditions are still not friendly.

In upper part of the column increase of water energy is obvious, culminating in storm-influenced deposition visible in M 3 type of sediment (Fig. 1). Abundant fossil fragments from surrounding habitats (sponges and bryozoans) are mixed with autochtonous biota (calcareous algae and foraminifers). Composition of microfossil assemblage points to the recovery of biota. Fusulinid foraminifera (*Nankinella*) and calcareous algae (*Mizzia* and gymnocodiaceans) are common in these sediments. Gymnocodians are more tolerant than dasyclad algae, and are present in Paleotethys up to the Permian-Triassic transition. Some of them survived into the Mesozoic era.

Investigated sequence exhibits cyclic mode of deposition, with general coarsening upward trend. Sea level, salinity and water energy oscillations, together with oxygen crisis, heavily affected shallow marine shelf biota, and only tolerant opportunistic taxa could survive under such conditions. During the emersions, only cyanobacterial stromatolite crusts are present. Rhythm of cyclicity is more pronounced and faster in upper part of the sequence, which is visible from the microfacies patterns.

According to Isozaki et al. (2011) extinction of large alatoconchid bivalves (*Shikamaia*) is one of three markers of GL extinction event. Such disappearance is visible in the analysed sequence. Nevertheless, the described deposits originate from an unfavorable environment, and disappearance of alatoconchids in this area could be the consequence of locally unfavorable conditions.