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CARBONATE FACIES AND DEPOSITIONAL ENVIRONMENTS OF THE JURASSIC AND LOWER CRETACEOUS OF THE COASTAL DINARIDES (CROATIA)

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Key words: Carbonate facies, Jurassic and Lower Createaceous carbonates, peritidal and shallow-marine sediments, emersions, early-diagenetic dolomites, coastal Dinarides.

Ključne riječi : Karbonatni facijesi, jurski i donjokredni karbonati , periplimski i plitkomorski sedimenti, emerzije, ranodijagenetski dolomiti, priobalni Dinaridi.

The Dinaric karst region consists predominantly of Jurassic and Cretaceous shallow-marine limestones, late-diagenetic dolomitized limestones,late-diagenetic dolomites and rare early-diagenetic dolomites, and intraformational breccias. In the Jurassic, oncoidal and pelletal wackestones and mudstones or environment of the restricted shoals and lagoons clearly prevail. Furthermore, peritidal fenestral limestones and ooid grainstones of the environment of ooid shoals and bars follow. Late-diagenetic dolomites are very frequent. Subordinated parts are early-diagenetic supratidal dolomites, bioclastic perireefal grainstones/ rudstones, and biostromal and patch reef boundstones. In some places there are peritidal and tempestite breccias and short-lasting emersions with typical paleokarst features. In the Lower Cretaceous, shallow subtidal and/or lagoonal wackestones/mudstones and oncolites are predominant, and peritidal limestones (LLH-stromatolites, tidal bar grainstones and fenestral wackestones) are frequent, but supratidal early-diagenetic dolomites and intraclastic/bioclastic grainstones of the shoals with agitated water and patch reef are rare.The late-diagenetic dolomites are periodically frequent and locally very thick. The emersion breccias in the Lower Cretaceous limestones of the karst region in coastal Dinarides indicate the Aptian and Early Albian emersions, but with different duration in different areas.

Dinarsko krško područje pretežno se sastoji od jurskih i krednih plitkomorskih vapnenaca, kasnodijagenetski dolomitiziranih vapnenaca, kasnodijagenetskih dolomita i rjeđe ranodijagenetskih supratidalnih dolomita i peritidalnih breča. U juri izrazito prevladavaju vapnenci: onkoidni i paletni wackestone i mudstone taloženi u zaštićenim plićacima i/ili lagunama, a po učestalosti odmah iza njih su peritidalni fenestralni vapnenci te ooidni graistone vapnenci taloženi u okolišima plićaka i prudova s pokretljivom vodom. Vrlo česti i široko rasprostranjeni su kasnodijagenetski dolomiti. U ukupnoj litološkoj građi jurskih naslaga podređen je udio supratidalnih ranodijagenetskih dolomita, bioklastičnih prigrebenskih graistone i rudstone vapnenaca te biostromalnih i "patch reef" vapnenaca. Na pojedinim lokalitetima unutar periplimskih vapnenaca pojavljuju se peritidalne i tempestitne breče te kratkotrajne emerzije s tipičnim paleokrškim fenomenima. U donjoj kredi prevladavaju onkoliti i peletni wackestone do mudstone vapnenci taloženi u plitkom subtidalu. Česti su periplimski stromatolitni i fenestralni vapnenci te skeletni i intraklastični grainstone vapnenci plimskih prudova.Znatno su rjeđi, u ukupnoj gradi donjokrednih sedimenta prisutni s malim udjelom , supratidalni ranodijagenetski dolomiti te bioklastični grainstone vapnenci taloženi u plićacima s pokretljivom vodom ili plićacima s manjim,uglavnom razorenim, "krpastim" grebenima. Na mnogim lokalitetima pojavljuju se kasnodijagenetski dolomiti sa značajnim udjelom u ukupnoj građi donjokrednih naslaga. Emerzijske breče ukazuju na učestala izronjavanja i prekide taloženja vapnenaca različirog trajanja, posebice u aptu i donjem albu. Takvi prekidi kontinuiteta taloženja i emerzije u znatnoj

1. INTRODUCTION

Petrological composition, depositional environments as well as vertical and horizontal facies distribution are features which have played an important role during the karstification and karst morphology-forming processes, thus determining the hydrological and hydrotechnical characteristics of the underground water regulations in the karst region.

The Dinaric karst region consists predominantly of Jurassic and Cretaceous, less Triassic. limestones, dolomitic limestones, late diagenetic dolomites, and intraformational breccias. These rocks are typical examples of shallow marine platform carbonates, which were depostited mainly in the restricted shoals, lagoons, peritidal to supratidal environments and shallows with agitated water.

This paper deals with the synthesis of extensive petrological and sedimentological investigations of Jurassic and Lower Cretaceous carbonates in the karst region along the northern coast and islands of the Adriatic sea. The subject implies differentiation of the main lithofacies types, environmental interpretation and depositional conditions together with lithological, sedimentological and diagenetic characteristics which effect formation of the karst morphology.

The studied region represents a 60 - 140 km wide and about 350 km long belt.

2. JURASSIC

On the basis of several detailed geological sections, lithological, textural and structural characteristics, fossil

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flora and fauna content, as well as diagenetic changes,the Jurassic carbonate sediments of the karst region in the coastal Dinarides are separated into 7 facies types and corresponding depositional environments as follows:
J-1. Peritidal facies;
J-2. Facies of lagoons and restricted shoals;
J-3. Facies of shoals with agitated water;
J-4. Facies of perireefal limestones;
J-5. Facies of biostromal and patch-reef boundstones;
J-6. Facies of ooid shoals and bars;
J-7. Lithofacies of late-diagenetic dolomites (Fig. 1.).

In parts where the coastal Dinaric karst is composed of the Jurassic sediments, oncoindal, pelietal and skeletal wackestones and mudstones very clearly prevail (Facies type J-2).Furthermore, peritidal fenestral and/or vadose limestones (Facies type J-1), ooid graistones (Facies type J-6) and late-diagenetic dolomites (lithofacies type J-7) follow. Subordinated part in the composition of the Jurassic sediments are bioclastic perireefal limestones (Facies J-4) . rarely biostromal and patch-reef limestones (Facies type J-5) and skeletal and intraclastic grainstones (Facies type J-3).

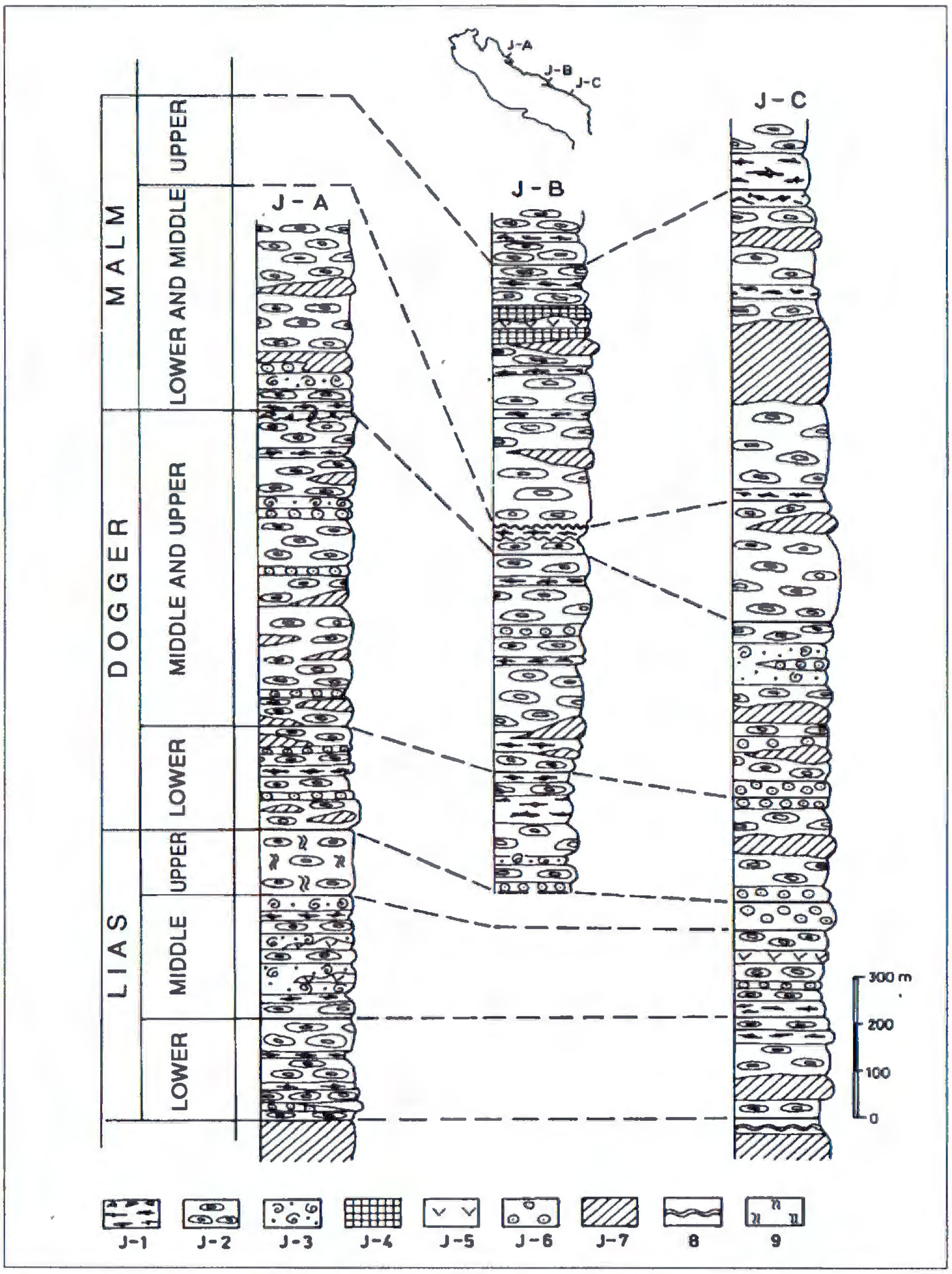

Fig. 1. Schematic lithofacies columns of the Jurassic in the Adriatic coastal area. A= Velebit Mountain, B= Biokovo Mountain C = Dubrovnik environ (J-1=Peritidal facies, J-2=Facies of lagoons and restricted, shoals,J-3= Facies of shoals with agitated water, J-4= Facies of perireefal limestones, J-5= Facies of biostromal and patch-reef boundstones, J-6=Facies of ooid shoals and bars, J-7=Lithofacies of late-diagenetic dolomites).

Slika 1. Shematizirani litofacijesni stupovi jure u jadranskom obalnom području. A = Velebit, B = Biokovo, C = okolica Dubrovnika (J-1= peritidalni facijes, J-2= facijes laguna i zaštićenih plićaka, J-3= facijes plićaka s pokretljivom vodom, J-4= facijes prigrebenskih vapnenaca, J-5=facijes biostroma i krpastih grebena, J-6=facijes ooidnih plićaka i plaža, J-7= litofacijes kasnodijagenetskih dolomita).

2.1. PERITIDAL FACIES: FENESTRAL AND/ OR VADOSE LIMESTONE AND VERY UNFREQUENT OCCURENCES OF TEMPESTITE AND/OR EMERSION BRECCIAS - FACIES TYPE J-1

Peritidal facies is predominantly composed of the fenestral and/or vadose limestones i.e. mudstones and pelletal and/or skeletal wackestones with fenestral fabric, and desiccations (Fig. 2.), whereas LLH-stromatolithes, ooid and cortoid tidal bar grainstones/rudstones and pelletal or skeletal wackestones with vadose features occur sporadically. Peritidal, black pebble and tempestite breccias, and supratidal early-diagenetic dolomi tes occur very seldom, too.

Fig. 2. Fenstral wackestone with desiccation cracks. Middle Lias of Velebit Mt. (Mali Halan).
Facies J-1.
Slika 2. Fenestralni wackestone s desikacijskim pukotinama. Srednji lijas Velebita (Mali Halan).
Facijes J-1.

In some places (the Tithonian of western Istria, i.e "Kirmenjak desiccation mudstone facies"(TIŠLJAR & VELIĆ, 1987),the limestones of the facies type J-1 consist of rhythmically deposited mudstones, fenestral mudstones and/or fenestral pisoid and algal pelloid wackestones/packstones with vadose features or black pebble breccias. Individual cycles (1,2 - 2,3 m thick) end with desiccation breccia and/or breccia containing black pebbles (Fig. 3.). The cycles exibit structural and textural characteristics of gradual shallowing from the base to the top of the sequence, i.e. gradual changes from the shallow subtidal into the low intertidal and intertidal with desiccation or vadose zone. The shallowing is manifested by rhythmic sedimentation of homogenous mudstone to mudstone with vertical burrows and fenestral mudstone with erosion surface or desiccation cracks. Black pebble breccias overlie the eroded bed surfaces of fenestral mudstone and surfaces with desiccation cracks or tidal channels. The black pebbles were originated by storm wave, ripping up black brackish or freshwater deposits (STRASSER & DAVAUD, 1983; TIŠLJAR, 1986). In the upper part of those rhythmically deposited limestones there are desiccation and tempestite cycles (VELIĆ & TIŠLJAR, 1988). The cycles consist of mudstone with desiccation cracks and/or desiccation brecccia and fenestral grainstone/pebble conglomerate with vadose features. The fenestral grainstones/pebble conglomerates, i.e. tempestites, were deposited in the intertidal onto the mudstone surfaces with desiccations by storm waves.

Peritidal and tempestite breccias occur very often but are of small thicknes or small lateral extent, especially in the Lias and Dogger. In the middle part of the Lower Dogger and Upper Dogger of the Mali Halan - southern Velebit Mt., for example, there are very frequent rhythms or coarsening-upwards sequences: mudstone - intraclastic rudstone or tempestite breccia.Peritidal and tempestite breccias were formed by redeposition of abraded limestones, because of shallowing and change in water energy. During stormy weather,wave activity accumulated

Fig. 3. Black-pabble breccia: terminal member of upward shallowing sequence. Upper Tithonian of Poreč, Istria. Facies J-1.
Slika 3. Breča s crnim ulomcima: završni član sekvencije opličavanja u gornjem titonu Poreča,Istra.
Facijes J-1.

the coarsest carbonate detritus and caused tempestite breccia formation in the shallowest part of the shoals (TIŠLJAR, 1990).

Early-dia genetic supratidal dolomites with desiccation cracks and birds-eye structures occur only in some places of the Lias peritidal limestones in the Velebit Mt. and Lika region (Ličko Cerje).

Emergences and emersion breccia with typical paleokarst features and ca 300 m sediment reduction occurs in the Malm of the Biokovo Mountain (TIŠLJAR et. al. 1989; Figs. 4a, 4b, in this paper). Similar reductions, with smaller gap, were registred in the Upper Malm of the Dinara Mt. and in the Upper Kimmeridgian - Upper Tithonian of the Western Istria (VELIĆ & TIŠLJAR, 1988).

Thin bedded (0,1-0,4 m) mudstones and wackestones with vadose features, laminoid and irregular fenestrae and shell molds (*Gastropoda* and *Dasycladaceae*) and solutional vugs usually filled with mosaic drusy calcite cement or internal sediment (i.e. vadose crystalline silt) and microstalactite cement occur often in the Middle Lias, Upper Dogger and Upper Malm. Vadose pisolithic limestones ("vadolithes"-PERYT, 1983) have been found in the Tithonian and Tithonian-Berriasian sediments (Lastovo Island - Fig. 5, environs of Dubrovnik, Biokovo

Fig. 4a. Two Upper Jurassic emergences (arrows) with emergence breccias within well-badded limestones of J-1 and J-2 facies. Top left-massive dolomite body (D) of latediagentically dolomitized shallow-marine limestones of the Tithonian age - lithofacies J-7. Older emergance - Oxfordian, younger one - Kimmeridgian. Sedimentation gap 250-300 m. Biokovo Mt. (Lađana).

Slika 4a. Dvije malmske emerzije s emerzijskim brečama u dobro uslojenim vapnencima J-1 i J-2 facijesa. U gornjem lijevom dijelu naslaga masivno dolomitno tijelo (D) nastalo kasnodijagenetskom dolomitizacijom vapnenaca - litofacijes J-7. Starija emerzija u oksfordu, mlađa emerzija u kimeridžu, masivni dolomit unutar titonskih vapnenaca,. Zbog emerzije nedostaje oko 250 do 300 m sedimenata mlađeg oksforda, kimeridža i starijeg titona. Biokovo (Lađana).

Mt., Platak Mt., the region of Gorski Kotar).They rhythmically alternate with fenestral peritidal limestones. The characteristic "vadose rhythms" and "vadose cycles" are distinquished (TIŠLJAR, 1985):

The "vadose rhythms" are usuallly below the "vadose cycles" and consist of a thick fenestral/pelletal wackestone or mudstone layer and a 20-40 cm thick vadose ooid layer. Vadose ooid layer consists of vadose ooids ("vadoids"-PERYT,1983), drusy mosaic calcite cement and/or mechanically deposited crystalline silt (Fig. 6.).

The "vadose cycles" consist of four lithological

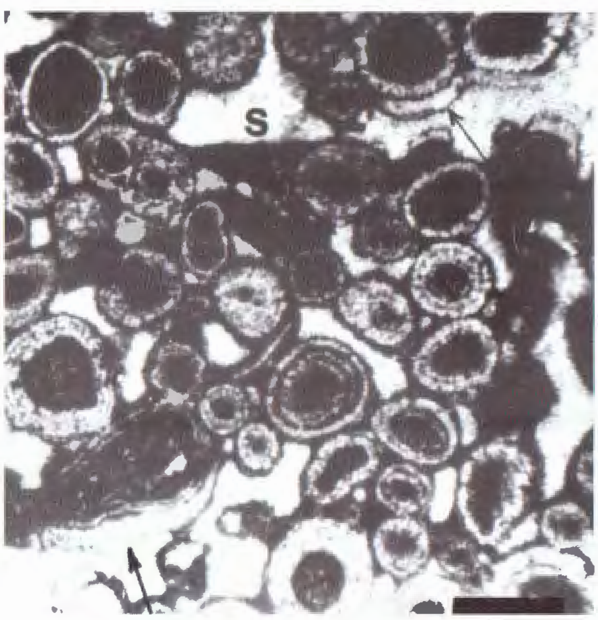

Fig. 5. Vadose ooid-grainstone/packstone (pisolithic limestone) from the "vadose cycles": a gravitational calcite cement (arrows) and vug flooring with vadose crystal silt (s). The facies type J-1 of the Tithonian from Island of Lastovo. Scale = 1 mm.

Slika 5. Pizolitni vapnenac ili vadozno-ooidni grainstone/packstone iz "vadoznih ciklusa" facijesa J-1 na otoku Lastovo: gravitacijski (mikrostalaktitni) kalcitni cement (strelica) i šupljine ispunjene vadoznim kristalnim siltom, mjestimice s geopetalnom teksturom (s). Titon Lastova (Skrivena Luka). Dužina linije = 1 mm.

Fig. 4b. Detail from Fig. 4a: Kimmerdgian emergence with typical features of the paleokarstification. Paleokarst breccia (light-coloured limestone bottom) of the Kimmerdgian is overlain by Tithonian fenestral peritidal limestones.

Slika 4b. Detalj sa slike 4a: mađa emerzija s tipičnim fenominima paleookršavanja - paleokrška breča (svijetli vapnenac na slici dolje) stratigrafski pripada kimeridžu, a prekrivena je fenstralnim peripliplimskim vapnencem titonske starosti.

members: 1. - thick mudstone/pelletal wackestone layer; 2.- fenestral mudstone/wackestone with algal coating and crusts; 3.-pink-colored 15-30 cm thick vadose ooid layer ("vadolithe") with coated pisolithe intraclasts and 4.- oolite with drifted, broken and regenerated vadose ooids. The broken and regenerated vadose ooids often show a growth tendency only on the upper side. Besides

Fig. 6. Limestone with vadose features: pelletal wackestone with fenestral fabric and some vadose ooids (bottom), erosional surface and vadose ooids, chrystal silt and roof of vugs with gravitational (microstalactite) calcite cement. Tithonian of Dubrovnik environ. Facies J-1 (33x).

Slika 6. Vapnenac s vadoznim tvorevinama: peletni wackestone s fenestalnom građom i pojedinim vadoznim ooidima (dolje), erozijska površina i vadozni ooidi, kristalni silt i gravitacijski (mikrostalaktitni) kalcitni cement po krovu šupljine. Titon okolice Dubrovnika. Facijes J-1 (poveć. 33x).

drusy mosaic calcite also gravitational (i.e. microstalactitic) and meniscus cement as well as crystalline silt are usually found in those limestones. The formation of the "vadose rhythms" and "vadose cycles" is interpreted as follows: after a reletively long sedimentation of carbonate mud and pellets in the lagoonal to shallow subtidal environment, a progressive shallowing started until reaching the subtidal and lower intertidal phase (sea level oscillation or shore line progradation?). Here, the algal crusts were formed by the activity of cyanophyceans. With its further emergence a partial erosion of the sediments occured.Then the formation of vadoids started in the vadose and subaerial zone. In contrast to the "vadose rhythms", broken and regenerated vadose ooids with oblique lamination were deposited during the gradual flooding of the surface with vadoids, crystalline silt and undissolved mudstone relicts. These vadoids had drifted from the neighbouring flooded vadose zone during the storm waves. A new cycle started with the repeated subtidal sedimentation.

In some places, in Jurassic limestones of the facies type J-1, especially the Oxfordian-Kimmeridgian of western Istria ("Muča tidal bar calcarenite facies" - TIŠLJAR & VELIĆ, 1987), characteristicly thick-bedded to massive (0,6-2,5 m)ooid-graistones and ooid/bioclastic grainstones and rudstones with cross-bedding occur, and in some places large wave ripples. The ooid-grainstones consist predominantly of very well-sorted (0,2-0,4 mm in diameter)tangential ooids. The bioclastic grainstones/rudstones are composed of an ooid graistone matrix with variable amounts of large (2-55 mm in diameter) coated bioclasts of *Cladocoropsis*, other stromatoporoids hydrozoans, corals and pachyodont bivalves (i.e. "cortoids" - FLÜGEL, 1982). The larger bioclasts or cortoids are wornout and abraded components deposited as tidal bar deposits by tidal current sand storm waves. The ooid grainstones and bioclastic rudstones are only partially cemented. The intergranular and interskeletal porosity is very significant. The tidal bar ooid grainstones and bioclastic rudstones occur within the limestones of the facies type J-2 in large, 250-1.500 m long and 20-50 m thick,lens-like bodies.

2.2. FACIES OF LAGOONS AND RESTRICTED SHOALS: ONCOLITHES AND PELLETAL WACKESTONES AND MUDSTONES - FACIES TYPE J-2

This facies is represented by thick - bedded or massive oncolites, oncoid floatstones/packstones, pelletal wackestones to mudstones and, especially in the Upper Lias, thin-bedded bioturbation-bearing "spotty limestones". The main lithological characteristics of this facies are high content od carbonate mud, oncoids , especially algal oncoids and"cyanoids" (RIDING , 1983), pellets, coated bioclasts of gastropods, centripetally micritized skeletons of benthic foreminifers and green-algae. The oncoids and coated bioclasts of gastropods, and green-algea (*Dasycladaceae*) are predominant or significant components of the oncolites and oncoid-bearing floatstones/packstones. Carbonate mud and pellets, micritized benthic foraminifers and dasycladaceans predominate in the wackestones (Fig. 7.).

Fig. 7. *Clypeina jurassica* FAVRE wackestone. Tithonian of Velika Kapela Mt. Facies J-2 (7x).
Slika 7. Klipeinski wackestone. Titon Velike Kapele.Facijes J-2 (7x).

The variation of structural properties, shapes and dimensions of oncoids is the result of changing sedimentary conditions.Large and irregular algal oncoids are the most frequent components of limestones deposited in the restricted shoals and lagoons with calm water and low rate of sediment accumulation (Fig. 8.).

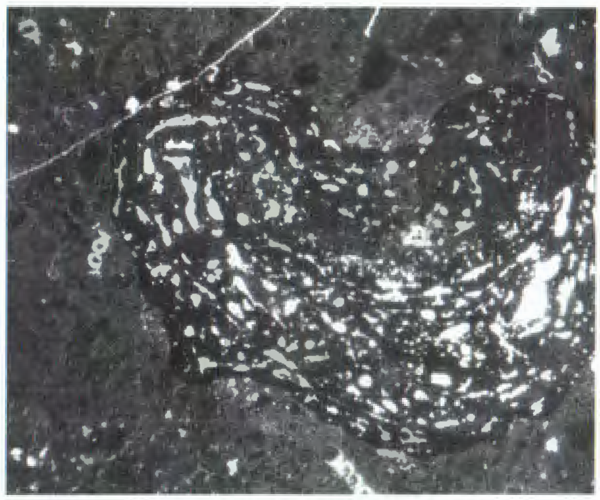

Fig. 8. Oncolite of the oncoid wackestone /floatstone type containing algal oncoid and bioclasts of green algae *Clypeina jurassica* FAVRE. Tithonian of Osojnik, Dubrovnik environ. Facies J-2 (26x).
Slika 8. Onkolit tipa onkoidnog wackestone/floatstone koji sadrži algalne onkoide i bioklaste alge *Clypeina jurassica* FAVRE. Titon Osojnika, okolica Dubrovnika. Facijes J-2 (26x).

Sphaerical-concentric oncoids with concentric structure of the cortex were deposited in the shallow subtidal without higher water energy but with constant currents. The oncoids and cyanoids usually associated with carbonate mud, pellets and restricted marine biota(green-algae, gastropods, ostracods and micritized benthic foraminifers) are typical of the facies type J-2 in the coastal Dinaric karst region. They distinctly dominate within the Lower and Upper Malm and Upper Dogger of the south Adria region, and are widespread in the Lower and Middle Lias of the whole karst region in the Coastal Dinarides.

Thin-bedded, bioturbation-bearing "spotty limestones" of the Uppper Lias, especially in Velebit Mt., are bioturbated and spotty late-diagenetic dolomitized mudstones (Fig. 9.). These limestones were deposited in restricted (isolated) shoals with low water energy and low sedimentation rates of carbonate mud. The spotty appearance is a consequence of bioturbation, i.e. different content of organic matter within the burrowings and host rock that is mud-eating animal food with organic matter).

Fig. 9. Bioturbations in thin-bedded "spotty limestone" of the Upper Lias. Velebit Mt. (Kubus). Facies J-2.
Slika 9. Bioturbacije u "mrljastom vapnencu" gornjeg lijasa Velebita (Kubus). Facijes J-2.

2.3. FACIES OF SHOALS WITH AGITETED WATER: SKELETAL AND INTRACLASTIC GRAINSTONES - FACIES TYPE J-3

Limestones of facies type J-3 are represented by frequent alternations of thin-bedded skeletal and intraclastic grainstones,more rarely rudstones. They contain well sorted and rounded intraclasts, bioclasts and coated bioclasts ("cortoids") , 0,5-10 mm in size. The dominating fragments are skeletons of hydrozoans, stromatoporoids, codiaceans, shells echinoderms and benthic foraminifers (Fig. 10.). Fragments of corals and gastropods occur rarely. The grainstones of the facies type J-3 show very high primary intergranular and interskeletal porosity and have also a high content of drusy mosaic and often rim-fibrous calcite cement. A community of fosil fauna, particulary well sorted and rounded fragments of hydrozoans, stromatoporoids, echinoderms and corals indicate the deposition in open shoals with agitated water and normal marine salinity.In the karst region of the coastal Dinarides lithofacies of skeletal and intraclastic grainstones occur more often only in the Upper Dogger in the south Adria region and in the Upper Malm of the Biokovo Mt. and of the Gorski Kotar region.

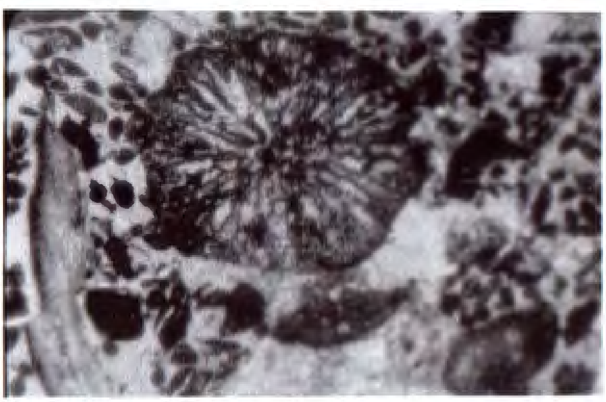

Fig. 10. Bioclastic and intraclastic grainstone composed of well-rounded intraclasts, shell and hydrozoan bioclasts and cemented with fibrous and drusy calcite cement. Upper Dogger of Biokovo Mt.
Facies J-3 (12x).
Slika 10. Biointraklastični grainstone izgrađen od dobro zaobljenih intraklasta i bioklasta školjkaša i hidrozoa cementiranih vlaknstim i druznim kalcitnim cementom. Gornji doger Biokova. Facijes J-3(12x).

2.4. FACIES OF PERIREEFAL LIMESTONES : BIOCLASTIC GRAINSTONES AND RUDSTONES - FACIES TYPE J-4

Facies of perireefal limestones consists of bioclastic grainstones and rudstones, and sporadically of floatstones. These rocks were originated by destruction of skeletons of reef and patch-reef organisms, i.e. hydrozoans, corals, stromatoporoids, pachyodont bivalve and encrusting codiaceans, and by sedimentation of bioclasts in shoals with high water energy , especially in the Upper Malm (Biokovo Mt.,Gorski Kotar region).

Shell coquinas and tempestite coquinas consist of coarse debris of lithiotids, diceratids and brachyopods occur very often in the Middle Lias of the Velebit Mt. (especially the Mali Halan pass,the Kubus pass - Fig. 11.). Tempestite coquinas were deposited by storm waves in shalow subtidal to low intertidal environment and associated with limestones of the facies type J-1 and J-2. Shell bioherms and patch reefs were by storm waves whole destroyed.

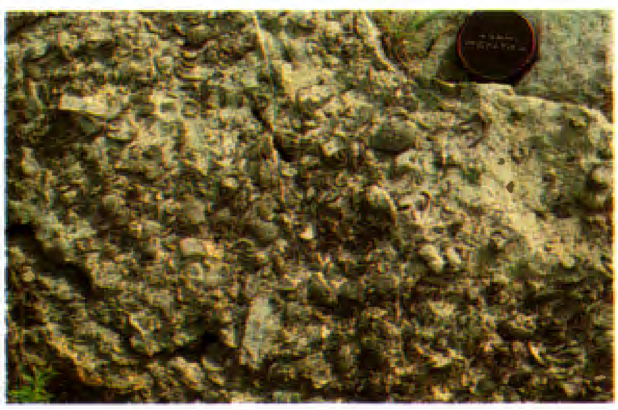

Fig. 11. Coquina composed of flooded shells of braciopods,diceratids and lithiotids. Middle Lias of Velebit Mt. (Kubus).Facies J-4.
Slika 11. Kokina izgrađena od naplavljenih kućica brahiopoda, diceratida i litiotida. Srednji lijas Velebita(Kubus). Facijes J-4.

Primary intergranular or interskeletal porosity was very high. Pores contain large amount of mosaic drusy calcite cement. Facies of bioclastic perieefal limestones occurs together with limestones of the facies type J-3, and seldom with the facies type J-5 . In general, it occurs in very small thickness in the Lower Doger in the region of Dubrovnik and more frequently in the Upper Malm (Tithonian) of Biokovo Mt., Velebit Mt. and Gorski Kotar region.

2.5. FACIES OF BIOSTROMAL AND PATCH-REEF BOUNDSTONES - FACIES TYPE J-5

Facies of biostromal and patch reef limestones of the Coastal Dinarides occur only sporadically in the Jurassic. However, large organic reefs or reef complexs

Fig. 12. Lithiotid biostrome with shells in living position. Middle Lias of Ivanjica, Dubrovnik environ. Facies J-5.
Slika 12. Litiotidna biostroma s litiotidnim ljušturama u živućem položaju. Srednji lijas Ivanjice kraj Dubrovnika. Facijes J-5.

Fig. 13.Lithiotid biostrome. In the bottom and top part of the bed streamy oriented shells and in the middle of the bed in living position. Middle Lias of Velebit Mt. (Mali Halan). Facies J-5.
Slika 13. Litiotidna biostroma. U donjem i vršnom dijelu sloja strujno orijentirane ljušture, a u sredini ljušture u živućem položaju. Srednji lijas Velebita (Mali Halan). Facijes J-5.

with biostromes have not been recognized in the Jurassic carbonates of the Dinaric karst region. They must have been completely destroyed and redeposited, for example "Muča tidal bar facies"in Oxfordian-Kimmeridgian of western Istria (see Facies type J-1 in TIŠLJAR & VELIĆ, 1987).

Biostromes 0,3-0,8 m thick, with limited lateral extent, composed of very large shells of lithiotids, brachyopods and diceratids which are lithified in living position appear only in some places of the Middle Lias (Ivanjica near Dubrovnik, Fig. 12., Mali Halan pass, Fig. 13. and Kubus pass - Velebit Mt.) .

Smaller coral and/or hydrozoan patch-reefs are well developed in the Oxfordian of the Lastovo Island and in the Tithonian of the Biokovo Mt. and in the Gorski Kotar region (Zlobin) within the limestones of the facies types J-3 and J-4 (Lastovo Island) of facies type J-4 (Biokovo Mt.. and Gorski Kotar). Individual coral and hydrozoan colonies are in this place often incrusted with algal crusts.

2.6. FACIES OF OOIDE SHOALS AND BARS: OOID GRAINSTONES OR OOLITES - FACIES TYPE 6

Facies of oolites almost exlusively contain well-sorted, spheroidal and frequently broken ooids and sparry calcite (i.e. ooid grainstones). The oolites are composed of the following structural ooid types: radial, tangential, micritic, oomoldic and leached, and latediagenetic dolomitized ooids. Typical Jurassic oolites of the Dinaric karst region are composed of the radial (Fig 14.), tangential and micritic ooids. The radial and tangential ooids are predominant structural type.The structural characteristics and construction of the other types are the result of digenetic changes (TIŠLJAR, 1985) . The radial ooids were formed in shoals with agitated water, but with much lower energy compared to the water where the tangential ooids were formed (FLÜGEL,1983). The micritic ooids are the most abundant structural type of the Jurassic oolites in the Dinaric karst region, particularly in the southern Adriatic region. Their primary structure (probably primarily radial ooids) is completely or predominantly destroyed by diagenesis: mostly due to the micritization by *Cyanophiceae* and cryptocrystalline recrystallization.The tidal currents have transported this structural type of ooids from the shoals with agitated water and ooid sand-bars to shoals with lower water-energy and that made possible their micritization and early-diagenetic transformation from the radial or tangential type to the micritic ooids.

The oomoldic and leached ooids have been found in somewhat larger guantity only among oolites of the Lower Dogger in Osojnik village,near Dubrovnik and of the Lower Lias in the Velebit Mt. Their abundance indicates that the ooid tidal bars, usually submarine, were occasionally exposed to the influence of rain water. Therefore, ooid-sands were occasionally uplifted higher than the medium tide level, that caused complete or partial leaching of their cortexes which were probably originally aragonite.

Late-diagenetic dolomitization of ooids is very often in Jurassic oolites in the southern Adriatic region, Velebit Mt. and Gorski Kotar region. Only ooids are generally dolomitized, and sparry calcite cement very rarely. The nuclei of ooids are most intensively dolomitized, while concetric cortexes are in a lesser degree, probably due to differences in the structural constitution of the nucleus and cortex: while the nuclei were primarily composed of cryptocrystalline high Mg-calcite, the cortexes were composed of microcrystalline aragonite.

The oolites of the facies type J-6 were deposited

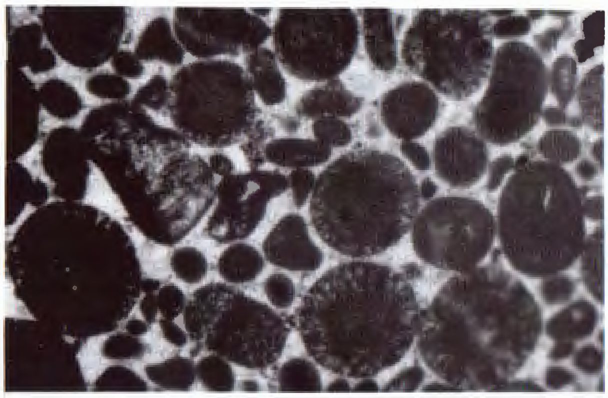

Fig. 14. Ooid grainstone composed of ooids with radial microstructure and micritic ooids. Fibrous and mosaic calcite cement. Upper Dogger of Biokovo Mt. Facies J-6 (33x).
Slika 14. Ooidni grainstone izgrađen od ooida s radialnom mikrostrukturom i mikritnim ooidima. Vlaknasti i mozaični kalcitni cement. Gornji doger Bikova. Facijes J-6 (33x).

in the environment of ooid shoals and bars with high water-energy. They are very important lithological member for the Middle and Upper Lias and Lower Dogger, especially in the southern Adria karst region. They occur very often in the Lower Lias and Dogger of the Velebit Mt., in the region of Gorski Kotar and in the Upper Malm on the Island of Lastovo and Platak Mt.

2.7. LITHOFACIES OF LATE-DIAGENETIC DOLOMITES - LITHOFACIES TYPE J-7

Lithofacies of late-diagenetic dolomites includes large masses, bodies and layers of microcrystalline to macrocrystalline dolomites (Figs.2, 4a,4b). They often contain relicts of more or less intensively dolomitized limestones. mainly of the facies type J-2 and J-6,and rarely of the facies type J-1.

The late-diagenetic dolomites were formed by the late-diagenetic dolomitization of the already lithified limestones of the facies type J-2, J-6 and J-1 under the condition of circulating pore-waters with lower supersaturation with respect to Mg^{2+} ions. Their late-diagenetic origin is suggested by the following features: relatively large dolomite crystals of 0,02 - 0,8 mm; complete dolomitization of all organic and inorganic compounds of limestones; irregular features of dolomite lenses and bodies within the primeval undolomitized or weakly dolomitized limestones; gradual transitions of limestones to dolomites and undolomitized relicts

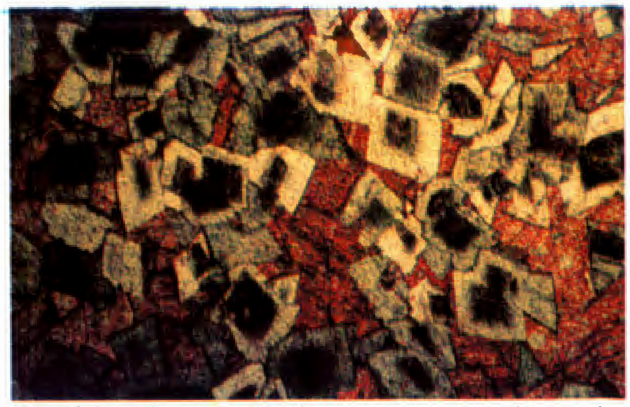

Fig. 15. Late diagenetic dolomite; macrocrystalline calcite in the intercrystalline pores: zonal distribution of kerogene within the dolomite rombs. Lower Lias of Gornje Jelenje, Gorski Kotar. Facies J-7 (33x).
Slika 15. Kasnodijagenetski dolomiti; makrokristalasti kalcit u međukristalnim porama: zonalni raspored kerogena u dolomitnim romboedarskim kristalima. Donji lijas Gornjeg Jelenja. Facijes J-7 (33x).

of limestone in dolomites; constant types of structures and composition of dolomites in the large areas during the dolomitization of different structural, genetic and stratigraphic limestone types as well as the high Ca-excess and the low degree of lattice-ordering of these dolomites (i.e. "protodolomites").

Lithofacies of late-diagenetic dolomites is, next to the facies type J-2, and, in the same localities facies type J-6, the most widespread facies type within Jurassic carbonate sediments of the karst region in the coastal Dinarides. It is the dominant type of the Upper Malm ,and very often of the Lower Lias and Lower Dogger, before all in the southern Adria region (Lastovo Island, region of Dubrovnik, Biokovo Mt.),in the Velebit Mt. and Gorski Kotar.

3. LOWER CRETACEOUS

The Lower Cretaceous sediments of the Dinaric karst region are separated into 5 facies types and corresponding depositional enviroments :

K-1. Facies of supratidal and/or temporary emersion;
K-2. Facies of intertidal to shallow subtidal;
K-3. Facies of lagoons and restricted shoals;
K-4. Facies of shoals with agitated water and patch-reefs;
K-5. Lithofacies of late-diagenetic dolomites.

In the Lower Cretaceous of the karst region in the coastal Dinarides, facies K-3 is predominant, K-2 is frequent, and K-1 and K-4 are rare. The lithofacies K-5. i.e. late-diagenetic dolomites, is sometimes frequent and locally very thick (Fig. 16.).

3.1. FACIES OF SUPRATIDAL AND/OR TEMPORARY EMERSIONS: EARLY-DIAGENETIC DOLOMITES, SOFT PEBBLE CONGLOMERATES AND EMERSION BRECCIAS - FACIES TYPE K-1

Facies type K-1 is characterized by supratidal early-diagenetic dolomites and soft pebble conglomerates or by emersion breccias.

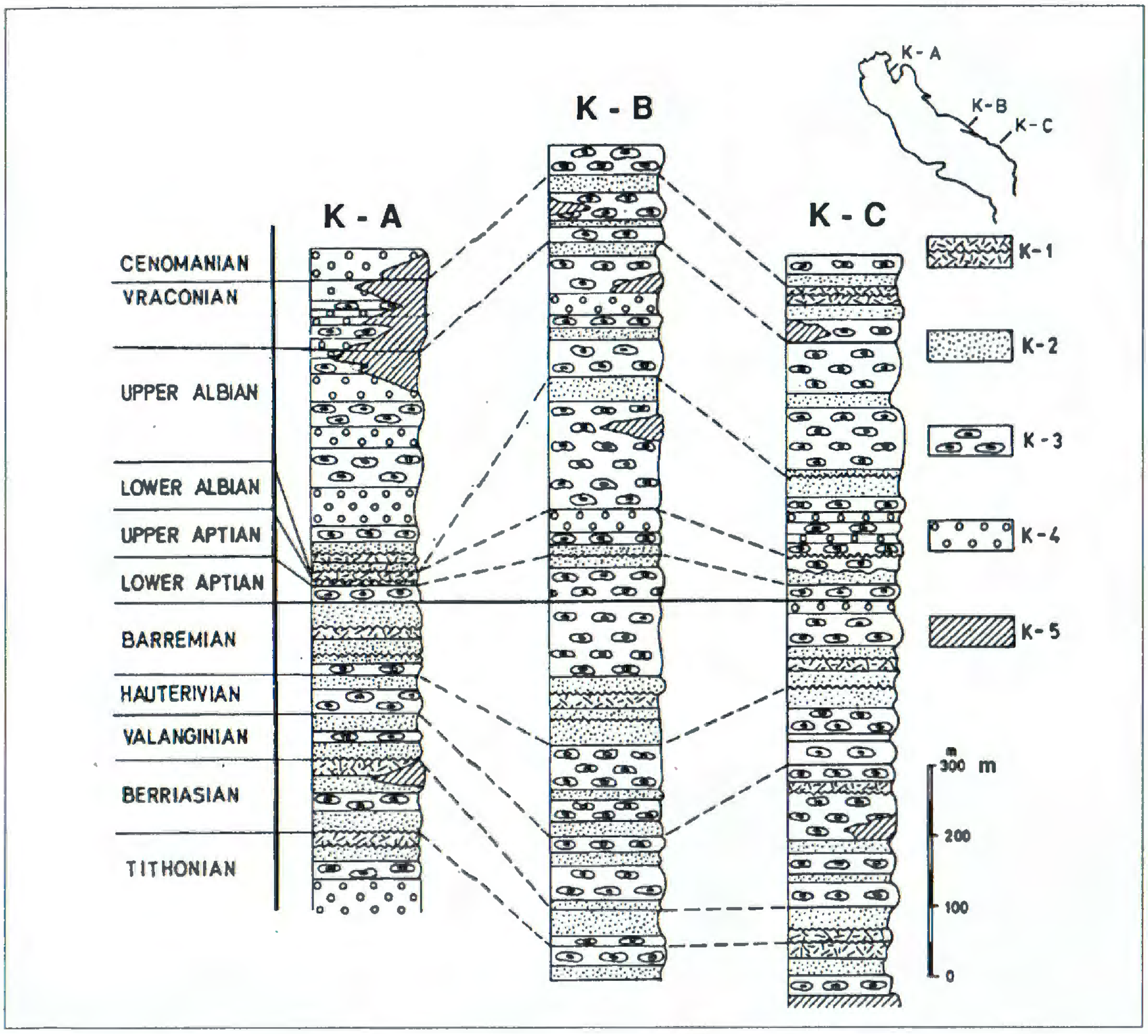

Fig. 16. Schematic lithofacies columns of the Lower Cretaceous in the Adriatic coastal area. A = Istria, B = Biokovo Mountain, C = Dubrovnik environ (K-1=Facies of supratidal and /or temporary emersions, K-2= Facies of intertidal to shallow subtidal, K-3= Facies of lagoons and restricted shoals, K-4= Facies of shoals with agitated water and patch-reefs, K-5= Lithofacies of late-diagenetic dolomites).

Slika 16. Shematizirani litofacijesni stupovi donje krede u jadranskom obalnom području. A = Istra, B = Biokovo, C = okolica Dubrovnika (K-1= facijes supratidala i povremenih emerzija, K-2= facijes intertidala do plitkog subtidala, K-3=facijes laguna i zaštićenih plićaka, K-4= facijes plićaka s pokretljivom vodom i krpastih grebena, K-5= litofacijes kasnodijagenetskih dolomita).

Early-diagenetic dolomites contain desiccation and shrinkage cracks, fenestrae ("bird-eyes structures" - SHINN, 1968), burrowings, cryptalgal laminas and stromatolites, often with "teepee structures". They are composed of the cryptocrystalline (< 0,01 mm in size) dolomitic crystals, dolomitic pellets and intraclasts, and stromatolitic dolomites. The pellets may merge into a dolomicrite matrix and they are thought to be fecal pellets which is suggested by their uniform size and their elongated shape. The intraclasts might have been formed by the reworkiong of layers, desintegrated by desiccation cracks, and partly in intertidal to suptratidal environments, and redestributed during storm flooding.

The early-diagenetic dolomites show two main criteria of supratidal deposition : 1. - desiccation cracks(Fig. 17.) and 2. - stromatolitic lamination as a result of blue-green algal-mat posibly formed by *Schizotrix*. A supratidal deposition is indicated also by the occurence of "bird eyes" and dolomite crystal size, which is generally less than 10 micrometers in size (FÜCHTBAUER & TIŠLJAR, 1976). The supratidal early-diagenetic dolomites appear in Lower Cretaceous carbonates of the coastal Dinarides only in the Berriasian of Istria, Vraconian from Hum near Dubrovnik and Biokovo Mt. and in the Barremmian of the Island of Mljet.

The frequent emersions in Lower Cretaceous limestones were accompanied by interruptions of sedimentation, weak or temporary emersions of incompletely consolidated deposits and appearance of thin intercalations of soft pebble conglomerates, black pebble breccias and emersion breccias (Fig. 18.). The breccias consist of poorly sorted angular to more or less rounded fragments or pebbles of stromatolitic, pelletal and fenestral limestones (LLH-stromatolites, pelletal wackestone/packestones, mudstones) from the next underlying beds. The fragments and pebbles are more or less cemented with marly and/or clayey matrix (illite, montmorillonite, chlorite).

A very shallow water depositional setting, practically

Fig. 17. Desiccation cracks on the surface of earlydiagenetic supratidal dolomite. Berriassian, "Fantazija" quarry, Rovinj-Istria. Facies K-1 (scale = 10 cm).
Slika 17. Desikacijske puktoine na površini ranodijagenetskog supratidalnog dolomita.Berijas, kamenolom "Fanatazija"u Rovinju. Facijes K-1 (mjerilo = 10 cm).

immediately below or within the intertidal zone with temporary emersions is inicated also by well preserved reptilian footptints on the upper bedding planes of soft pebble conglomerates and LLH-stromatolites in the Upper Barremian (Fig. 19.) and Upper Albian of the Veli Brijun Island of Istria (VELIĆ & TIŠLJAR, 1987).

Fig. 18. Aptian emersion-FaciesK-1: clayey emersion breccia between paleokarstified Lower Apatin massive mudstones/onkolites (Facies K-3) and Upper Albian thin bedded mudstones and mud pebble conglomerates. Selina quarry, Istria (breccia bed cca 120 cm thick).
Slika 18. Aptska emerzija -Facijes K-1: emerzijske breče s glinovitim vezivom između donjoaptskih masivnih mudstone/onkolitnih vapnenaca (Facijes K-3) i gornjoalbskih tanje uslojenih mudstone-a i konglomerata s muljnim valuticama. Kamenolom Selina,Istra (breča debela 1,2 m).

The emersion breccias in the Lower Cretaceous limestones of the coastal Dinarides generally indicate the Aptian and Early Albian emersions, but with different duration at different areas. The emersion breccias of the Aptian emersions are frequent in the Aptian on the Island of Korčula, Biokovo Mt., Dinara Mt., Velika Kapela Mt. and Istria (TIŠLJAR et al., 1983; VELIĆ et al., 1989).

The thin layers of the emersion breccias occur sporadically in the Valangian and Barremian near Dubrovnik, in the Barremian and Albian on the Island of Mljet, in the Hauterivian on the Island of Korčula and Biokovo Mt. and in the Berriasian, Valanginian, Hauterivian, Aptian and Upper Albian in Istria.

Fig. 19. Upper surface of a stromatolitic-pelletal wackestone bed with reptilian foot-prints. Barremian of the Veli Brijun Island, Istria. Facies K-1.
Slika 19. Gornja slojna površina stromatolitno-peletnog wackestonea s otiscima stopala gmazova. Barem otoka Veli Brijun. Facijes K-1.

3.2. FACIES OF INTERTIDAL TO SHALLOW SUBTIDAL LIMESTONES: LLH-STROMATOLITES, FENESTRAL MUDSTONES TO PELLETAL WACKESTONES AND TIDAL BAR GRAINSTONES - FACIES TYPE K-2

Facies type K-2 is characterized by alternation of thin bedded pelletal wackestones/packstones to grainstones and LLH-stromatolites. Festral fabric and rare vadose features are very significant.

The alternation of pelletal wackestones/packstones or grainstones and LLH-stromatolites at (Fig. 20.) some

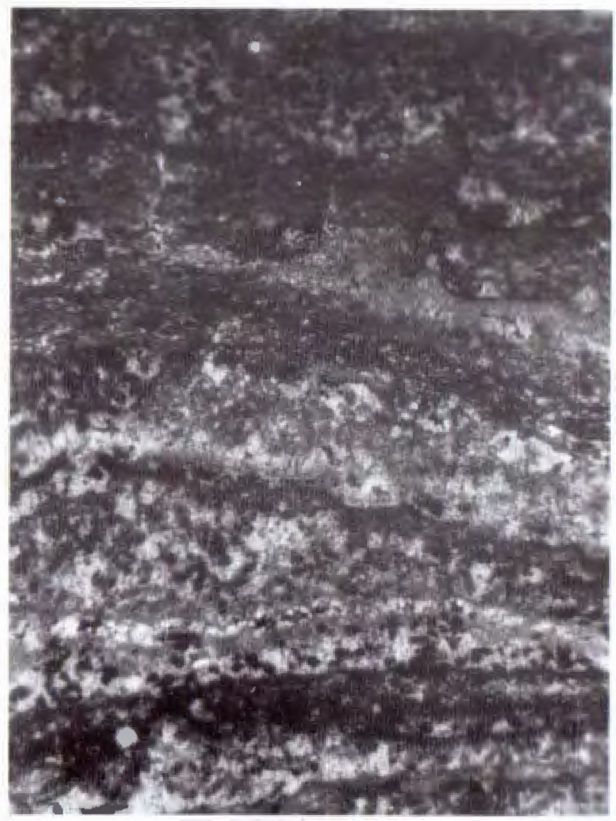

Fig. 20. Thin laminated LLH-strmatolite of the Facies K-2 composed of cryptocrystalline and pelletal laminae. Valanginian of Istria (12x).
Slika 20. LLH-stromatolit K-2 facijesa izgrađen od kriptokristalastih peletnih lamina. Valendis, Lim (Istra).

localities of the Lower Cretaceous of the Dinaric karst region is rhythmic. Shallowing-upwards sequences are frequent. The rhythms or shallowing-upwards sequences are composed of pelletal or skeletal (green-algae, gastropods, ostracods, benthic foraminifers) wackestone - LLH-stromatolite, and second type sequences: mudstone - skeletal or pelletal wackestone - LLH-stromatolite. Coarsening-upwards sequences occur sporadically. They are composed of pelletal wackestone/packstone - LLH-stromatolite - pelletal grainstone with herring-bone cross-bedding and/or small hummocky cross-stratification. In the Barremian of western Istria, for example, mudstone - stromatolite - peritidal breccia - stromatolite cycles occur (TIŠLJAR et al., 1983). The cycles originated in the subtidal-intertidal phase with desiccation (Fig. 21.), swelling/expansion and resedimentation of semi-consolidated carbonate deposits, und by storm waves transported fragments of algal-mat (stromatolitic tempestites), overgrowthing repeated by blue-green algal-mat.

Fig. 21. Uppward shallowing sequences of the Facies K-2: desiccation cracks on the surface of the fenestral and stromatolitic limestone. Barremian, St. Martin cove, Poreč-Istria (Scale 24 cm).
Slika 21. Sekvencija oplićivanja K-2 facijesa: desikacijske pukotine na površini fenestralnog i stromatolitnog vapnenca. Barem, uvala Sv. Martin, Poreč (Mjerilo 24 cm).

Thin layers of LLH-stromatolites formed by sediment trapping and binding with blue-green algal-mats, pelletal, micritic and bioclastic wackestones with fenestral fabric, erosion surfaces, desiccation cracks, vertical burrowing and sometimes internal sediments into solution vugs are the predominant types of limestones in this lithofacies of the karst region in the coastal Dinarides. Pelletal limestones contain high contents of fecal pellets (in the Valangian and Hauterivian the so - called "Favreina pellets"). In some places (Berriasian, Hauterivian of Istria) pellets were accumulated by tidal currents and storm waves in form of the tidal bars, overlied by the stromatolite on the tidal flat. In Tithonian and Berriasian of Dubrovnik region there are vadose limestones consisting of numerous irregular fenestrae, molds of shells, solutional vugs (Fig. 22.), vadose crystal

Fig. 22. Solutional vugs in pelletal wackestone of the facies type K-1: vugs filled with vadose crystal silt and partially with calcite cement (light). The Berriasian vadose limestones from Cerovac near Dubrovnik. Scale = 0,5 mm.
Slika 22. Šupljine otapanja u peletnom wackestone vapnencu facijesa K-1: šupljine ispunjava vadozni kristalni silt, a gornje dijelove druzni kalcitni cement (svijetlo). Vadozni vapnenci berijasa iz područja Cerovca u zaleđu Dubrovnika. Mjerilo = 0,5 mm.

silt and vadose pisolites. In these sediments three rhythmic sedimentation phases in shallowing-upwards sequences may be estimated (TIŠLJAR, 1979): mudstones to onkoid, algal and gastropod wackestones, (subtidal to lagonal phase); pelletal wackestones /packstones/ grainstones with fenestral fabric and LLH-stromatolites (shallow subtidal to intertidal phase), and pelletal wackestones with vadose features, i.e. vadose pisoids, solutional vugs filled with vadose crystal or pellet silt and gravitational cement, (intertidal to supratidal with vadose phase).

The limestones of the facies type K-2 were deposited in the intertidal and very shallow subtidal environment, and very often in the tidal flat, too. They occur in all Lower Cretaceous chronostratigraphic units on the entire karst region, but not always in the same unit and localities nor with the same frequency and thicknes.They are most frequent in the Valangian, Hauterivian and Barremian, especially in western Istria, in the Berriasian and Barremian in the region of Dubrovnik, Island of Korčula, Biokovo Mt., and Dinara Mt.

3.3. FACIES OF LAGOONS AND RESTRICTED SHOALS: MUDSTONE/WACKESTONE AND ONCOLITES - FACIES TYPE K-3

In the Lower Cretaceous of the Dinaric karst region the facies type K-3, i.e. mudstones/wackestones and oncolites, is the most frequent and the thickest member (Fig. 16.). It is represented by thick strata (0.4 - 3,0 m) of massive mudstones and skeletal wackestones to floatstones alternating with oncolithes. These limestones are typical micritic rocks consisting predominantly of carbonate mud, i.e. micrite.

The oncolites are composed of algal oncoids formed by overgrowth and incrustation of gastropods and blue-green algae skeletons, and carbonate mud. Large oncids appear in spherical, kidney-like or irregular clod-like shapes ranging from 4 - 8 mm in diameter. The large oncoids ("macroids" - PERYT, 1983) which built up oncolites of massive limestones in the Lower Aptian are often of fan-like distribution or they overgrow each/other (i.e. oncolite crusts). Alga *Bacinella irregularis* RADOIČIĆ or gastropod skeletons can be observed in most of the macroid-nucleus, even macroscopically. Thin section of macroids exhibits thick cryptocrystalline envelope arround the skeletons of the *Bacinella* or gastropod (Fig. 23.). The envelope may originate in two ways: 1. - more frequently, by trapping the fine carbonate mud by means of blue-green algae, and 2 - less often, of cryptocrystalline material left after algal boring activities.

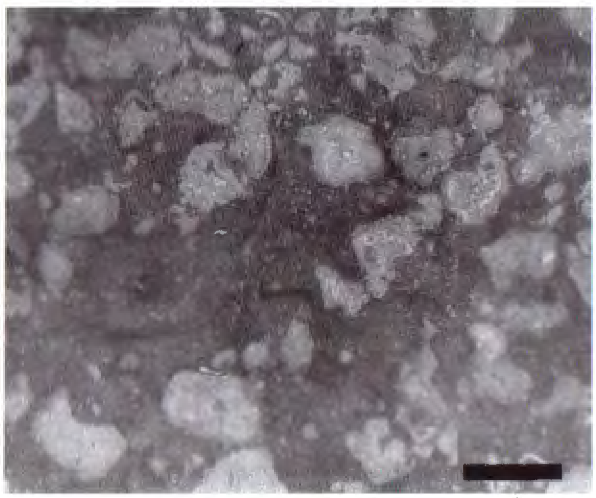

Fig. 23. *Bacinella* oncoid floatstone (oncolite). Large irregular oncoides in dense micrite matrix. Lower Apatin, "Kanfanar" quarry - Istria. Facies K-3 (Scale 6 cm).
Slika 23. Bačinelski onkoidni floatstone (onkolit). Veliki nepravilni onkoidi u gustom mikritnom matriksu. Donji apt, kamenelom u Kanfanaru. Facijes K-3 (Mjerilo 6 cm).

A decisive role in macroid formation was played by the processes of mud trapping and binding over mucus and filaments of blue-green algae as well as overgrowing *Bacinella* and gastropod skeletons (TIŠLJAR, 1986).

Oncolites, oncoid floatstones and wackestones contain irregular and spherical-concentic oncoids, carbonate mud and restricted marine flora and fauna: green-algae, gastropods, ostracods and micritized benthic foraminifers. There are vertical burrowing and centripetal micritization of oncoids and skeletons.

Rhythmical alternations of mudstones/wackestones with oncolites are frequent. They were deposited by periodical alternations of intervals of intensive mud accumulation and intervals of weak mud accumulation in the lagoons or restricted shallows. Mudstones and wackestones were originated during the period of high mud accumulation, and the oncolites were developed during the transition from slow to high mud accumulation accompanied by intensive blue-green algal growth. The limestones of the facies type K-3 contain flora and fauna which indicate restricted marine environments (blue-green algae, gastropods, ostracods and micritized benthic foraminifers). They were deposited in the lagoons and/or restricted shoals on the inner part of the carbonate platform. Within the Lower Cretaceous sediments of the Dinaric karst region facies type K-3 is the predominate lithological member, especially in the Valangian, Hauterivian, Aptian and Upper Albian of the south Adria region, in the Hauterivian, Aptian and Albian of the Biokovo Mt. and Dinara Mt., and in the Lower Aptian of Istria (Fig. 1 B).

3.4. FACIES OF SHOALS WHITH AGITATED WATER AND PATCH-REEFS: INTRACLASTIC AND BIOCLASTIC GRAINSTONES/ RUDSTONES - FACIES TYPE K-4

Facies type K-4 is composed of intraclastic and/or bioclastic grainstones and rudstones. Sporadically, for example in the Upper Aptian of western Istria and Aptian of the Velika Kapela Mt., small bioherms of rudists and rudist coquinas occur within the grainstones/rudstones. Numerous rudists, hydrozoans, echinoderms and rare coral fragments in the limestones of the facies type K-4, and rare rudist coquinae or small bioherms indicate the existence of open shoals and smaller patch-reefs. They were populated by these organisms, and from which their remains were washed, in some places by storm waves into the shoals of the inner part of the

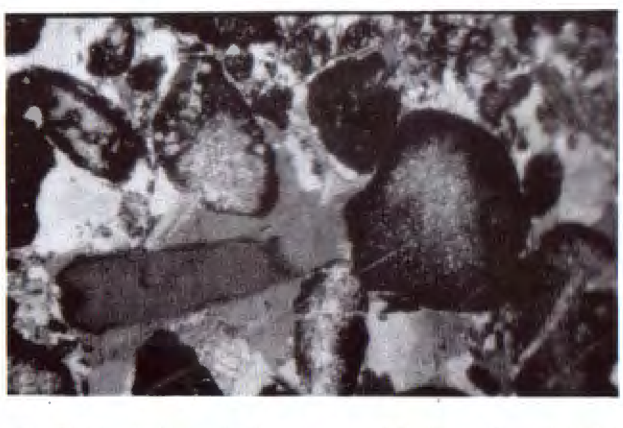

Fig. 24. Bio- and intraclastic grainstone of the Facies K-4: sintaxial rim calcite cement around an echinoid fragment. Upper Apatin, Dinara Mt. (25x).
Slika 24. Bioklastični i intraklastični grainstone K-4 facijesa: sintaksijalni obrubni kalcitni cement oko fragmenata bodljikaša. Gornji apt Dinare (25x).

carbonate platform, i.e. into the agitated water shoals (Fig. 24).

In the Lower Cretaceous of the Dinaric karst region facies type K-4 is rare. It occurs only sporadically in the Upper Barremian (near Dubrovnik), in the Upper Aptian (Istria, Biokovo Mt., Velika Kapela Mt.), in the Lower Albian (near Dubrovnik) and in the Upper Albian of Istria.

3.5. LITHOFACIES OF LATE DIAGENETIC DOLOMITES - FACIES TYPE K-5

This lithofacies,i.e.late-diagenetic dolomites, occurs very frequently in great quantities, large masses and bodies especially at the beginning and at the end of the Lower Cretaceous in the Dinaric karst region. Very thick and laterally large bodies of this lithofacies occur in Berriasian, Upper Albian and Vraconian on the Island of Korčula, in the Valangian and Vraconian of the Dubrovnik region, in the Albian of the Biokovo Mt. and Dinara Mt. and in the Berriasian and Albian of the western and southern Istria.

All late-diagenetc dolomites of the Lower Cretaceous are hypidiotopic and xenotopic mosaic dolomites, i.e. "protodolomites" with high Ca-excess and low degree of lattice-ordering. The structure of this dolomites was previously macrocrystalline and/or microcrystalline hypidiomorphic with many brownish inclusions of possibly organic material.

In large area, late-diagenetic dolomites are dedolomitized or calcitized and transformed into microcrystalline limestones of "recrystallized texture". The dedolomitization process is connected to the upper portion of the surface reaching a maximum depth of 10 to 40 meters. Here, intensive circulation of rain-water occured, with a low Mg/Ca moles-ratio and rapid remove of Mg^{2+} ions (TIŠLJAR, 1976).

The origin and other textural and structural characteristics of the Lower Cretaceous late-diagenetic dolomites of the Dinaric karst region are the same as in the late-diagenetic dolomites of the Jurassic.

4. FACIES TYPES AND THEIR REFERENCE TO THE KARST MORPHOLOGY

Petrological composition, structural and textural characteristics of the limestones and dolomites, as well as vertical and horizontal lithofacies distribution play an important role in the formation of karst morphology and karst phenomena.

Great variability of structural, textural and diagenetic characteristics of the sediments distinguished as the facies type J-1 in the Jurassic sediments and the facies type K-1 in the Lower Cretaceous sediments of the Dinaric kast region caused different behavior of certain lithological rock types during the weathering and karstification. This is the consequence of different but also changeable sediementary conditions and early-diagenetic processes in the peritidal environment especially in the upper intertidal, supratidal and vadose zone, but particularly during shorter or longer emersions in dry-land conditions. The weathering of the peritidal and tempestite breccias, black pebble breccias, and particularly emersion breccias which contain marly and clayey matrix, is more intensive than limestones in their footwall or hanging wall. That is why they form depression zones and trenches planted whith low trees and bushes, visually easily distinguished from the barren karst (Figs. 4a,4b). Beside those layers, interlayers and lenses of peritidal emersion breccias are also evident, as well as mechanical discontinnuity inside the limestones.

In comparison to the peritidal and emersion breccias, supratidal early-diagenetic dolomites are due to their specific texture, structure, mineral composition and genetical characteristics, very resistant to weathering and almost completely waterproof. They form elevated morphological forms in the karst, usually with smooth surface.

The vadose limestones which underwent early-diagenetic processes in a vadose zone (containing solutional vugs, mold of shells, fenestrae with internal vadose sediments, vadose ooids and pockets of vadose ooids), as well as limestones with paleokarst phenomena (paleokarstification in Jurassic or Cretaceous time caused by extended emersions) weather very unevenly, forming porous karst surface with irregular forms, sharp margins and toothed pike.

The tidal bar grainstones/rudstones occur as predominantly massive rocks, which were deposited in lense-like shapes or sandy waves.

The alternation of LLH-stromatolites, pelletal and mudstone limestones, i.e. intertidal limestones of the facies type K-2, weather into thin plates parallel with laminations planes, and are usually intensively karstified, thus forming negative morphological depressions filled by terra rossa or their own crushed fragments. Besides, these limestones show well developed thin bedding ("platy limestones"), which gives specific morphology to the karst terrains.

Homogeneous texture, high micrite participation, massive or thick-bedded structure, rather low primary porosity of Jurassic limestones classified into the facies type J-2 and Lower Cretaceous limestone of the facies type K-3 are the cause of even weathering and uniform karst morphology on the greater area. The facies types J-2 and K-3, forming thicker deposits always at the steeper karst-slopes, make perpendicular cliffs, impassable for people and cattle. If the limestones of the facies types J-2 and K-3 are tectonically fractured and crushed, their weathering and karstification loose such characteristics.

The higher are the weathering intensities and the more expressive the karst morphology of the limestones of the facies types J-3, J-4 and K-4, the lower the intensity of intergranular, interskeletal, intraskeletal and pore-cementation. The same is true with the mutual ratio and character of drusy mosaic and rim fibrous clacite cement. Primary mineral composition of skeletal debris is also very important. Higher contribution of skeletal debris, formed primarily of aragonite caused existence of numerous molds of shells and solutional vugs, which enhance more intensive weathering and karstification processes along with formation of porous, sharp-edged and prickly karst. On the other hand, uneven interskeletal pore cementation of fosils causes different rate of weathering and karstification from place to place and makes also porous, sharp-edged and rough karst surface.

The ooid-grainstones or oolites of the facies type J-6 have a very uniform composition, texture and structure, very high primary intergranular porosity and usually can be found in thicker layers or massive rocks. Their weathering is uniform, as well as specific morphology extending over large distances. These are big, rounded, compact and segregated swollen forms, usually without vegetation, only whith some lichens. However, if the cementation of ooid intergranular pores is weak or incomplete, they disrupt into ooid sand, forming negative morphological forms (concavities on steep slopes).

There are many localities in the Dinaric karst region, where the late-diagenetic dolomites are frequent of predominant rocks. Late-diagenetic dolomitization progressed over limestones of the same chronostratigraphic or lithofacies unit or even two neighbouring chronostratigraphic units. That is why we may often find dolomitic masses, i.e. late-diagenetic dolomites, which embrace older limestones in the footwall or hanging wall layers with different extent. It usually makes difficulties and problems in solving stratigraphy as well as in different interpretation of dolomite age and tectonic relations in the Dinaric karst region. Namely, some authors put stratigraphic boundary, for example Jurasic and Lower Cretaceous, below (POLŠAK & ŠIKIĆ, 1973), whereas the others put it within the dolomite bodies (VELIĆ & TIŠLJAR, 1988). However, dolomitic bodies, quite often, comprise limestones of younger and/or older chronostratigraphic units (e.g. in the Upper Tithonian and Berriasian of western Istria - VELIĆ & TIŠLJAR, 1988). In addition, the late-diagenetic dolomites are often in great quantities and masses in tectonically disrupted zones and thrusts, which have been the pathways for the most intensive pore-water circulation responsible for the late-diagenetic dolomitization of limestones. Also, their influence on the limestones of the some chronostratigraphic or lithofacies units was not uniform. Specific morphological shapes inside the late-diagenetic dolomites and dolomitic limestones in the karst are the result of different intensities of physical and chemical weathering of limestones and dolomites. In the case of pure late-diagenetic dolomites without limestone relicts, the dolomites appear like big massive bodies without clear stratification, swelling out from surrounding limestones (Fig. 4a). The forms have rounded surfaces, they are smooth and without vegetation. If the late-diagenetic dolomites appear as smaller lenses or masses inside the limestones and contain relicts of the dedolomitized or partly dolomitized limestones, or the transition between the limestones and dolomite are gradual and irregular, then the karst morphology is irregular, uneven and planted with low bushes and grass.

In the places where the late-diagenetic dolomites are more tectonically fractured or dedolomitized and transformed into microcrystalline limestones, i.e. dedolomites, their weathering is more intensive than that of the surrounding limestones. It is a place in karst with high grass and low stunted bushes. If the process of dedolomitization is complete, the dolomites weather and desintegrate into sandy mass which is easily washed out by rain waters, forming irregular concavities, caverns or greater depressions with smooth, rounded sides and shapes.

5. GENERAL REVIEW OF THE DEPOSITIONAL CONDITIONS AND ENVIRONMENTS OF THE JURESSIC AND LOWER CRETACEOUS CARBONATE SEDIMENTS OF THE COASTAL DINARIDES

The Jurassic and Lower Cretaceous carbonate sediments of the Dinaric karst region are part of the continual succession of the Mesozoic carbonate sedimentation (with temporary emersions) from the Upper Triassic to the end of the Cretaceous. At the examined Jurassic and Lower Cretaceous localites (Istria, Platak Mt., Gorski Kotar, Mala Kapela Mt., the Kubus pass and Mali Halan pass on Velebit Mt., Dinara Mt., Biokovo Mt., hinterland of Dubrovnik, Osojnik near Dubrovnik, Mljet, Korčula, and Lastovo islands) ,similar lithological, depositional, genetic and diagenetic properties have been established. This suggests similar depositional conditons and environments on the carbonate platform of Jurassic and Cretaceous in the whole area of the coastal Dinarides.

In general, all sediments from this region are typical examples of shallow marine platform carbonates, formed mainly in the inner part of the large carbonate platform.

5.1. JURASSIC

In Jurassic sediments distinct predomination of the facies type J-2 in alternation with the facies type J-1 (Fig. 1) suggests temporally and spatially dominant sedimentation in restricted shoals and/or lagoons of the inner part of the carbonate platform, with short shallowings and emergences into the peritidal, with or without vadose or land conditions. Supratidal environments with early-diagenetic dolomites were formed in the Lower Lias in the Velebit Mt. and Lika region.

The shoals were occasionally formed in the Dogger, where the ooids were sedimented ("ooide shoals and bars"). Shoals with smaller, now completely destructed patch-reefs, where skeletal debris was deposited, the facies type 4 appear seldom. In the Upper Dogger, shoals with agitated water predominated, where the skeletal and intraclastic grainstones/rudstones were sedimented. Shoals with lithiotids and and other shells tempestite coquinas are frequent in the Middle Lias of the Velebit Mt.

Perireefal environments, except those already mentioned in the Upper Dogger are very rare and mainly restricted to sporadic occurrences in the Lower and Middle Lias. Smaller coral and/or hydrozoan patch-reefs, usually with algal incrustations, are restricted only to the Lower Malm of the Island of Lastovo and the Tithonian of Gorski Kotar.

The limestones with vadose features occur in more significant amount. It is noteworthy that they temporally correspond to longer or shorter emergences with smaller sporadical occurences of bauxite deposits or emersion breccias in other wider areas of the coastal Dinarides (Istria, Dinara Mt.) .The emersion breccias, i.e. land conditions, occur in the Middle Malm of the Biokovo Mt. and in the Lower Kimmeridgian to Upper Tithonian of the western Istria. The littoral (shoreline) breccias in the Lower Kimmeridgian of the western Istria were originated in a regressive cycle, that means during the retreat and not during the ingression of the sea, so that their termination was at the same time with the end of the regressive cycle , which is clearly manifested by facies characteristics and sedimentation conditions of footwall tidal bar limestones (VELIĆ & TIŠLJAR, 1988). Looking at the older Jurassic units in Istria in the light of environmental changes and sedimentation conditions, there is a tendency to gradual shallowing from lagoon/ subtidal to intertidal - tidal bar, culminating in the formation of these breccias and ending in the emersion with bauxite during the Upper Kimmeridgian - Upper Tithonian. The discordant position of the bauxite upon breccias and the transgression of the Upper Tithonian limestones beginning with transgressive breccias/mud pebble conglomerates with marly matrix indicate that the contact zone between regressive breccias on the one side and Upper Tithonian limestones on the other side is at the same time the boundary of the one regressive and one transgressive cycle. It is interesting to note that in Upper Kimmeridgian and Lower Tithonian in the Platak Mt. (ca 70 km NE from bauxite deposits in western Istria) sedimentation was continuous with limestones of the facies types J-2 and J-1, i.e. fenestral and vadose limestones deposited in shallow subtidal and intertidal environments and exposed to vadose conditions. The Upper Malm in south Adriatic region (near Dubrovnik) have similar sedimentary conditions, i.e. fenestral and vadose limestones, with continual sedimentation between the Upper Malm and Lower Cretaceous. The emersion with breccias and ca 200 m sediment reduction occurs in the Middle Malm of the Biokovo Mt. , too.

5.2. LOWER CRETACEOUS

Lower Cretaceous limestones of the coastal Dinarides deposited in the lagoons and/or restricted shoals, are the most frequent and the thickest litholigical member (Fig. 16.) . The limestones deposited in the intertidal to very shallow subtidal environments are frequent, but early diagentic supratidal dolomites and emersion breccias are rare.

Supratidal early-diagenetic dolomites of the facies K-1 occur in the Berriasian of western Istria, Berremian on the Island of Mljet and in the Vraconian of the Dubrovnik region. The Ca-excess of the early-diagenetic dolomites of the western Istria indicate a humid climate similar to that of the Florida Keys today (FÜCHTBAUER & TIŠLJAR, 1975).

The frequent emersions in the Barremian, Aptian and Lower Albian were accompanied by sedimentation breaks, weak erosion of incompletely consolidated sediment and occurence of thin intercalations of intraformational breccias containing black pebbles and/ or marly or clayey matrix. The results of investigation generally indicate the Aptian emersion but with different duration at different areas. The most frequentlly the emersion lasted through the Late Aptian and Early Albian. Locally, however, it started later, i.e. at the end of the Late Aptian and came to an end during the Early Albian, while elswehere it started earlier in the Early Aptian and lasted into the Early Albian. The maximum gap has been recognized at Baderna in western Istria, where the uppermost Lower Albian or even the basal Upper Albian directly overlies the Middle Barremian approximately (VELIĆ et al., 1989). Here the gap (both materially and temporarily) is very significant: possibly some hundred meters of carbonate deposits are missing and spanning the time duration of some 10-15 MY. In comparison to the Aptian of western Istria, Biokovo Mt. and Dinara Mt., the emersions on the Island of Mljet took place in the Barremian.

Summing up, this data strongly indicate a differentiated uplifting "emergence" on diferent location of carbonate platform during the time span from the Late Barremian to the end of the Early Albian. Taken together, these factors have produced changeable sedimentary environments and variable rate of deposition per unit of time. The direct results are different thicknesses of both lithofacies, lithostratigraphic and biostratigraphic units. In conclusion, all these data suggest that the carbonate platform or platforms, in addition to "sinking" at different rates and/or velocities, locally and occasionally also displayed movement in the relatively opposite direction.

Lithofacies types, structural, textural, diagenetic and genetic properties, depositional environments and different thicknesses of the same lithofacies or lithological units suggest the following conclusions:

In various places of the Jurassic and Lower Cretaceous carbonate platform or platforms, the same depositional environments did not occur at the same time, or, if they did, they did not last for the same amount of time. Nevertheless, the same environments were created in various places, at various times, and in the same places particular environments were periodically repeaeted at various time intervals. Such circumstances caused lateral and vertical lithofacies changes, various depositional thicknesses and rhythmic and cyclic sedimentation.

The various depositional thicknesses were greatly affected by emersions, their frequency and duration in the Lower Cretaceous time, and by the relatively low rate of accumulation of the sediments in the intertidal and supratidal zone. Very gentle inclination of the inner part of the carbonate platform (or platforms), non-uniform sinking of some of its parts and different intensity of sediment accumulation in relation to the rate of sinking, account for these conditions of sedimentation. Even small differences in the balance of these factors, as well as the oscillations in the sea level, could have caused changes in the depositional environments at comparatively small distances in the supratidal - intertidal - tidal bar - shallow - subtidal - lagoon - restricted shoals - agitated water shoals - patch-reef zones.

5.3. CORRELATION

In dominant shallow-water paleoenvironments on the Adriatic carbonate platform, there were clear facies distinctions between the Jurassic and Cretaceous carbonate sediments.

Firstly, ooid grainstones, widely spread in the Jurassic (Facies J-6), i.e.environment of ooid shoals and bars, were not found in the Lower Cretaceous (see Figs.1. and 16.).

Secondly, facies of biostromal and patchreef boundstones (J-5) and facies of bioclastic perireefal grainstones/rudstones (J-4), are more frequent in the Jurassic than in the Lower Cretaceous. Stromatolites in the oldest Jurassic, J-1 facies, are less frequent in comparison with the similar K-2, the Lower Cretaceous facies. In general, it indicates that the open platform environments and shallow-water conditions with agitated water prevailed throughout the Jurassic, whereas the restricted shoals, lagoons and tidal flat environments were dominant in the Lower Cretaceous.

Lithiotidae coquina and/or biostromal limestones (Facies J-4 and/or J-5), in the Middle Lias, and ooid grainstones (Facies J-6), in the Middle and Upper Lias can be followed as regional facies throughout the Adriatic carbonate platform (especially in the Velebit mountain and the southern Adriatic coast). On the other hand, in the Lower Cretaceous carbonates as regional facies, can be noted, to a certain point, Aptian emersion and *Baccinella*-bearing oncolites in the Lower Aptian (Facies K-3). Thus the general characteristic of the Adriatic platform in the Lower Cretaceous is a frequent lateral and vertical changes of paleoenvironments between the restricted shoals, lagoons, and peritidal environments.

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FACIJESI I OKOLIŠI TALOŽENJA JURSKIH I DONJOKREDNIH KARBONATNIH SEDIMENATA OBALNOG DIJELA DINARIDA U HRVATSKOJ

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FACIJESI

Obalno područje Dinarida većim dijelom izgrađuju jurski i kredni plitkomorski karbonati. To su različiti varijeteti vapnenaca, dolomitičnih vapnenaca i kasnodijagenetskih dolomita, a vrlo rijetko i natplimski (supratidalni) ranodijagenetski dolomiti, peritidalne, olujne (temepestitne) i emerzijske breče. Na temelju opsežnih sedimentoloških istraživanja i snimanja detaljnih geloloških stupova od Istre do Konavala te teksturnih, strukturnih, litoloških, genetskih i dijagenetskih odlika, kao i sadržaja fosilne flore i faune, u jurskim i donjokrednim karbonatnim sedimenatima priobalnog dijela dinarskog krša i jadranskih otoka izdvojeni su karakteristični litofacijesi s odgovarajućim okolišima i uvjetima sedimentacije.

Unutar **jurskih** sedimenata izdvojeno je sedam facijesa. To su:

J - 1. PERIPLIMSKI FACIJES: FENESTRALNI I/ILI VADOZNI VAPNENCI

Pretežno se sastoji od peletnih i skeletnih wackestone do mudstone vapnenaca koji se odlikuju fenestralnom građom i vadoznim tvorevinama (vadoznim ooidima ili pizoidima, vadoznim kristalnim siltom). Rjeđi su LLH-stromatoliti nastali na plimskim zonama, te ooidni i kortoidni grainstone i rudstone vapnenci taloženi na plimskim prudovima djelatnošću struja plima i olujnih valova. Samo mjestimice na pojedinim lokalitetima nalaze se natplimski ranodijagenetski dolomiti i periplimske, olujne i "black pebble" - breče te emerzijske breče i emerzije s paleokrškim fenomenima ili boksitima. Za karbonatne sedimente ovog facijesa tipična je ritmička sedimentacija s ponavljanjem pojedinih litoloških članova u obliku sekvencija s jasnom tendencijom opličavanja. Sekvencije, odnosno ritmovi, obično počinju taloženjem mikrita ili pelmikrita/biomikrita u lagunama ili okolišu plitkog subtidala zaštićenog platformskog plićaka, a završavaju sa sedimentima plimskih prudova (ooidni i bioklastični grainstone ili rudstone) ili pak fenestralnim mikritnim vapnencima s desikacijskim pukotinama (sl. 2.) i desikacijakim brečama, a mjestimično i "black pebble" - brečama (sl. 3.) kao produktima resedimentacije brakičnih i/ili slatkovodnih močvarnih crnih vapnenačkih taloga. Kao posljedica izronjavanja taloga iznad srednje razine plime u vadoznu zonu česti su u ovom facijesu fenestralni vapnenci s vadoznim tvorevinama (vadozni ooidi ili pizoidi, vadozni kristalni i peletni silt (sl. 5. i 6.). Natplimski ili supratidalni ranodijagenetski dolomiti su nađeni samo u lijasu Velebita i Like. Emerzije su uvijek praćene većim ili manjim redukcijama debljine sedimenata, emerzijskim brečama ili paleokrškim fenomenima (sl. 4a i 4b).

J - 2. FACIJES ZAŠTIĆENIH PLIĆAKA I/ILI LAGUNA: ONKOLITNI, PELETNI I SKELETNI, MIKRITOM BOGATI VAPNENCI

To je najrasprostranjeniji facijesni tip u juri. Predstavljen je debeloslojevitim ili masivnim onkolitima (onkoidni floatstone i wackestone, sl. 8.) te peletnim i skeletnim (zelene alge, bentičke foraminifere, gastropodi) vapnencima wackestone (sl. 7.), packstone i mudstone tipa. U gornjem lijasu Velebita tom facijesu pripadaju i intenzivno bioturbirani mudstone vapnenci (sl. 9.) tzv. "mrljasti vapnenci" poznati i pod nazivom "Fleckenkalk". To su mikritni vapnenci taloženi u mirnim, izoliranim plićacima i/ili lagunama sa sporom akumulacijom karbonatnog mulja pri niskoj energiji vode što je ekološki pogodovalo obilnom razvoju crva i drugih organizama muljojeda. Zbog toga što su muljojedi u svom probavnom traktu apsorbirali organsku supstanciju njezin je sadržaj bitno manji u bioturbiranim dijelovima nego li u okolnom neporemećenom mikritu, odnosno stijeni koja sadrži bioturbacije. To je razlog zašto ti vapnenci imaju mrljasti izgled. Vapnenci facijesnog tipa J-2 sadrže, uz algalne onkoide, fekalne pelete i mikritizirane bioklaste, fosilnu floru i faunu tipičnu za zaštićene plićake i lagune potplimske zone: zelene alge, gastropode, ostrakode i mikritizirane bentičke foraminifere.

J - 3. FACIJES PLIĆAKA S POKRETLJIVOM VODOM: BIOKLASTIČNI I INTRAKLASTIČNI VAPNENCI GRAINSTONE DO RUDSTONE TIPA

Odlikuje se učestalim izmjenama tankoslojevitih skeletnih, bioklastičnih, kortoidnih i/ili intraklastičnih vapnenaca grainstone do rudstone, vrlo rijetko i floatstone tipa. Ti vapnenci sadrže skelete i/ili bioklaste ili kortoide hidrozoa, stromatoporoida, školjkaša, bodljikaša i bentičkih foraminifera, a mjestimice i gastropoda ili koralja. Sa zamjetljivim udjelom ovaj se facijes pojavljuje samo u srednjem lijasu Velebita, gornjem dogeru (sl. 10.) u području južnog Jadrana te u gornjem malmu Biokova i Gorskog Kotara, a samo se sporadično nalazi i u gornjem malmu Dinare.

J - 4. PRIGREBENSKI FACIJES: PRIGREBENSKI BIOKLASTIČNI VAPNENCI

U taj su facijes izdvojeni vapnenci nastali razaranjem i akumulacijom fragmenata skeleta i ljuštura organizama koji su tvorili grebene, manje "krpaste grebene" (patch-reef) ili kolonije hidrozoa, stromatoporoida, koralja, pahiodontnih školjkaša i inkrustirajućih kodiaceja. U ovaj facijes nisu ubrojeni bioklastični vapnenci nastali akumulacijom bioklasta i kortoida takvih organizama na plimskim prudovima (facijes J-1). U facijes J-4 su uvršteni bioklasti akumulirani u prigrebenskim plićacima i u plitkom potplimskom do plimskom okolišu, kao i strujno orijentirani krupni fragmenti litiotida, brahiopoda i diceratida naplavljeni u obliku olujnih kokina (tempestite coquinae), kao što je to slučaj u srednjem lijasu Velebita (Mali Halan, Kubus - sl. 11.).

J - 5. FACIJES BIOSTROMALNIH I "PATCH-REEF" VAPNENACA

Unutar jurskih karbonatnih sedimenata obalnog područja Dinarida ovaj se facijes nalazi samo sporadično i s malim udjelom u ukupnoj građi tih sedimenata. Samo sporadično u srednjem lijasu (Ivanjica kod Dubrovnika, Mali Halan i Kubus na Velebitu) nalaze se 0,3 - 0,8 m debele, bočno ograničeno rasprostranjene, biostrome sastavljene od ljuštura litiotidnih školjkaša litificiranih u poziciji i na mjestu rasta (sl. 12. i 13.). Manji koraljni i hidrozojski "krpasti grebeni" (patch reefs) ili kolonije litificirane u položaju rasta nađene su u donjem malmu na Lastovu i u titonu Gorskog Kotara (Zlobin, Velika Kapela).

Nigdje nisu pronađeni nikakvi veći grebenski kompleksi s očuvanim biostromama ili biohermama, koje bi mogli smatrati grebenskim barijerama, premda su one vjerojatno i postojale ali su pod udarima valova bile razorene i poslužile za taloženje bioklastičnog detritusa vapnenaca prigrebenskog facijesa J-4 tipa.

J - 6. FACIJES OOIDNIH PLIĆAKA I PRUDOVA: OOLITNI FACIJES

Oolitni facijes je vrlo važan i po udjelu značajan litofacijesni član u srednjem i gornjem lijasu i donjem dogeru, posebice u području južnog Jadrana, a često se nalazi i u donjem lijasu i dogeru Velebita, Gorskog Kotara, donjem malmu Istre i gornjem malmu Lastova i Platka. To su oolitni vapnenci grainstone tipa sastavljeni od jednog ili više strukturnih tipova ooida. Najčešći su radijalni, tangencijalni i mikritni ooidi(sl.14.). Česti su još i kalupni ili oomoldički ooidi te izluženi i regenerirani, kao i kasnodijagenetski selektivno dolomitizirani ooidi. Na taloženje ooida na prudovima ukazuju kosa i "riblja kost" kosa slojevitost te oomoldički ili izluženi ooidi sa spuštenom i ekscentričnom jezgrom kao posljedicom otapanja aragonitnih ovoja ooida uslijed utjecaja meteorskih voda na ooidne pijeske, koji su kratkotrajno bili iznad morske razine (vrhovi ooidnih pješčanih valova na prudovima).

J - 7. LITOFACIJES KASNODIJAGENETSKIH DOLOMITA

Ima široku rasprostranjenost, a po udjelu u ukupnoj građi jurskih sedimenata slijedi odmah iza facijesa J-2 i J-6, mjestimično i J-1 tipa. U taj su litofacijes uključene velike mase, tijela ili nepravilne leće i slojevi mikrokristalastih i makrokristalastih dolomita koji obično sadrže relikte manje-više intenzivno kasnodijagenetski dolomitiziranih vapnenaca facijsnog tipa J-2, J-6 i rjeđe J-1. Na temelju relikata vapnenaca u dolomitima ustanovljeno je da su dolomiti nastali uglavnom kasnodijagenetskom dolomitizacijom vapnenaca tih triju facijesnih tipova. Kasnodijagenetski dolomiti su osobito česti u donjem lijasu, donjem dogeru i gornjem malmu u cijelom obalnom području Dinarida (sl. 1.)

U **donjokrednim** sedimentima obalnog područja Dinarida izdvojeno je pet facijesa;

K - 1. FACIJES NATPLIMSKIH (SUPRATIDALNIH) RANODIJAGENETSKIH DOLOMITA I EMERZIJSKIH BREČA

Karakteristični sedimenti tog facijesa su ranodijagenetski dolomiti, konglomerati s muljnim valuticama i emerzijske breče te vapnenci s jasnim paleookršavanjem.

Ranodijagenetski dolomiti pokazuju dva glavna kriterija kojima je određen njihov postanak u natplimskom ili supratidalnom okolišu uz evaporitne uvjete: sadrže desikacijske i sinerezis pukotine te stromatolitnu laminaciju i fenestralnu građu kao rezultat postojanja algalnih livada *Schizotrix* tipa. Osim toga, karakteristična je i struktura dolomita koja se odlikuje dolomitnim kristalićima promjera < 0,01 mm te odlično očuvanim primarnim strukturnim karakteristikama taloga koji su bili ranodijagenetski dolomitizirani (peleti, stromatoliti, intraklasti). Sve su to u strukturnom pogledu dolomikriti, dolopelmikriti ili dolopelspariti, dolointraspariti ili dolomitne breče i dolomitni stromatoliti. Ranodijagenetski dolomiti se unutar donjokrednih sedimenata obalnog područja Dinarida nalaze samo sporadično (berijas Istre - sl. 17., barem Mljeta, vrakon Biokova i područje

Huma u zaleđu Dubrovnika).

Emerzijske breče se pojavljuju vrlo često, ali s malim debljinama i lokalnim rasprostranjenjem, osim opće regionalne aptske emerzije. No i ona je na različitim lokalitetima počela i završila u različito vrijeme. Njaduže je trajala u zapadnoj Istri, ca 10-15 milijuna godina (od srednjeg barema do gornjeg alba - VELIĆ i dr., 1989).

K - 2. FACIJES PLIMSKIH (INTERTIDALNIH) I NAJPLIĆIH POTPLIMSKIH (SHALLOW SUBTIDAL) VAPNENACA

Odlikuje se učestalom, u pravilu ritmičkom izmjenom vapnenaca taloženih u plitkom subtidalu, intertidalu i na plimskim prudovima i plimskim kanalima. Česte su sekvencije oplićavanja i sekvencije s povećanjem, veličine zrna na više. Karakteristična su četiri glavna tipa takvih sekvencija ili ritmova: 1. - peletni ili skeletni wackestone koji sadrži zelene alge, gastropode, ostrakode ili bentičke foraminifere - LLH-stromatolit; 2. - mudstone - fenestralni peletni/skeletni wackestone - LLH-stromatolit; 3. - peletni/skeletni wackestone - LLH-stromatolit - peletni ili skeletni grainstone s kosom slojevitošću, "riblja kost" kosom slojevitošću ili humčastom kosom slojevitošću; 4.- mudstone - LLH-stromatolit - peritidalna breča - LLH-stromatolit pri čemu je peritidalna breča obično taložena u plimskim kanalima i zatim nakon ispunjavanja kanala obraštena stromatolitima. Dok su prvi i drugi tip sekvencija posljedica ritmičke sedimentacije uzrokovane progradacijom ili autocikličkim procesima različitog odnosa brzine tonjena i brzine sedimentacije, treći i četvrti tip je, uz to, nastao i uslijed promjene energije vode, tj. naplavljivanjem detritusa na plimsku ravnicu i plimsku zonu pri većim (olujnim) valovima, tako da ti članovi sekvencija imaju odlike olujnih sedimenata ili tzv. "tempestita".

Ovaj facijes je široko rasprostranjen, naročito u nižem dijelu donje krede, na cijelom obalnom području Dinarida, a posebice je čest i obilno prisutan u valendisu, otrivu i baremu Istre, berijasu i baremu okolice Dubrovnika, Korčule, Biokova i Dinare.

K - 3. FACIJES LAGUNA I ZAŠTIĆENIH PLIĆAKA: ONKOLITNIH, MUDSTONE I WACKESTONE VAPNENACA

To je po ukupnom udjelu i učestalosti prevladavajući facijes u donjoj kredi obalnog područja Dinarida (sl. 16.). Sastoji se od debeloslojevitih do masivnih vapnenaca tipa mudstone/wackestone u izmjeni s onkolitima. Uz izrazito prevladavanje karbonatnog mulja ti vapnenci sadrže varijabilni udio algalnih onkoida ili skeleta organizama tipičnih za zaštićene plićake i lagune (zelene alge, ostrakodi, gastropodi, mikritizirane bentičke foraminifere). Za njih su karakteristična i cijanoficejska obavijanja i intenzivna mikritizacija (sl. 23.).

K - 4. FACIJES PLIĆAKA S POKRETLJIVOM VODOM ILI FACIJES INTRAKLASTIČNIH I BIOKLASTIČNIH VAPNENACA GRAINSTONE DO RUDSTONE TIPA

U donjoj kredi obalnog područja Dinarida ovaj facijes se nalazi samo sporadično. Uglavnom je ograničen na barem Istre i okolice Dubrovnika, gornji apt Istre, Biokova, Velike i Male Kapele i donji alb južnog Jadrana te gornji alb Istre. Na pojedinim lokalitetima, uz bioklastične vapnence, nalaze se i rudistne kokine, a rjeđe i manje bioherme ili kolonije u poziciji rasta (gornji apt i alb Istre, apt Male Kapele).

K - 5. LITOFACIJES KASNODIJAGENETSKIH DOLOMITA

Nalazi se vrlo često i s velikim udjelom u građi donjokrednih sedimenata obalnog područja Dinarida, posebice u berijasu, gornjem albu i vrakonu Korčule, valendisu i vrakonu šireg područja Dubrovnika, albu Biokova i Dinare te berijasu i gornjem albu Istre. To su mikrokristalasti do makrokristalasti "protodolomiti" s visokim suviškom Ca u rešetci. Nastali su kasnodijagenetskom dolomitizacijom pretežno vapnenaca facijesa tipa K-2 i K-3.

Litološki sastav, strukturne i teksturne odlike vapnenaca i dolomita izdvojenih u pojedine facijese i litofacijese, kao i vertikalni i bočni raspored facijesa, imali su vrlo važnu ulogu u stvaranju krške morfologije. Posebno to vrijedi za emerzijske breče, emerzije i vapnence facijesnog tipa J-1 i K-1 (Tabla I, sl.2). S druge pak strane, odnosno sa suprotnim efektom okršavanja, ponašaju se facijesi tipa J-3 i J-6 te K-3 i K-4.

OKOLIŠI

U pogledu uvjeta i okoliša taloženja, općenito gledano, platformni jurski i donjokredni sedimenti obalnog područja Dinarida imaju slijedeće karakteristike: taloženi su na unutrašnjem dijelu prostrane karbonatne platforme na relacijama od supratidala s emerzijama i izronjavanjima u vadoznu zonu, preko intertidala, plimskih prudova, plitkog subtidala, laguna i plićaka s pokretljivom vodom do prigrebenskih okoliša s manjim krpastim grebenima. Na različitim mjestima na karbonatnoj platformi ili platformama nisu uvijek u isto vrijeme postojali isti okoliši i uvjeti sedimentacije, a ako su postojali nisu na svim mjestima trajali jednako dugo vremena. Takve promjene, osobito u oscilacijama morske razine i/ili nejednake brzine tonjenja i zapunjavanja bazena sedimentacije, kao i promjene u energiji vode uzrokovane visokim plimama i olujnim valovima, uvjetovale su česte vertikalne i lateralne promjene facijesa te različite debljine istih stratigrafskih jedinica na različitim mjestima na platformi. Sudeći po različitim vremenima i trajanjima emerzija nameće se i zaključak o postojanju sinsedimentacijske vertikalne tektonike i različite brzine spuštanja i tonjenja pojedinih dijelova platforme.

USPOREDBA

Premda se na Jadranskoj karbonatnoj platformi u juri i donjoj kredi nisu dogodile neke značajnije promjene općeg plitkomorskog režima taloženja, ipak postoje neke jasne facijesne razlike između jurskih i donjokrednih platformnih karbonata.

Prvo, u juri su široko rasprostranjeni ooidni grainstone vapnenci (facijes J-6), tj. okoliši ooidnih plićaka i prudova, kojih u donjoj kredi uopće nema (vidi sl. 1. i 16.).

Drugo, u juri su u odnosu na donju kredu bitno češći facijes biostromalnih i patch-reef boundstone vapnenaca (J-5) i facijes bioklastičnih prigrebenskih grainstone/rudstone vapnenaca (J-4), a znatno se rjeđe pojavljuju stromatoliti unutar facijesa J-1 u usporedbi sa sličnim facijesom donje krede, tj. K-2. To ukazuje da su, generalno, tijekom jure na Jadranskoj karbonatnoj platformi češće i duže prevladavali okoliši otvorene platforme s uvjetima povišene energije, a u donjoj kredi okoliši zaštićenih plićaka, laguna i plimskih zaravni.

Na gotovo cijelom području Jadranske platforme mogu se kao regionalni facijes pratiti litiotidne kokine i/ili biostromalni vapnenci u srednjem lijasu (facijes J-4 i/ili J-5), a u donjem i srednjem lijasu i donjem dogeru (posebice u području južnog Jadrana i Velebita) ooidni grainstone vapnenci (facijes J-6). S druge pak strane, unutar donjokrednih karbonata, osim generalne aptske emerzije i donekle onkolita s baćinelama u donjem aptu (facijes K-3) praktički ne postoji neki regionalno rasprostranjeni facijes. Naime, u donjoj kredi Jadranska se platforma očito odlikovala čestim lateralnim i vertikalnim promjenama okoliša na relaciji zaštićeni plićaci - laguna - peritidal na malom prostoru.