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Triassic and Jurassic beds in Krim Mountain area (Slovenia)

Triasne in jurske plasti na območju Krima

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Ključne besede: trias, jura, stratigrafija, Dinarska karbonatna platforma, Krim, Slovenija

Abstract

The Krim Mountain and its surroundings are characterized by Upper Triassic to Middle Jurassic rocks, which were deposited on the northern margin of the Dinaric Carbonate Platform. Upper Triassic beds are represented by Main dolomite that exhibits supra- to subtidal Lofer facies. The uppermost Triassic is characterized by approximately 40 m thick horizon of dolomitic breccia. Upper Triassic beds pass gradually into Lower Liassic dolomitic breccia, coarse-grained dolomite and micritic limestone. Presence of dolomitic breccias and absence of supra-intertidal sedimentary structures indicate sea-level rise. Middle Liassic beds consist of oolitic-oncolitic and lithiotid limestones deposited in alternating restricted lagoonal and open shallow-water environment. Upper Liassic beds are characterized by oolitic-oncolitic limestones, bituminous dolomitized limestones and dolomitic breccia deposited in high-energy shallow-water environment. Middle Jurassic beds consist of oolitic, oolitic-oncolitic and micritic limestones, formed predominantly in high-energy subtidal environment.

Izvleček

Ozemlje Krima in okolice gradijo zgornjetriasne, spodnje in srednjejurske kamnine, ki so nastale na severnem robu Dinarske karbonatne platforme. Zgornjetriasne plasti predstavlja glavni dolomit v loferskem razvoju. V njegovem zgornjem delu se pojavlja tudi okrog 40 m debel horizont dolomitne breče. Zgornjetriasne plasti prehajajo v spodnjeliasno dolomitno brečo, zrnati dolomit in mikritni apnenec. Dolomitna breča in odsotnost nadplimskih in medplimskih sedimentnih tekstur nakazujeta poglabljanje morja. Spodnjeliasnim plastem sledi menjavanje srednjeliasnih ooidno-onkoidnih in litiotidnih apnencev, ki so nastali v zaprtem, lagunskem do občasno odprtem plitvovodnem okolju. Zgornjeliasne plasti sestavljajo ooidno-onkoidni apnenec, bituminozni dolomitizirani apnenec in dolomitna breča, ki so bili odloženi v višjeenergijskem plitvovodnem okolju. Srednjejurske plasti so zastopane z ooidnimi, ooidno-onkoidnimi in mikritnimi apnenci, ki so nastali pretežno v visokoenergijskem podplimskem okolju.

Introduction

Krim Mountain (Fig. 1) with its 1107 m.a.s.l. represents one of the highest hills in the Ljubljana region. It is located about 20 km SSW from Ljubljana and bordered to the north by Ljubljansko Barje basin, to the south by Rakitna-Bloke plateau, and to the east by Iški Vintgar gorge. Krim Mountain and its surroundings are characterized by Upper Triassic to Middle Jurassic karstified platform carbonates and are famous for outcrops of characteristic Lower Jurassic stratigraphic unit; the "Lithiotid horizons". However due to the heavy karstification, dense woods, poor quality and limited extent of the outcrops in the Krim Mountain area the detailed stratigraphy and spatial relations between Upper Triassic to Middle Jurassic lithostratigraphic units have not been completely defined yet. In order to improve our understanding of Lower Jurassic – Middle Jurassic lithostratigraphy of the area, we performed detailed mapping of the area, accompanied by lithostratigraphical study.

Geological setting

The investigated area of the Krim Mountain and its surroundings represents southern border of the Ljubljansko Barje basin. In structural sense, the area represents a smaller unit of External Dinarides (Placer, 1998), cut by NW-SE and NE-SW trending normal and dextral faults. In the Triassic and Jurassic the area belonged to the Dinaric Carbonate Platform, more exactly to

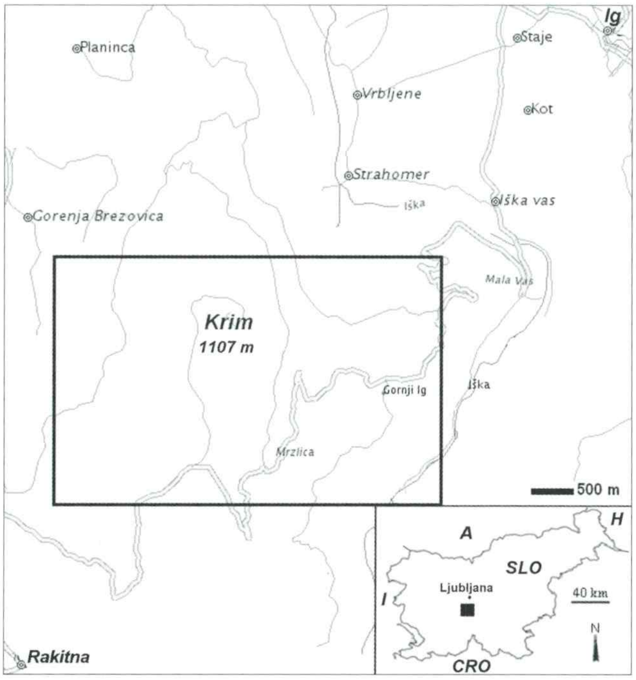

Fig. 1. Location of investigated area

Sl. 1. Položaj raziskanega ozemlja

the inner platform environments, proximal to the northern margin of Dinaric Carbonate Platform (Buser, 1989, Buser & Debeljak, 1996, Turnšek & Košir, 2000).

Previous investigations

First geological studies of the Krim Mountain area were carried out by Lipold (1858) during mapping of southern part of Slovenia. Stache (1889) first mentioned Jurassic beds in the area. Kramer (1905) mapped the Krim in 1:75.000 scale and recognized Lower Jurassic beds with megalodontids and oolitic limestones. Waagen (1914) subdivided Triassic and Jurassic beds. Germovšek (1955) studied southeastern margin of Ljubljansko Barje basin. Rakovec (1955) gave a detailed description of Lower Jurassic beds, namely he believed that Middle Jurassic beds were missing. Ramovš (1961) described Jurassic beds of southern part of Ljubljansko Barje basin and for the first time in Slovenia mentioned foraminifer *Orbitopsella praecursor*. Buser (1965a,b) interpreted the development of Jurassic beds in Krim-Mokrec area and subdivided Jurassic beds into Lower Liassic, Middle Liassic and Upper Liassic-Middle Jurassic. The emphasis of his study was on Middle Liassic beds with lithiotid bivalves.

The Krim area was also mapped for the Basic geological map of Yugoslavia at a scale 1:100.000 by Buser and co-authors (1967) (the Postojna sheet) and Pleničar (1970) (explanatory note of Postojna sheet). The authors, however, did not define the boundary between Lower Jurassic and Middle Jurassic beds. Buser and Debeljak (1996) studied the Middle Liassic beds with "Lithiotid horizon". Turnšek and Košir (2000) described 7 species of Pliensbachian corals found in and above the "Lithiotid horizon" near Lopata and Gornja Brezovica, West of Krim.

Methods

Detailed mapping was carried out for the 13 km^2 large Krim Mountain area on a 1:5 000 scale. More than 50 thin sections were prepared for microfacial and biostratigraphical analysis. Rocks were classified according to Folk's (1959, 1962) petrographic classification of limestones and Dunham's (1962) classification of carbonate rocks supplemented by Embry and Klovan (1972). The age of stratigraphic units was determined on basis of microfossils, corals (determined by Dragica Turnšek) and specific microfacies.

Stratigraphic units

Krim Mountain area is characterized by shallow-water carbonate deposits of the Dinaric Carbonate Platform. Due to poor exposure that did not allow detailed measuring, the lithostratigraphic units were studied in limited outcrops. The stratigraphic span of the investigated lithostratigraphic units, that are described in stratigraphic order below, ranges from Upper Triassic to Middle Jurassic.

Triassic (Norian and Rhaetian)

Upper Triassic beds (T_3^{2+3}) are represented by Main dolomite and occupy the largest area of the mapped territory. They outcrop in the eastern part, between Iški Vintgar and Vogle and in the western part, west of Kamnice and Lopata (Fig. 2). Gradual lithologic transition from Upper Triassic to lowermost Jurassic beds is present at Mrzli dol, Vogle and Žvencelj area, while the boundary in the western part is tectonic. The maximum thickness of Upper Triassic beds reaches more than 400 m.

Main dolomite exhibits cyclic bedded, inter- to subtidal "Lofer facies" (Fischer, 1964). It is characterized by rhytmic alternation of dark grey to black dolomitic breccia (member A), grey to dark grey micritic dolomite with stromatolitic laminae and grey oncodolomicrosparite (member B) and grey to light grey coarse- and medium-grained dolomite (member C). Similar development of Upper Triassic beds near Borovnica was described by Ogorelec and Rothe (1992). Beds of

Explanation of Fig. 2
Legenda k sl. 2

1 - Middle Jurassic, 2 - Upper Liassic, 3 - Middle Liassic, 4 - Lower Liassic, 5 - Upper Triassic, 6 - presumed lithostratigraphic boundary, 7 - dip and strike of beds, 8 - spring, 9 - quarry, 10 - presumed fault, 11 - dip and strike of fault plane, 12 - dip and strike of fractures, 13 - crushed zone, 14 - macrofauna, 15 - microfauna, 16 - microflora, 17 - corals

1 - srednja jura, 2 - zgornji lias, 3 - srednji lias, 4 - spodnji lias, 5 - zgornji trias, 6 - domnevna litostratigrafska meja, 7 - vpad plasti, 8 - izvir, 9 - kamnolom, 10 - domneven prelom, 11 - vpad prelomne ploskve, 12 - vpad razpok, 13 - zdrobljena cona, 14 - makrofavna, 15 - mikrofavna, 16 - mikroflora, 17 - korale

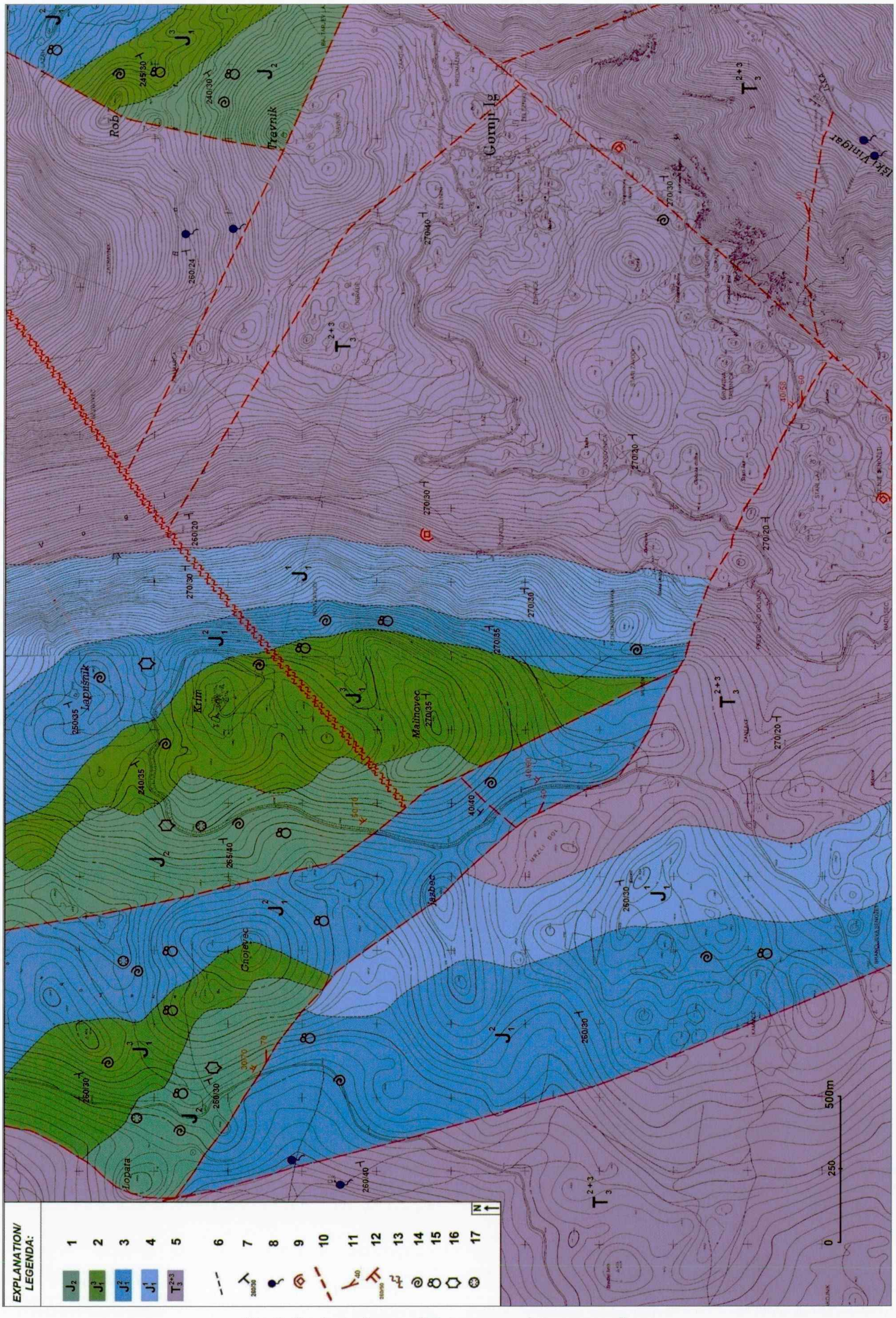

Fig. 2. Geological map of Krim area and its surroundings

Sl. 2. Geološka karta ozemlja Krima in okolice dolomitic breccia are up to 1 m thick and composed of up to 10 cm large angular clasts of light grey dolomite. Beds of dolomitic breccia are more frequent in the upper part of the formation. Breccia is usually overlain by 20 cm thick beds of laminated micritic dolomite with alternation of dolomicritic and dolomicrosparitic laminae, formed by planar, collenia type stromatolites. Laminated dolomite is overlain by up to 80 cm thick beds of oncodolomicrosparite (floatstone-rudstone) that consists of oncoids (Pl. 1, Fig. 1), having approximately 7 mm in diameter. Buser (1966) considered these oncoids to be algae "*Sphaerocodium bornemanni*". Light grey medium-grained dolomite of member C contains rare remains of megalodontid bivalves (Pl. 1, Fig. 2).

Approximately 40 m thick horizon of dolomitic breccia occurs in the uppermost Triassic. Dolomitic breccia consists of over 10 cm large very angular clasts of light grey coarse-grained and grey laminated dolomite in medium-grained matrix. Due to limited extent of the outcrops, geometry of the horizon could not be defined.

The Norian-Rhaetian age of Main dolomite was determined on basis of megalodontid bivalves.

Jurassic

Hettangian and Sinemurian

Lower Liassic beds (J_1^1) stretch out over Vogle, Novi zavodi and Florjanova ravan area. West of Mrzli dol and Koren the extent of Lower Liassic beds was not precisely defined, due to lack of outcrops (Fig. 2). Their thickness is about 200 m.

The lower part of the succession is represented by alternation of black dolomitic breccia beds and beds of light grey to black medium- to coarse-grained dolomite (Fig. 3). Dolomitic breccia consists of medium-grained dolomitic matrix and clasts of light grey medium-grained dolomite, laminated dolomite and grey coarse-grained dolomite. It passes upwards into grey to black fine- to medium-grained dolomite and light grey coarse-grained dolomite with intercalations of light grey to grey dolomitic breccia containing black and light grey clasts in medium-grained dolomitic matrix. In the upper part of Lower Liassic succession dolomites pass upwards through light grey micritic dolomitized limestone into light grey micritic limestone.

The above-mentioned succession of dolomitic breccias, dolomites and limestones was tentatively placed into Lower Liassic on the basis of stratigraphic position and carbon and oxygen stable isotope analysis (Miler, 2007; Miler et al., 2007).

Pliensbachian

The Middle Liassic beds (J_1^2) outcrop in the northeast. In the central part of the studied area they extend across Lapušnik, area east of Krim and Murn. In the west they are in tectonic contact with Upper Triassic beds (Fig. 2).

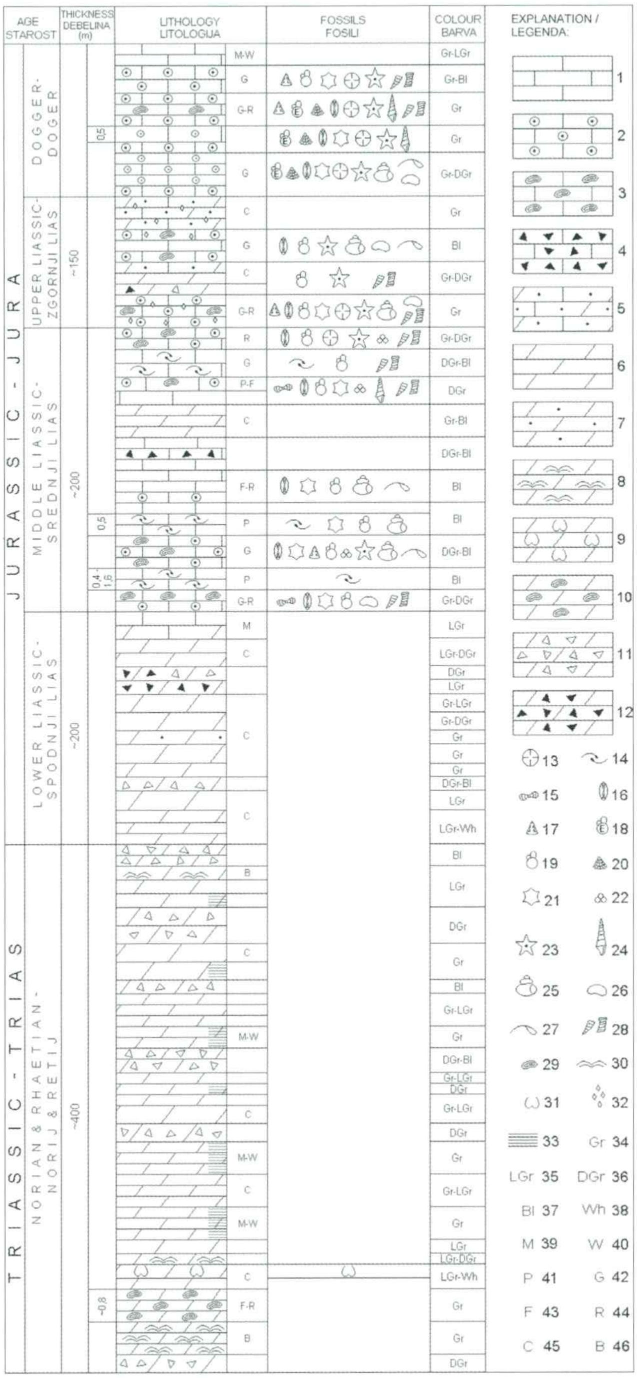

Fig. 3. Lithostratigraphic column of Triassic and Jurassic beds in Krim area

Sl. 3. Litostratigrafski stolpec triasnih in jurskih plasti na območju Krima

Middle Liassic beds are represented by four different facies associations: oolitic-oncolitic limestone, lithiotid limestone, rare limestone breccia and dolomite, and limestone with corals (Fig. 3). The thickness of Middle Liassic beds ammounts to approximately 200 m.

Oolitic-oncolitic limestone

Limestone consists of grey to dark grey oncointrabiosparite (rudstone) with asymmetrical oncoids, having up to 1 cm in diameter, oobioin-

Explanation of Fig. 3
Legenda k sl. 3

1 - limestone, 2 - oolitic limestone, 3 - oncolitic limestone, 4 - limestone breccia, 5 - coarse-grained bituminous dolomitized limestone, 6 - dolomite, 7 - bituminous dolomite, 8 - stromatolitic dolomite, 9 - dolomite with megalodontids, 10 - oncolitic dolomite, 11 - dolomitic breccia with light grey clasts, 12 - dolomitic breccia with black clasts, 13 - corals, 14 - lithiotids, 15 - orbitopsellas, 16 - *Agerina*, 17 - *Trocholina*, 18 - *Endothyra*, 19 - foraminifers in general, 20 - orbitolinids, 21 - microflora (algae), 22 - sponges, 23 - crinoids, 24 - nerineids, 25 - gastropods, 26 - ostracods, 27 - bivalves, 28 - bioclasts, 29 - oncoids, 30 - stromatolites, 31 - megalodontids, 32 - rhomboids of dolomite, 33 - parallel lamination, 34 - grey, 35 - light grey, 36 - dark grey, 37 - black, 38 - white, 39 - mudstone, 40 - wackestone, 41 - packstone, 42 - grainstone, 43 - floatstone, 44 - rudstone, 45 - crystalline, 46 - boundstone

1 - apnenec, 2 - oolitni apnenec, 3 - onkolitni apnenec, 4 - apnenčeva breča, 5 - zrnati bituminozni dolomitiziran apnenec, 6 - dolomit, 7 - bituminozni dolomit, 8 - stromatolitni dolomit, 9 - dolomit z megalodontidami, 10 - onkolitni dolomit, 11 - dolomitna breča s svetlosivimi klasti, 12 - dolomitna breča s črnimi klasti, 13 - korale, 14 - litiotide, 15 - orbitopsele, 16 - *Agerina*, 17 - *Trocholina*, 18 - *Endothyra*, 19 - foraminifere (splošno), 20 - orbitolinide, 21 - mikroflora (alge), 22 - spongije, 23 - krinoidi, 24 - nerineide, 25 - polži, 26 - ostrakodi, 27 - školjke, 28 - bioklasti, 29 - onkoidi, 30 - stromatoliti, 31 - megalodontidne školjke, 32 - dolomitni romboedri, 33 - vzporedna laminacija, 34 - siva, 35 - svetlo siva, 36 - temno siva, 37 - črna, 38 - bela, 39 - mudstone, 40 - wackestone, 41 - packstone, 42 - grainstone, 43 - floatstone, 44 - rudstone, 45 - zrnata struktura, 46 - boundstone

trasparite (grainstone) with symmetrical micritic ooids and black intrabiopelmicrite (floatstone) with nerineid gastropods. Oolitic-oncolitic limestone contains numerous fossil remains of foraminifers *Orbitopsella* sp. (Pl. 1, Fig. 3), *Amijiella* sp. (Pl. 1, Fig. 4), *Agerina martana* (Farinacci) (Pl. 1, Figs. 5, 6), *Cristellaria* sp. (Pl. 1, Fig. 7), *Glomospira* sp., *Textularia* sp., gastropods *Nerinea jeanjeani* (Roman) (Pl. 1, Fig. 8) and algae *Cayeuxia* sp. (Pl. 1, Fig. 9).

At places, oolitic-oncolitic limestone gradually passes upwards into microsparitic lithiotid limestone that consists of up to 1 cm large oncoids and bioclasts and large white recrystallized lithiotid shells in black microsparitic and sparitic matrix.

The Middle Liassic age of oolitic-oncolitic limestone was determined according to abovementioned well preserved fossils.

Lithiotid limestone

Lithiotid limestone and intermediate marly limestone form three distinctive horizons. Their thickness changes laterally and ranges from 40 to 160 cm (Fig. 3). Lithiotid limestones are black biointramicrosparite (packstone-floatstone) and biointrasparite (grainstone) with remains of white mostly recrystallized lithiotid bivalves represented by genera *Cochlearites* sp. and *Lithioperna* sp. (Debeljak & Buser, 1997) that can somewhere still be found preserved in their life position. Among other fossils are the most common foraminifers *Pseudocyclammina* sp. (Tab. 1, sl. 10, 11), *Textularia* sp., *Glomospira* sp., *Amijiella* sp. and algae *Thaumatoporella* sp.

The Middle Liassic age of the litihiotid limestone was determined on basis of lithiotid bivalves *Cochlearites* sp. and *Lithioperna* sp. and foraminifers *Pseudocyclammina* sp. and *Amijiella* sp.

Limestone breccia and dolomite

Within black micritic limestones rare intercalations of grey to dark grey limestone breccia and dark grey medium- to coarse-grained bituminous dolomite appear.

The Middle Liassic age of limestone breccia and dolomite was determined on basis of their stratigraphic position.

Limestone with corals (biolithite)

In uppermost part of oolitic-oncolitic limestone, above the third "Lithiotid horizon", outcrops of grey biolithite (framestone) with intraclasts, symmetrical ooids and coral colonies (Fig. 3) were found in Plane Lopate area. Biolithite contains foraminifers: *Agerina martana* (Farinacci), *Paleomayncina* sp. and *Lenticulina* sp. and corals *Thecactinastraea krimensis* (Turnšek, 2000) (Pl. 1, Fig. 12), *Phacelophyllia bacari* (Turnšek, 2003) (Pl. 1, Fig. 13), *Cuifastraea lopatensis* (Turnšek, 2000) (Pl. 1, Fig. 14) and *Actinastraea gibbosa* (Duncan, 1867) (Pl. 1, Fig. 15). All corals form phaceloid colonies, except species *Actinastraea gibbosa*, which forms cerioid colonies.

The above mentioned foraminifers and corals indicate Late Pliensbachian age of the biolithite.

Toarcian

The Upper Liassic beds (J_1^3) extend across Krim, Malinovec and Murn area, where they are cut off by a major fault. They also outcrop north of Bajtarjev laz, southeast of Rob and between Gnojevec and northeast of Lopata (Fig. 2).

The Upper Liassic beds consist of three facies associations: oolitic-oncolitic limestone, intermediate dolomitic breccia, fine-grained dolomite and bituminous dolomitized limestone. The overall thickness of Upper Liassic beds is approximately 150 m.

Oolitic-oncolitic limestone

Oolitic-oncolitic limestone prevails in the lower part of Upper Liassic succession. Interbeds of oolitic-oncolitic limestone are also present higher, between bituminous dolomitized limestones (Fig. 3).

Limestone is represented by grey bioncointraoosparite (rudstone) with rhomboids of dolomite and up to 1 cm large symmetrical oncoids, grey to black biointraoosparite (grainstone) with symmetrical, partly dolomitized ooids and grey to dark grey oointrabiomicrosparite (floatstone).

The oolitic-oncolitic limestone contains partially recrystallized and dolomitized remains of foraminifers *Haplophragmoides* sp., *Agerina martana* (Farinacci), *Trocholina* sp. (Pl. 2, Fig. 1), *Ophthalmidium* sp. (Pl. 2, Fig. 2), *Dentalina* sp. (Pl. 2, Fig. 3), *Spirillina* sp., crinoids *Pentacrinus* sp., gastropods *Nerinea* sp. and corals *Actinastraea plana* (Duncan, 1867), *Allocoeniopsis dendroidea* (Duncan, 1867) and *Goldfusastraea toarciensis* (Beauvais, 1986) (Tab. 2, sl. 4), forming thamnasterid plocoid colonies.

The Upper Liassic age of oolitic-oncolitic limestone was determined according to foraminifers *Trocholina* sp., *Haplophragmoides* sp., *Ophthalmidium* sp. and *Spirillina* sp., crinoids *Pentacrinus* sp. and coral *Goldfusastraea toarciensis* (Beauvais, 1986).

Dolomitic breccia

Dark grey dolomitic breccia overlies the oolitic-oncolitic limestone (Fig. 3). It consists of dark grey and light grey, 5 mm to over 15 cm large, poorly rounded clasts of oolitic limestone. Matrix of dolomitic breccia is dark grey laminated oobiointradolomicrite (wackestone) with dolomite rhomboids. Laminae consist of alternating dark dolomicritic and light dolomicrosparitic stripes. Symmetrical ooids appear in limestone clasts, as well as in dolomitic matrix.

Well preserved miliolids *Istriloculina* sp. and *Decussoloculina* sp. appear often in dolomitic matrix. The Upper Liassic age of dolomitic breccia was determined on basis of its stratigraphic position.

Fine-grained dolomite and bituminous dolomitized limestone

Upper part of the Upper Liassic beds is represented by fine-grained dolomite and dolomitized limestone (Fig. 3). Fine-grained dolomite is grey to dark grey biodolomicrosparite (packstone-wackestone) with corroded and recrystallized crinoid fragments. Bituminous coarse-grained dolomitized limestone is biooointradolosparite (grainstone) with rare, partially recrystallized and dolomitized ooids and crinoids *Pentacrinus* sp.. Dolomitized limestone is rather weathered in its upper part. The Upper Liassic age of fine-grained dolomite and dolomitized limestone was determined on basis of crinoids *Pentacrinus* sp. and stratigraphic position.

Middle Jurassic (Dogger)

Middle Jurassic beds (J_2) outcrop in the northeastern part of the investigated area, between Rob, Travnik and Bajtarjev laz. In the central part they occur west of Krim and Malinovec and are in tectonic contact with Middle Liassic beds. In the northwestern part, they outcrop between Gnojevec and Lopata, where they are separated from Upper Triassic and Middle Liassic beds by a fault (Fig. 2).

Middle Jurassic beds are represented by monotonous oolitic, oolitic-oncolitic limestones, rich in microflora and microfauna, and micritic limestones.

Oolitic limestone

Oolitic limestone is a prevailing lithologic member of Middle Jurassic beds. It is represented by coarse-grained oolitic limestone, which is built of grey to dark grey biointraoosparite (grainstone), grey intraoobiomicrosparite (packstone) with mostly symmetrical, partially recrystallized and dolomitized ooids and grey to black biooointramicrosparite (packstone-floatstone).

Coarse-grained oolitic limestone, in its lower part, is interbedded with up to 50 cm thick distinctive beds of fine-grained oolitic limestone, although, gradual transition between them is also observed in some places. Fine-grained oolitic limestone consists of light grey to grey biointraoosparite (grainstone) with symmetrical, partly micritized and dissolved ooids and grey biooointramicrosparite (packstone) with symmetrical ooids.

Coarse-grained oolitic limestone is also intercalated with light grey to grey biolithite (framestone) containing intraclasts, symmetrical ooids and well preserved corals.

Oolitic limestone contains well preserved foraminifers *Spiraloconulus* sp. (Pl. 2, Fig. 7), *Endothyra* sp. (Pl. 2, Fig. 8), *Dictyoconus* sp. (Pl. 2, Fig. 9), *Agerina* sp. (Pl. 2, Fig. 10), *Lucasella* sp., *Pseudocyclammina* sp., *Siphovalvulina* sp., *Duotaxis* sp., *Haplophragmoides* sp., algae *Cayeuxia* sp., *Thaumatoporella* sp. (Pl. 2, Fig. 5), *Solenopora* sp., crinoids *Pentacrinus* sp., gastropods *Nerinea* cf. *jeanjeani*, phaceloid coral colony *Stylophyllopsis veneta* (Airaghi, 1907) with corallites, having up to 6,95 mm in diameter (Pl. 2, Fig. 6) and cerioid coral colony *Actinastraea plana* (Duncan, 1867).

According to well preserved foraminifers: *Spiraloconulus* sp., *Dictyoconus* sp., *Endothyra* sp. and *Lucasella* sp. the age of oolitic limestone is Middle Jurassic. On the contrary, the corals from intercalated biolithite: *Stylophyllopsis veneta* (Airaghi, 1907) and *Actinastraea plana* (Duncan, 1867) point to Upper Pliensbachian, Lower Toarcian age respectively. There are three possible explanations of biolithite occurence: 1. The biolithite is a part of Toarcian bioherm that was fragmented and transported by gravity flow into Middle Jurassic sediments, 2. The biolithite is a part of Toarcian bioherm, rising upwards into younger beds, 3. The biolithite is of Middle Jurassic age, which means that the stratigraphic span of coral *Stylophyllopsis veneta* is wider. Due to rare and poor quality outcrops of biolithite, the exact interpretation of the biolithite origin was not possible.

Oolitic-oncolitic limestone

Interbeds of oolitic-oncolitic limestone lie within oolitic limestone in the middle part of Middle Jurassic column. Interbeds consist of grey oobiooncointrasparite (rudstone) with asymmetrical, partially corroded ooids and large oncoids. Distinctive stylolites, along which rock was considerably dissolved (Pl. 2, Fig. 11), are also present in some places.

The Middle Jurassic age of oolitic-oncolitic limestone was determined according to well preserved foraminifers *Trocholina* sp., *Endothyra* sp. (Pl. 2, Figs. 12, 13), *Dictyoconus* sp. (Pl. 2, Fig. 14), *Lucasella* sp. (Pl. 2, Fig. 13), *Spiraloconulus* sp., *Agerina* sp., *Duotaxis* sp. (Pl. 2, Fig. 15), *Pseudocyclammina* sp., crinoids *Pentacrinus* sp. (Pl. 2, Fig. 15) and nerineid gastropods.

Micritic limestone

Light grey to grey micritic limestone is the youngest lithologic member in the studied area. Limestone does not contain any fossil remains, therefore, its Middle Jurassic age was determined according to stratigraphic position.

Late Triassic to Middle Jurassic sedimentary and paleogeographic evolution

The studied area of Krim Mountain and its surroundings is situated in the northern part of External Dinarides and in Triassic and Jurassic belonged to northern margin of Dinaric Carbonate Platform.

The uppermost Triassic beds of the investigated area are composed of Main dolomite that exhibits cyclic "Lofer facies" (FISCHER, 1964) indicating deposition in lagoonal platform interior in inter-supratidal to subtidal environment. In the uppermost part of the formation there is a gradual increase in the inter-supratidal breccias of member A. We interpret this increase as a consequence of short-termed marine regression that was also proved in the Northern Calcareous Alps (MCROBERTS et al., 1997, KRYSTYN et al., 2005). The sea-level changes in the Northern Calcareous Alps are explained as a consequence of short-termed tectonic uplift, possibly regional thermal uplift connected to the activity in the Central North Atlantic Magmatic Province, and slow rebound within a locally or regionally limited area (KRYSTYN et al., 2005). Uppermost Triassic beds are also characterized by 40 m thick horizon of dolomitic breccia. Well lithified and angular clasts of underlying lithology indicate exhumation of older strata, most probably by normal faulting. The horizon of dolomitic breccia was not studied in detail, thus causes for its formation were not precisely defined.

Upon shallow-water Main dolomite coarse-grained dolomite with intercalated dolomitic breccias deposited in Lower Liassic. Absence of the supra-intertidal sedimentary structures indicates deepening of the sea and deposition in shallow-water subtidal environment. We interpret the deepening of the environment as a consequence of global sea-level rise (HALLAM, 1997, MCROBERTS et al., 1997) most probably accompanied by Lower Liassic normal faulting as indicated by intercalated breccia beds. Micritic limestones in the upper part of Lower Liassic were most probably deposited in quiet-water lagoonal environment.

The Middle Liassic beds are characterized by the alternation of oolitic-oncolitic limestones, lithiotid limestones and grainy dolomites, indicating alternate open and restricted lagoonal environments and correspond to the outer part of the inner platform environments, proximal to the northern margin of Dinaric Carbonate Platform (BUSER, 1989, BUSER & DEBELJAK, 1996, TURNŠEK & KOŠIR, 2000). Coral limestones with coral colonies, intercalated between oolitic-oncolitic limestones, indicate that smaller and some larger coral bioherms formed in the open lagoonal environment, rising upwards into younger beds in some places.

Upper Liassic oolitic-oncolitic limestones and bituminous dolomitized limestones represent continuation of shallow-water sedimentation most probably in alternating high-energy open shallow-water environment to low-energy (restricted) lagoonal environment (OREHEK & OGORELEC, 1981, DOZET & ŠRIBAR, 1997). The high organic content in the bituminous dolomitized limestone is tentatively intepreted as a consequence of Toarcian Ocean Anoxic event (HALLAM, 1986, JENKYNS, 1988).

Middle Jurassic is characterized by monotonous succession of oolitic, oncolitic and sparse micritic limestones, formed in shallow, high-energy subtidal sand belt environment.

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Triasne in jurske plasti na območju Krima

Povzetek

Območje osrednjega dela Krimskega hribovja (Sl. 1), ki obsega približno 13 km^2, je bilo raziskano z namenom natančnejše določitve meje trias-jura ter razčlenitve spodnje- in srednjejurskih plasti (Sl. 2). V paleogeografskem smislu je ozemlje v triasu in juri pripadalo Dinarski karbonatni platformi (BUSER, 1989).

Največjo površino zavzema zgornjetriasni glavni dolomit v loferskem razvoju (FISCHER, 1964) z jasno razvitimi členi, ki nakazujejo nastanek v nadplimskem do podplimskem okolju. Sestavlja ga menjavanje temnosive do črne dolomitne breče s klasti svetlosivega dolomita (člen A), sivega do temnosivega mikritnega dolomita s stromatolitnimi laminami (člen B) in sivega onkodolomikrosparita z onkoidi, ki jih je BUSER (1966) označil kot alge "*Sphaerocodium bornemanni*" (Tab. 1, sl. 1) ter sivega do svetlosivega

zrnatega in srednjezrnatega dolomita z megalodontidami (Tab. 1, sl. 2) (člen C) (Sl. 3). Podoben razvoj zgornjetriasnih plasti je pri Borovnici (Ogorelec & Rothe, 1992). Pogostejše pojavljanje člena A loferske cikloteme v zgornjem delu stolpca kaže na regresijo morja, ki je bila dokazana tudi na območju Severnih Apneniških Alp (McRoberts et al., 1997 in Krystyn et al., 2005). V zgornjem delu zgornjega triasa se pojavlja tudi okrog 40 m debel horizont dolomitne breče, ki jo sestavljajo dobro litificirani ostrorobi klasti starejših kamnin. Vendar horizont ni bil podrobneje preučen.

Triasni glavni dolomit prehaja v spodnje spodnjejurski svetlosiv do črn srednjezrnat do zrnat dolomit in črne dolomitne breče s klasti sivega zrnatega in laminiranega dolomita (Sl. 3). Odsotnost nadplimskih in medplimskih sedimentnih tekstur kaže na poglabljanje morja in sedimentacijo v plitvem podplimskem okolju. Sprememba sedimentacijskega okolja je verjetno posledica globalnega dviga gladine morja (Hallam, 1997 in McRoberts et al., 1997). V zgornjem delu dolomiti preidejo v svetlosiv mikriten apnenec, ki je nastal v mirnem lagunskem okolju.

Značilne srednjeliasne plasti predstavlja črn litiotidni apnenec, ki nastopa v treh horizontih med temnosivimi ooidno-onkoidnimi in mikritnimi apnenci ter temnosivimi zrnatimi dolomiti (Sl. 3). To zaporedje je verjetno nastalo zaradi menjavanja odprte lagune, v kateri so nastali sparitni ooidno-onkoidni apnenci, z zaprto laguno, v kateri so nastali črni litiotidni in mikritni apnenci ter odgovarja sedimentacijskemu okolju zunanjega dela notranje platforme, proksimalno robu Dinarske karbonatne platforme (Buser & Debeljak, 1996 in Turnšek & Košir, 2000). Ooidno-onkoidni apnenec sestavljajo siv do temnosiv

PLATE 1 - TABLA 1

1 Oncodolomicrosparite with oncoid
Onkodolomikrosparit z onkoidom

2 Light grey coarse-grained dolomite with megalodontid bivalve
Svetlosiv zrnat dolomit z megalodontidno školjko

3 Oobiointrasparite with ooids, intraclasts and foraminifer *Orbitopsella* sp.
Oobiointrasparit z ooidi, intraklasti in foraminifero *Orbitopsella* sp.

4 Biointrasparite with intraclasts and foraminifer *Amijiella* sp.
Biointrasparit z intraklasti in foraminifero *Amijiella* sp.

5 Oobiointrasparite with intraclasts and foraminifer *Agerina martana* (Farinacci)
Oobiointrasparit z intraklasti in foraminifero *Agerina martana* (Farinacci)

6 Biointrasparite with intraclasts and foraminifer *Agerina martana* (Farinacci) (center)
Biointrasparit z intraklasti in foraminifero *Agerina martana* (Farinacci) v sredini

7 Oncobioointrasparite with intraclasts, ooids and foraminifer *Cristellaria* sp.
Onkobioointrasparit z intraklasti, ooidi in foraminifero *Cristellaria* sp.

8 Intrabiopelmicrite with gastropod *Nerinea jeanjeani* (Roman)
Intrabiopelmikrit s polžem *Nerinea jeanjeani* (Roman)

9 Biointramicrosparite with alga *Cayeuxia* sp.
Biointramikrosparit z algo *Cayeuxia* sp.

10,11 Biointramicrosparite with foraminifera *Pseudocyclammina* sp.
Biointramikrosparit s foraminiferami *Pseudocyclammina* sp.

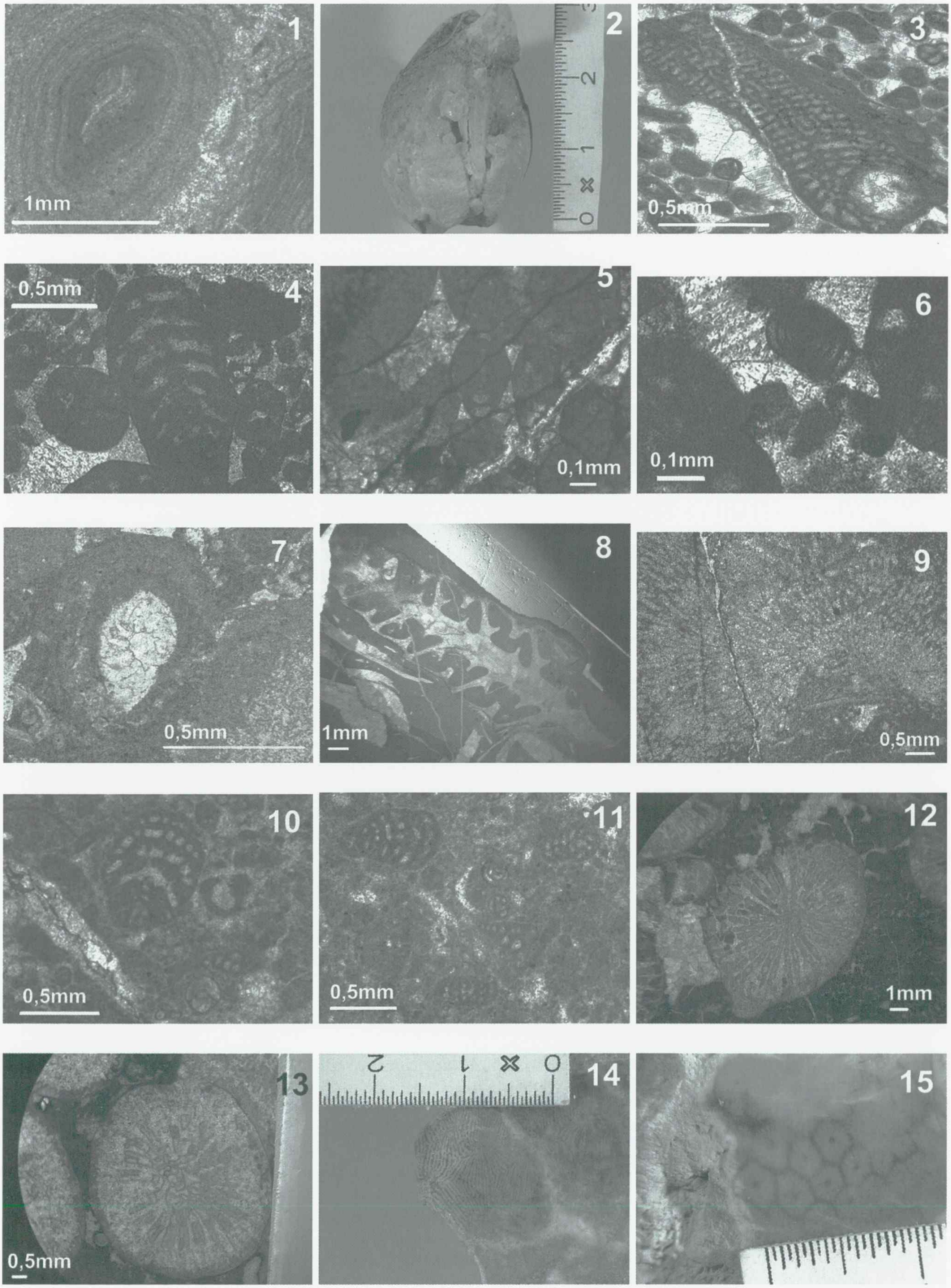
12 Biolithite with intraclasts, ooids and corals *Thecactinastraea krimensis* (Turnšek, 2000)
Biolitit z intraklasti, ooidi in koralami *Thecactinastraea krimensis* (Turnšek, 2000)

13 Biolithite with corals *Phacelophyllia bacari* (Turnšek, 2003)
Biolitit s koralami *Phacelophyllia bacari* (Turnšek, 2003)

14 Grey oolitic-oncolitic limestone with coral colony *Cuifastraea lopatensis* (Turnšek, 2000)
Siv ooidno-onkoidni apnenec s kolonijo koral *Cuifastraea lopatensis* (Turnšek, 2000)

15 Biolithite with coral colony *Actinastraea gibbosa* (Duncan, 1867)
Biolitit s kolonijo koral *Actinastraea gibbosa* (Duncan, 1867)

PLATE 1 - TABLA 1



onkointrabiosparit, siv oobiointrasparit ter črn intrabiopelmikrit s foraminiferami *Orbitopsella* sp. (Tab. 1, sl. 3), *Amijiella* sp. (Tab. 1, sl. 4), *Agerina martana* (Farinacci) (Tab. 1, sl. 5, 6), *Cristellaria* sp. (Tab. 1, sl. 7), polžem *Nerinea jeanjeani* (Roman) (Tab. 1, sl. 8) in algo *Cayeuxia* sp. (Tab. 1, sl. 9). Litiotidne apnence predstavljajo črn biointramikrosparit in biointrasparit s prekristaljenimi školjkami *Cochlearites* sp. ali *Lithioperna* sp. (Debeljak & Buser, 1997) in foraminifero *Pseudocyclammina* sp. (Tab. 1, sl. 10, 11). V zgornjem delu ooidno-onkoidnega apnenca (Sl. 3) se pojavlja siv biolitit s kolonijskimi koralami *Thecactinastraea krimensis* (Turnšek, 2000) (Tab. 1, sl. 12), *Phacelophyllia bacari* (Turnšek, 2003) (Tab. 1, sl. 13), *Cuifastraea lopatensis* (Turnšek, 2000) (Tab. 1, sl. 14) in *Actinastraea gibbosa* (Duncan, 1867) (Tab. 1, sl. 15).

Zgornjeliasne plasti gradijo ooidno-onkoidni apnenec, temnosiva dolomitna breča, drobnozrnat dolomit in bituminozen dolomitiziran apnenec. Te kamnine predstavljajo nadaljevanje plitvovodne sedimentacije v visokoenergijskem odprtem plitvovodnem okolju in nizkoenergijskem (zaprtem) lagunskem okolju (Orehek & Ogorelec, 1981 in Dozet & Šribar, 1997). Ooidno-onkoidni apnenec sestavljajo delno dolomitiziran siv bioonkointraoosparit z dolomitnimi romboedri, siv do črn biointraoosparit in temnosiv oointrabiomikrosparit s foraminiferami *Trocholina* sp. (Tab. 2, sl. 1), *Agerina martana* (Farinacci), *Ophthalmidium* sp. (Tab. 2, sl. 2), *Dentalina* sp. (Tab. 2, sl. 3), kolonijo koral *Goldfusastraea toarciensis* (Beauvais, 1986) (Tab. 2, sl. 4) in krinoidi *Pentacrinus* sp.. Vmesno temnosivo dolomitno brečo sestavljajo svetlosivi in temnosivi klasti ooidnega apnenca ter vezivo, ki ga predstavlja temnosiv laminiran oobiointradolomikrit z dolomitnimi romboedri in foraminiferami *Istriloculina* sp. in *Decussoloculina* sp.. Drobnozrnat

PLATE 2 - TABLA 2

1 Biooíntrasparite with intraclasts and foraminifer *Trocholina* sp.?
Biooíntrasparit z intraklasti in foraminifero *Trocholina* sp.?

2 Biointraoosparite with ooids and foraminifer *Ophtalmidium* sp. (center)
Biointraoosparit z ooidi in foraminifero *Ophtalmidium* sp. (sredina)

3 Biointraoosparite with ooids, intraclasts and foraminifer *Dentalina* sp.
Biointraoosparit z ooidi, intraklasti in foraminifero *Dentalina* sp.

4 Grey oolitic limestone with coral colony *Goldfusastraea toarciensis* (Beauvais, 1986)
Siv ooidni apnenec s kolonijo koral *Goldfusastraea toarciensis* (Beauvais, 1986)

5 Biolithite with intraclasts, ooids and alga *Thaumatoporella* sp.
Biolitit z intraklasti, ooidi in algo *Thaumatoporella* sp.

6 Biolithite with intraclasts, ooids and corals *Stylophyllopsis veneta* (Airaghi, 1907)
Biolitit z intraklasti, ooidi in koralo *Stylophyllopsis veneta* (Airaghi, 1907)

7, 8 Biooíntramicrosparite with *Spiraloconulus* sp. (7) and *Endothyra* sp. (8)
Biooíntramikrosparit s *Spiraloconulus* sp. (7) in *Endothyra* sp. (8)

9 Biointraoosparite with intraclasts, ooids and foraminifer *Dictyoconus* sp.
Biointraoosparit z intraklasti, ooidi in foraminifero *Dictyoconus* sp.

10 Biooíntramicrosparite with intraclasts, ooids and foraminifer *Agerina* sp.
Biooíntramikrosparit z intraklasti, ooidi in foraminifero *Agerina* sp.

11 Oobiooncointrasparite with partially dissolved intraclast along stylolite
Oobioonkointrasparit z delno raztopljenim intraklastom ob stilolitu

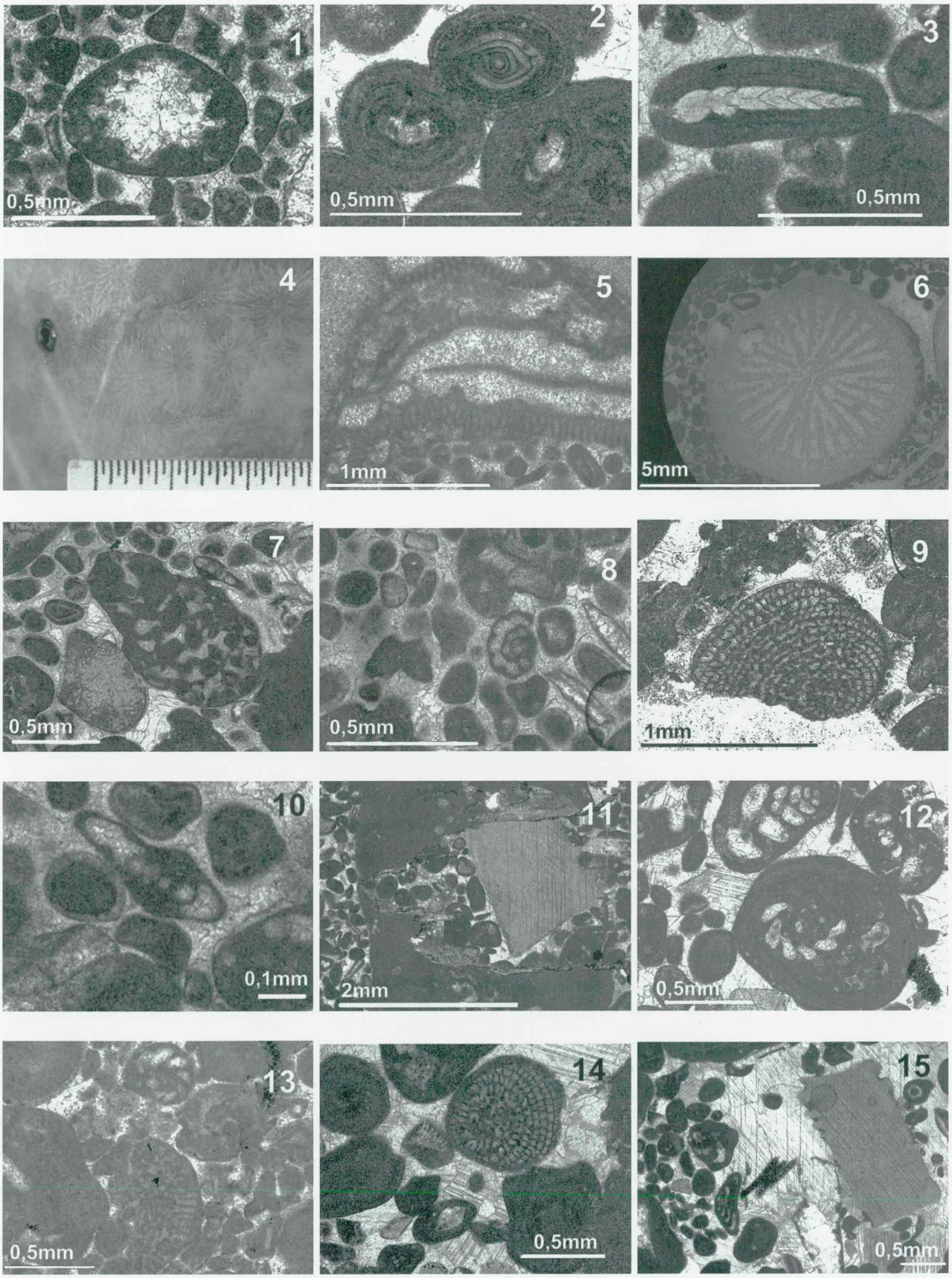
12 Oobiooncointrasparite with foraminifera *Endothyra* sp. and *Textularia* sp.
Oobioonkointrasparit s foraminiferami *Endothyra* sp. in *Textularia* sp.

13 Biooíntramicrosparite with foraminifera *Endothyra* sp. and *Lucasella* sp.
Biooíntramikrosparit s foraminiferama *Endothyra* sp. in *Lucasella* sp.

14 Oobiooncointrasparite with intraclasts, ooids and *Dictyoconus* sp.
Oobioonkointrasparit z intraklasti, ooidi in foraminifero *Dictyoconus* sp.

15 Oobiooncointrasparite with crinoid and foraminifer *Duotaxis* sp.
Oobioonkointrasparit s krinoidom in foraminifero *Duotaxis* sp.

PLATE 2 - TABLA 2



dolomit in dolomitiziran apnenec sestavljata siv do temnosiv biodolomikrosparit in siv biointradolosparit z ostanki krinoidov *Pentacrinus* sp.. Visoka vsebnost organske komponente v bituminoznem dolomitiziranem apnencu bi lahko bila posledica toarcijskega anoksičnega dogodka.

Srednjejurske kamnine zastopajo monotoni ooidni in ooidno-onkoidni apnenci ter mikritni apnenci, ki so se odložili v plitvem, visokoenergijskem podplimskem okolju. Ooidne apnence sestavljajo siv do temnosiv biointraoosparit in siv intraoobiomikrosparit z ostanki foraminifer *Spiraloconulus* sp. (Tab. 2, sl. 7), *Endothyra* sp. (Tab. 2, sl. 8), *Dictyoconus* sp. (Tab. 2, sl. 9), *Lucasella* sp., *Agerina* sp. (Tab. 2, sl. 10) ter algo *Thaumatoporella* sp. (Tab. 2, sl. 5). Med ooidnimi apnenci je vložen svetlosivi do sivi biolitit s kolonijo koral *Stylophyllopsis veneta* (Airaghi, 1907) (Tab. 2, sl. 6). Pojavljanje biolitita je možno pojasniti na tri načine: 1. biolitit predstavlja del toarcijske bioherme, ki je bila v srednji juri fragmentirana in transportirana z gravitacijskim tokom med srednjejurske sedimente, 2. biolitit je del toarcijske bioherme, ki se dviga v mlajše srednjejurske plasti, 3. biolitit je srednjejurske starosti, kar pomeni, da je stratigrafski razpon korale *Stylophyllopsis veneta* večji. Med ooidnimi apnenci se pojavlja ooidno-onkoidni apnenec, ki ga predstavlja siv oobioonkointrasparit s foraminiferami *Endothyra* sp. (Tab. 2, sl. 12, 13), *Lucasella* sp. (Tab. 2, sl. 13), *Dictyoconus* sp. (Tab. 2, sl. 14), *Spiraloconulus* sp., *Duotaxis* sp. (Tab. 2, sl. 15) in krinoidi *Pentacrinus* sp. (Tab. 2, sl. 15). Ponekod so prisotni izraziti stilolitski šivi, ob katerih je kamnina močno raztopljena (Tab. 2, sl. 11). Najmlajši člen je svetlosiv do siv mikritni apnenec.

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