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The Dinaric Carbonate Platform margin in the Early Jurassic: a comparison between successions in Slovenia and Montenegro

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ABSTRACT

Lower Jurassic successions of the Dinaric Carbonate Platform (DCP) margins were analyzed for sedimentology and fossil content at Trnovski gozd in Slovenia and at Rumija in Montenegro.

The succession at Trnovski gozd (northern DCP margin) ranges in age from the Pliensbachian to the Aalenian and consists of: i) peritidal lithiotid limestone; ii) peloidal grainstone with oncoids; iii) brownish-reddish condensed limestone with hardgrounds; and iv) crinoidal-ooidal limestone.

At Rumija (SW DCP margin) the most distal succession ranges from the Triassic-Jurassic boundary to the Aalenian and consists of: i) micritic limestone, directly overlying the Dachstein limestone; ii) fine-grained calcareous turbidites with chert, and a middle subunit of chert-free oolitic limestone; iii) marly limestone with radiolarians and sponge spicules; and iv) bioclastic limestone with abundant brachiopods. With two complementary sections, a depositional system of a southwest dipping carbonate ramp was reconstructed for the Pliensbachian: lithiotid limestone in the inner platform, oolitic limestone in mid-ramp and resedimented limestone with chert in outer-ramp setting.

The Trnovski gozd succession is lithologically almost identical to the most proximal succession with lithiotid limestone at Rumija. Contrary to this, the outer-ramp limestone with chert has so far been documented only on the SW DCP margin in Montenegro. The first order transgressive-regressive cycle is clearly recognized in all sections, with the major early Toarcian transgressive peak being recorded in condensed facies with hardgrounds at Trnovski gozd, and marly limestone at Rumija.

Regionally, the studied successions are correlative to formations of the western part of the Trento Plateau, i.e. to the Calcari Grigi Formation and the San Vigilio Group.

KEY WORDS: *Early Jurassic, Pliensbachian, Toarcian, Dinaric Carbonate Platform, stratigraphy, benthic foraminifers, carbonate ramp.*

RIASSUNTO

Il margine della Piattaforma Carbonatica Dinarica nel Giurassico inferiore: un confronto tra le successioni della Slovenia e del Montenegro.

Il Giurassico della Piattaforma Carbonatica Dinarica (PCD) è stato studiato da numerosi Autori. Studi biostratigrafici di fondamentale importanza sono stati svolti in questa area (RADOIČIĆ, 1966; NIKLER & SOKAČ, 1968; GUŠIĆ, 1969; GUŠIĆ & BABIĆ, 1970; GUŠIĆ, 1975) e sono disponibili sintesi paleogeografiche a carattere generale (BUSER, 1989; TIŠLJAR *et alii*, 2002; VLAHOVIĆ *et alii*, 2005). Le variazioni di facies nel Giurassico inferiore sono state studiate per lo più nelle parti interne della PCD (BUCKOVIĆ *et alii*, 2001, 2005; TIŠLJAR *et alii*, 2002), ma solo poche successioni in facies di margine di piattaforma sono state descritte finora (e.g. DRAGIČEVIĆ & VELIĆ, 2002). Il fatto che il margine rimane poco conosciuto rappresenta un problema notevole per la ricostruzione dell'architettura della piattaforma, come sottolineato da VLAHOVIĆ *et alii* (2005).

Gli obiettivi di questo lavoro sono:

1) Presentare nuovi dati stratigrafici sui calcari del Giurassico inferiore, deposti su differenti porzioni del margine della Piattaforma Carbonatica Dinarica.

2) Confrontare i caratteri principali delle successioni del Giurassico inferiore della Slovenia e del Montenegro, con particolare riguardo all'intervallo Pliensbachiano-Toarciano.

3) Comparare le relazioni di facies descritte in Montenegro con i modelli deposizionali proposti per altre piattaforme carbonatiche del Giurassico inferiore della Tetide Mediterranea.

Le successioni del Giurassico inferiore dei margini della PCD sono state analizzate dal punto di vista sedimentologico e paleontologico a Trnovski gozd, in Slovenia, ed a Rumija, in Montenegro.

La successione di Trnovski gozd (margine settentrionale della PCD) ha un'età Pliensbachiano-Aaleniano e consiste di i) calcare peritidale a Lithiotidi; ii) grainstone peloidale con oncoidi; iii) calcare condensato da brunastro a rossastro con hardgrounds; e iv) calcare a crinoidi ed ooidi.

A Rumija (margine SW della PCD) la successione più distale ha un'età che va dal limite Triassico-Giurassico all'Aaleniano e consiste di: i) calcare micritico, direttamente sovrapposto al Calcare di Dachstein; ii) torbiditi calcaree a grana fine con selce, ed una sub-unità intermedia di calcare oolitico senza selce; iii) calcare marnoso con radiolari e spicole di spugne; e iv) calcare bioclastico con abbondanti brachiopodi. Con l'aiuto di due sezioni complementari, è stato possibile ricostruire per il Pliensbachiano un sistema deposizionale di rampa carbonatica immergente a sud-ovest: calcare a lithiotidi nella piattaforma interna, calcare oolitico nella rampa intermedia e calcari risedimentati con selce nella rampa esterna.

La successione di Trnovski gozd è litologicamente quasi identica alla successione più prossimale con calcare a lithiotidi di Rumija. Al contrario i calcari con selce di rampa esterna sono stati documentati fino ad ora solo sul margine sud-ovest della PCD, in Montenegro. Il ciclo trasgressivo-regressivo di primo ordine è chiaramente riconoscibile in tutte le sezioni, con il picco trasgressivo del Toarciano inferiore registrato da facies condensate con hardgrounds a Trnovski gozd, e calcari marnosi a Rumija.

Regionalmente le successioni studiate sono correlabili con formazioni della parte occidentale del Plateau di Trento, cioè la Formazione dei Calcari Grigi ed il Gruppo di San Vigilio.

TERMINI CHIAVE: *Giurassico inferiore, Pliensbachiano, Toarciano, Piattaforma Carbonatica Dinarica, stratigrafia, foraminiferi bentonici, rampa carbonatica.*

INTRODUCTION

Lower Jurassic sections were investigated at Trnovski gozd in Slovenia and Rumija in Montenegro. These sections are more than 600 km apart, but belonged to the same Dinaric Carbonate Platform throughout the Mesozoic. Shallow-water carbonates, several km thick, were deposited on the platform and are now exposed along an approximately 200 km wide belt in the Dinarides (fig. 1a). Trnovski gozd was located on the northern margin (a in fig. 1a) and Rumija was located on the southwestern margin of the platform (b in fig. 1a).

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Lower Jurassic platform carbonates are well documented in the Tethys area. Many biostratigraphic studies are based on Italian sections: biozonation of foraminifers and dasycladaleans (SARTONI & CRESCENTI, 1962; CHIOCCHINI *et alii*, 1994), detailed studies on foraminifers (FUGAGNOLI & BROGLIO LORIGA, 1998) and dasycladaleans (BARATTOLO & ROMANO, 2005), and numerous general biostratigraphic studies (e.g. MANCINELLI *et alii*, 2005). Eustatic control on carbonate platform-to-basin depositional systems has been studied (e.g. in Spain, GOMEZ & GOY, 2005), together with drowning events (ZEMPOLICH, 1993; BLOMEIER & REIJMER, 1999; ŠMUC & GORIČAN, 2005). Facies patterns on a slope of a flat-topped carbonate platform were researched in detail in Morocco (SCHEIBNER & REIJMER, 1999; BLOMEIER & REIJMER, 2002), and a ramp model was proposed for the interpretation of Early Jurassic carbonate platforms growing in extensional tectonic settings of the Betic Cordillera in Spain (RUIZ-ORTIZ *et alii*, 2004).

The Jurassic of the Dinaric Carbonate Platform has been studied by numerous researchers. Fundamental biostratigraphic studies have been carried out in this area (RADOIČIĆ, 1966; NIKLER & SOKAČ, 1968; GUŠIĆ, 1969; GUŠIĆ & BABIĆ, 1970; GUŠIĆ, 1975) and general paleogeographic reviews exist (BUSER, 1989; TIŠLJAR *et alii*, 2002; VLAHOVIĆ *et alii*, 2005). Lower Jurassic facies variability was studied mostly in the internal parts of the Dinaric Carbonate Platform (BUCKOVIĆ *et alii*, 2001, 2005; TIŠLJAR *et alii*, 2002), but only a few marginal successions have been described so far (e.g. DRAGIČEVIĆ & VELIĆ, 2002). The fact that the margin remained unexplored has been a major problem in reconstruction of the platform architecture, as pointed out by VLAHOVIĆ *et alii* (2005).

The aims of this paper are:

1) To present new stratigraphic data on the Lower Jurassic carbonates, deposited on different parts of the Dinaric Carbonate Platform margin.

2) To compare the main characteristics of Lower Jurassic successions between Slovenia and Montenegro, focusing on the Pliensbachian-Toarcian time interval.

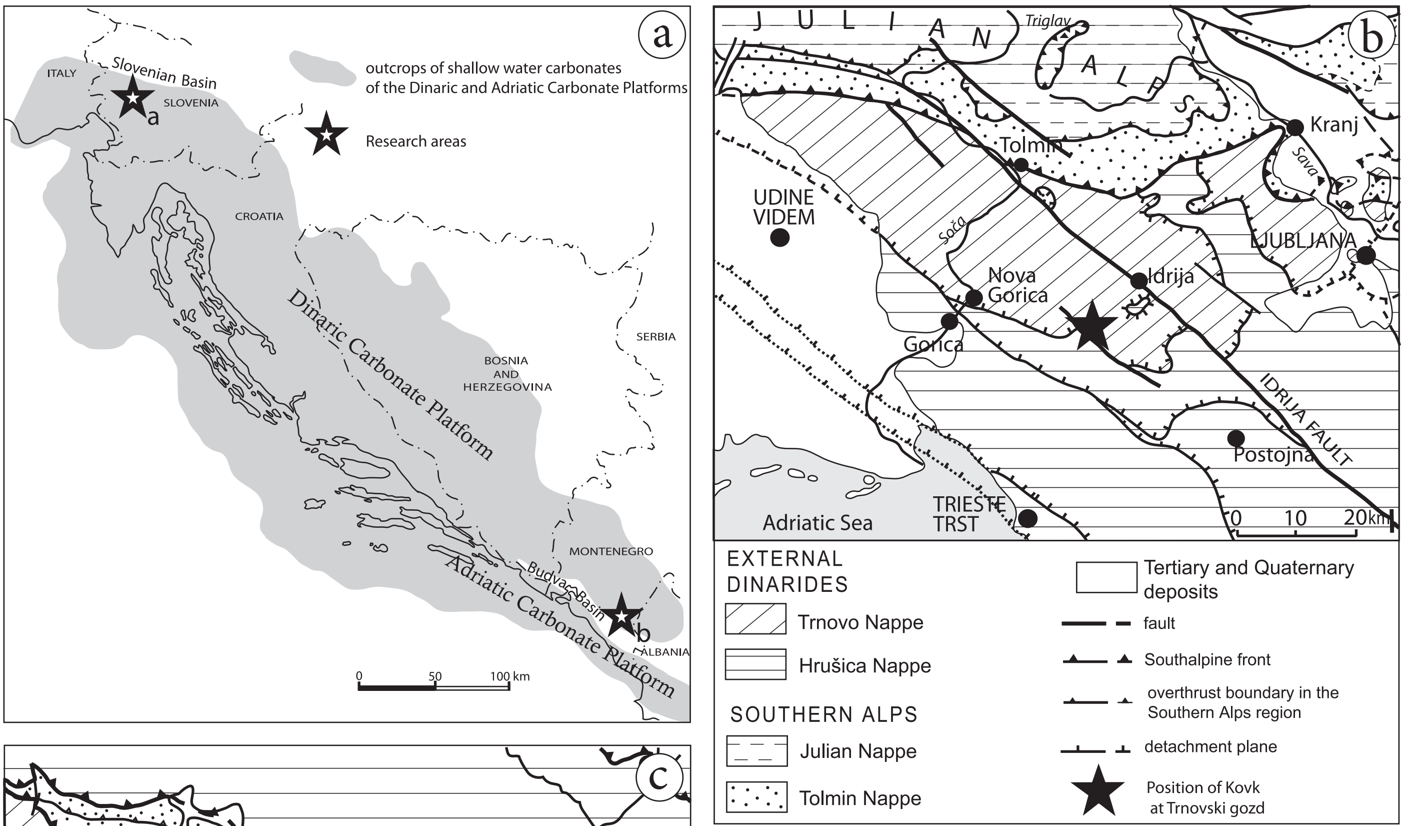
3) To compare the described facies relationships in Montenegro to depositional models proposed for other Early Jurassic carbonate platforms in the Mediterranean Tethys.

GEOLOGICAL SETTING

Both localities in Slovenia and Montenegro are part of the same carbonate platform, for which different names, regional distribution and stratigraphic ranges have been proposed (review in VLAHOVIĆ *et alii*, 2002). Several researchers consider the region of the External Dinarides as belonging to a single, more or less differentiated carbonate platform, but contrary opinions also exist (review in VLAHOVIĆ *et alii*, 2002). Recently, this large Mesozoic carbonate platform was named the Adriatic Carbonate Platform (AdCP in VLAHOVIĆ *et alii*, 2002, 2005). Regionally (fig. 1a), it is reasonable to define the area, where shallow-water carbonates deposited during most of the Mesozoic as one paleogeographic entity. On the other hand, when discussing the paleogeographic evolution of Montenegro, one cannot disregard the fact that since the Middle Triassic a deeper basin existed, the Budva Basin, dividing the «single» carbonate platform into two parts. Therefore recognition of two carbonate platform domains, i.e. Adriatic Carbonate Platform on the SW and Dinaric Carbonate Platform on the NE (D'ARGENIO *et alii*, 1971; RADOIČIĆ, 1982), should be considered in Montenegro. Since both research areas, Rumija and Trnovski gozd, are located in the same continuously exposed Jurassic platform facies belt in the Karst Dinarides, we will use the name Dinaric Carbonate Platform (DCP) for the purpose of this paper. Geological setting is given for each study area separately.

The first study area is at Kovk on Trnovski gozd, which is a high karst plateau in SW Slovenia and is structurally part of the Trnovo Nappe of the External Dinarides (fig. 1b; PLACER, 1981). Paleogeographically, this area corresponded to the northern margin of the DCP during the mid-Mesozoic and was bordered on the north by the Slovenian Basin (BUSER, 1989; 1996). The area of Trnovski gozd was mapped for the Basic Geological Map of Yugoslavia, at a scale of 1:100,000 by BUSER (1968, 1987). Basic stratigraphic data and a composite stratigraphic column of Trnovski gozd were given by BUSER (1978). In general, Upper Triassic thick-bedded and stromatolitic «Hauptdolomit» or Dachstein limestone (BUSER, 1989; 1996) is overlain by Lower Jurassic micritic limestone or dolomite (BUSER, 1978). Lower Jurassic stratigraphy of southern Slovenia, with emphasis on lithiotid facies, was researched by BUSER & DEBELJAK (1996); in-depth research of bivalve assemblage was done by DEBELJAK & BUSER (1998). Only a few km from our outcrop at Kovk, TURNŠEK *et alii* (2003) described a coral patch reef directly overlying «Lithiotid limestone» (i.e. a limestone bearing three large bivalve genera: *Lithiotis*, *Cohlearites* or *Lithioperna* sensu BUSER & DEBELJAK, 1996). We studied a 170 m thick succession at Kovk with a stratigraphic range from the Pliensbachian to the Middle Jurassic. The bottom part consists of shallow-water carbonates with abundant bivalves, which are regionally known to occur with the three large-bivalve genera within the lithiotid horizon or facies (BUSER & DEBELJAK, 1996). Even though «real» lithiotid bivalves were not found at Kovk, we will use the term lithotid limestone throughout this paper for bivalve-rich shallow-water limestone of Early Jurassic age, since: 1) typical bivalves accompanying the «real» lithiotid facies in southern Slovenia were found at Kovk.; and 2) lithiotid bivalves (*Lithiotis problematica* and *Lithioperna scutata*) were found in the same stratigraphic horizon at Gozd (TURNŠEK *et alii*, 2003), located 3 km from our outcrop.

The second study area is located in the southernmost part of Montenegro, Rumija region, which is bordered in the northeast by the Skadar Lake and on the southwest by the Adriatic Sea. Rumija is a part of the High Karst Zone, which is structurally the highest nappe, emplaced toward the SW over the Budva and Dalmatian zones (fig. 1c). Paleogeographically, the High Karst Zone was part of the Dinaric Carbonate Platform and the Dalmatian Zone corresponded to the Adriatic Carbonate Platform, equivalent to the Gavrovo-Tripolitza Carbonate Platform in Greece. Between these two carbonate platforms the deep Budva Basin existed as the NW continuation of the Pindos Basin. Overall development and evolution of the DCP was described by RADOIČIĆ (1987a, 1987b) and RADOIČIĆ & D'ARGENIO (1999). The SW margin of the DCP, including Rumija, supplied large amounts of platform carbonate production to the adjacent Budva Basin (GORIČAN, 1994).



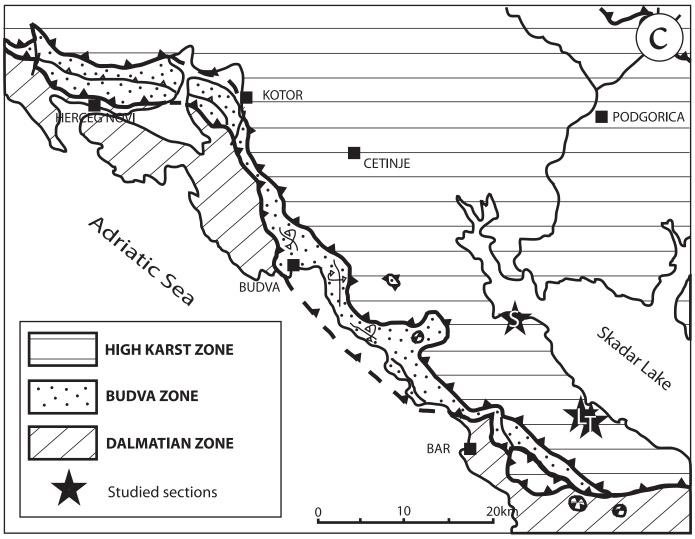


Fig. 1 - a) Geographic locations of study areas (a-Trnovski gozd in Slovenia, b-Rumija in Montenegro) with present-day extent of shallow-water carbonates of the Dinaric and Adriatic Carbonate Platforms (modified after VLAHOVIĆ *et alii*, 2005); *b*) Structural map of western Slovenia (after PLACER, 1999) with location of Kovk section at Trnovski gozd; *c*) Structural map of coastal Montenegro (from GORIČAN, 1994) with location of studied section: S-Strbina, L-Livari, T-Tejani.
– a) *Ubicazione geografica delle aree studiate (a-Trnovski gozd in Slovenia, b-Rumija in Montenegro) ed estensione attuale dei carbonati di mare basso delle Piattaforme Carbonatiche Dinarica ed Adriatica (modificato da VLAHOVIĆ* et alii*, 2005);* b) *Carta strutturale della Slovenia occidentale (da PLACER, 1999) con ubicazione della sezione di Kovk a Trnovski gozd;* c) *Carta strutturale della zona costiera del Montenegro (da GORIČAN, 1994), con ubicazione della sezione studiata: S-Strbina, L-Livari, T-Tejani.*

Detailed stratigraphic studies and geological mapping at Rumija were carried out by MILADINOVIĆ (1964) and the area was mapped for the Basic Geological Map of Yugoslavia at a scale of 1:100,000 by MIRKOVIĆ (1977). We studied three sections which are geographically close but significantly differ from each other stratigraphically: Livari, Tejani and Strbina.

STRATIGRAPHY OF THE TRNOVSKI GOZD (NORTHERN DCP MARGIN)

DESCRIPTION: KOVK

The Kovk section is located by the side road, leading from the village Kovk to Predmeja. The complete section (approximately 170 m thick) is composed of eight shorter sections (fig. 2); thickness of covered intervals was estimated in the field. The succession consists of four main lithostratigraphic units: 1) lithiotid limestone; subdivided into three subunits; 2) peloidal grainstone; 3) brownish-reddish limestone with hardgrounds; and 4) crinoidal-ooidal limestone.

Lithiotid limestone

This unit consist of three subunits with an overall thickness of 100 m. The first subunit (TG2, TGZ, TG3 in fig. 2a) is thick-bedded peritidal limestone containing bivalves ?*Lithiopedalion* and *Gervilleioperna*. From 0.6 m to 2 m thick cycles are composed of subtidal wackestone, rarely packstone, containing abundant bivalves and gastropods, passing into intertidal to supratidal fenestral mudstone or fenestral pelletal packstone, sometimes with brownish to greenish mudchips. The average size of bivalve shells is 5 cm, maximum 10 cm. Shells are mostly closely packed and randomly oriented (fig. 3a); in some beds they are parallel to the bedding. Only one bed was found with bivalves in their life position (see TGZ section). Fenestrae are from a few mm to a few cm large, sometimes laminoid (fig. 3b), and are typically filled with sparite cement, and some of them also with geopetal crystal silt. In the lower part of the succession (TG2) a few beds of peloidal grainstone, containing rare ooids, are interstratified within the cyclic alternation of micritic limestone with bivalves and fenestral mudstone or fenestral packstone. Lituolid foraminifers are abundant throughout the peritidal limestone, involutinids within the peloidal grainstone. Also present are fragments of dasycladalean algae and in places intraclasts enveloped by sponges (fig. 3c). The following foraminifers are present throughout the subunit: textulariids, *Siphovalvulina* sp., *Ammobaculites* sp., *Evertycyclammina* sp., *Haplophragmoides* sp., *Haurania* sp., ?*Spiraloconulus* sp., *Orbitopsella* sp., and in peloidal grainstone *Involutina farinacciae* Brönniman & Koehn-Zaninetti.

The second subunit is composed of at least 7 m thick package of peloidal grainstone (TG4 in fig. 2) with ooids, unidentified lituolid foraminifers, also *Orbitopsella* sp. and ?*Spiraloconulus* sp. (fig. 3d), fragments of algae and brachiopods, encrusting microproblematica, and in the topmost beds echinoderm fragments. In places fenestrae are present. Horizontal lamination and cross-stratification are frequent.

The third subunit (TG5, base of TG6) is equivalent to the first one. It is composed of wackestone and packstone with bivalves typical of lithiotid facies, gastropods, fragments of dasycladaleans (fig. 3e), and sponge encrusted intraclasts, but contains more packstone than the first subunit. The following foraminifers are present: textulariids, *Siphovalvulina* sp., and *Orbitopsella* sp.

Peloidal grainstone

Overlying the peritidal limestone is 20 m of peloidal grainstone with oncoids (upper part of TG6 and base of TG7); a few beds of wackestone containing bivalves typical of lithiotid facies and lituolids are still present. Peloidal grainstone contains bivalves, gastropods, ooids, oncoids and in the upper part abundant brachiopods. The cortex of the oncoids is formed by sponges and encrusting foraminifers. The main difference with the underlying peritidal limestone is the presence of larger amounts of ooids together with oncoids; only a few beds contain fenestrae. *Orbitopsella primaeva* (Henson) was identified from the first few beds of this section (fig. 3f). The following foraminifers were also found: *Ammobaculites* sp., ?*Spiraloconulus* sp., *Involutina farinacciae*, and ?*Haplophragmoides* sp.

Brownish-reddish limestone with hardgrounds

A 5 m thick unit of brownish-reddish mudstone to packstone occurs above the peloidal grainstone. We observed multiple ferruginous hardgrounds and marly limestone layers (fig. 4a, b) together with irregular patches containing crinoids, and abundant glauconite grains (fig 4c). The last distinctive hardground exhibits a dissolution surface (fig. 4b), with pinnacles of mostly just a few mm, but sometimes up to 1 cm high. Immediately above the hardground brachiopods and red intraclasts are abundant; *Lingulina* sp., encrusting foraminifers (fig. 4d) and small ammonites were found in thin sections.

Crinoidal-ooidal limestone

The highest unit at this locality is a 40 m thick section of medium-bedded (15 to 40 cm), reddish and gray crinoidal-ooidal grainstone and packstone (fig. 4f) with well-preserved brachiopod fauna and intraclasts of red micrite (fig. 4e). Cross-stratification is common. Interstratified are packages of nodular micrite composed almost entirely of lime mud without recognizable grains; the thickness varies from 30 cm to 1.6 m. Crinoid fragments in the grainstone decrease upsection, whereas the amount of ooids increases. The uppermost part of the section is grainstone with radial ooids, which frequently appear partly recrystallized; dolomitic crystals are observed in thin sections (fig. 4g).

Age

Orbitopsella sp. and bivalves typical of lithiotid facies found throughout the peritidal limestone indicate a Pliensbachian age for the first unit of the section according to Septfontaine *et alii* (1991) and Buser & Debeljak (1996). Based on *Orbitopsella primaeva* (Henson) in the overlying peloidal grainstone, a Carixian age is determined for the peritidal deposits according to the biozonations of Septfontaine (1984) and Bassoullet (1997). The base of the peloidal limestone is Carixian, and the upper part most probably Domerian according to the stratigraphic position.

Brownish-reddish limestone with hardgrounds represents the deepest marine facies of all lithostratigraphic units, recognized at Trnovski gozd, and is correlated with the first order maximum trangression in the early Toarcian (Hallam, 1988).

The age of the crinoidal-ooidal limestone has been partially determined with previously found foraminifers. Buser (1978) reports the occurrence of *Gutnicella minoricensis* (Bourrouilh & Moullade) (determined as *Lucasella minoricensis* by Buser) 50 m above the horizon with abundant brachiopods, which corresponds to the position of about 20 m above our last logged bed. Septfontaine *et alii* (1991) determined a late Aalenian-early Bajocian age for *Gutnicella* sp. Based on stratigraphic position and presence of the above mentioned foraminifer, the crinoidal-ooidal limestone is ?late Toarcian to Aalenian or possibly early Bajocian in age.

Depositional environment

Shallowing-upward cycles in peritidal limestones of the first unit indicate a shallow subtidal (wackestone with bivalves and gastropods) to inter-supratidal (fenestral mudstone) environment. The relatively small size of bivalve shells indicates unfavourable conditions for their growth (higher-energy environment), since growth of larger shells is favoured by low-energy conditions of a restricted lagoon (Buser & Debeljak, 1996). Several consecutive beds of peloidal grainstone in the middle subunit represent higher-energy shoals. Meter thick Pliens-

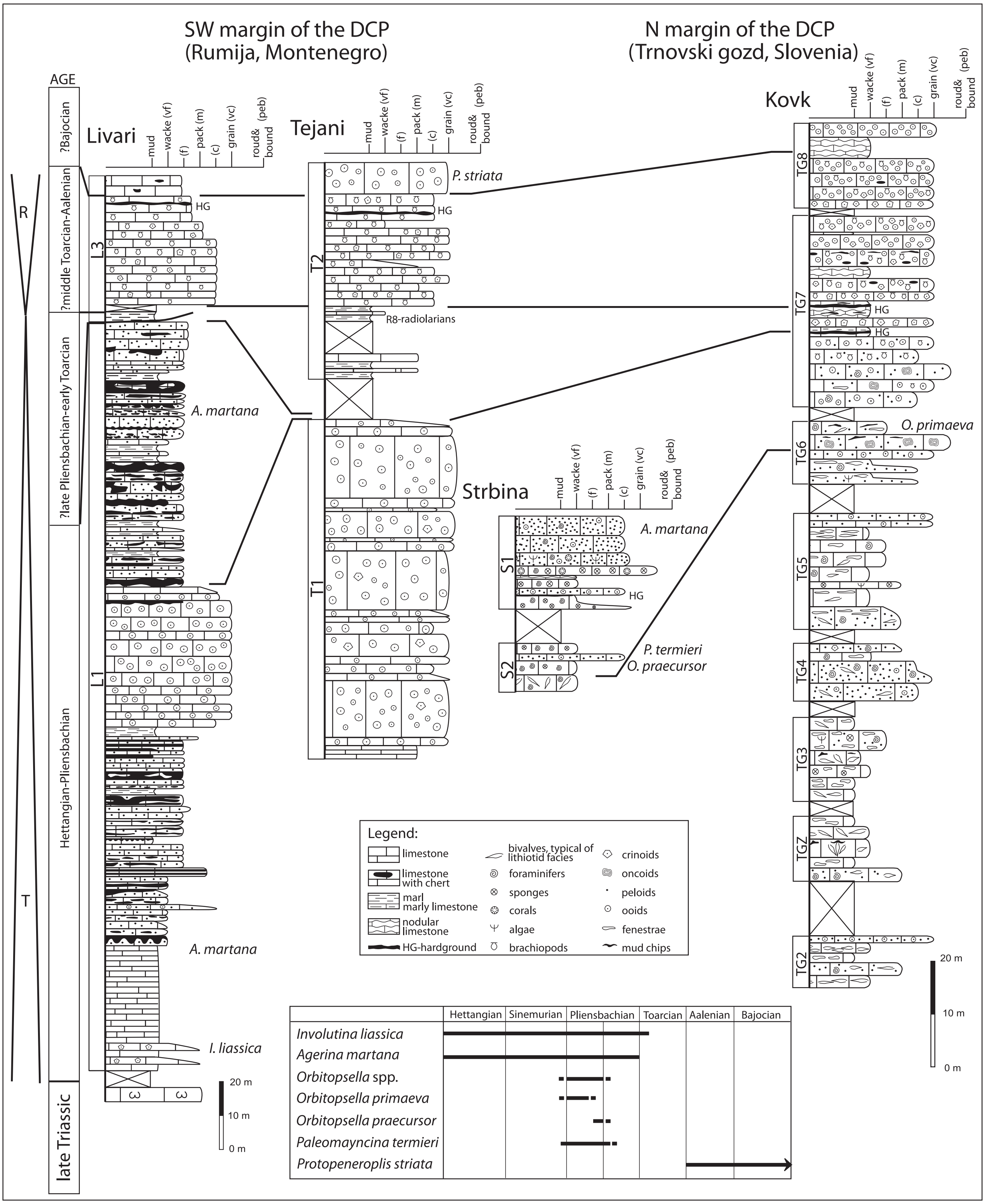


Fig. 2 - Stratigraphic logs of the studied sections and correlations; notations on the left of each log (L1, L2 etc.) correspond to partial sections measured. Occurrences of stratigraphically important foraminifers are shown. In the Livari section only the first and last occurrence of *Agerina martana* is indicated. Ranges in the table below are based on works by Radoičić (1966), Septfontaine (1984), Septfontaine *et alii* (1991), Chiocchini *et alii* (1994), and Bassoullet (1997). First order maximum transgression after Hallam (1988). Note different scales: left scale for Livari, Tejani and Strbina sections, right scale for Kovk section.

– Colonne stratigrafiche e correlazioni fra le sezioni studiate; le annotazioni a sinistra di ogni colonna (L1, L2 etc.) corrispondono alle sezioni parziali misurate. È indicata anche la distribuzione dei foraminiferi più importanti dal punto di vista stratigrafico. Nella sezione di Livari è stata indicata solo la comparsa e la scomparsa di Agerina martana. *I range stratigrafici nella tabella sottostante sono basati sui lavori di Radoičić (1966), Septfontaine (1984), Septfontaine* et alii *(1991), Chiocchini* et alii *(1994), e Bassoullet (1997). L'età del massimo trasgressivo di primo ordine è presa da Hallam (1988). Notare le scale differenti. La scala di sinistra vale per le sezioni di Livari, Tejani e Strbina. La scala di destra è per la sezione di Kovk.*

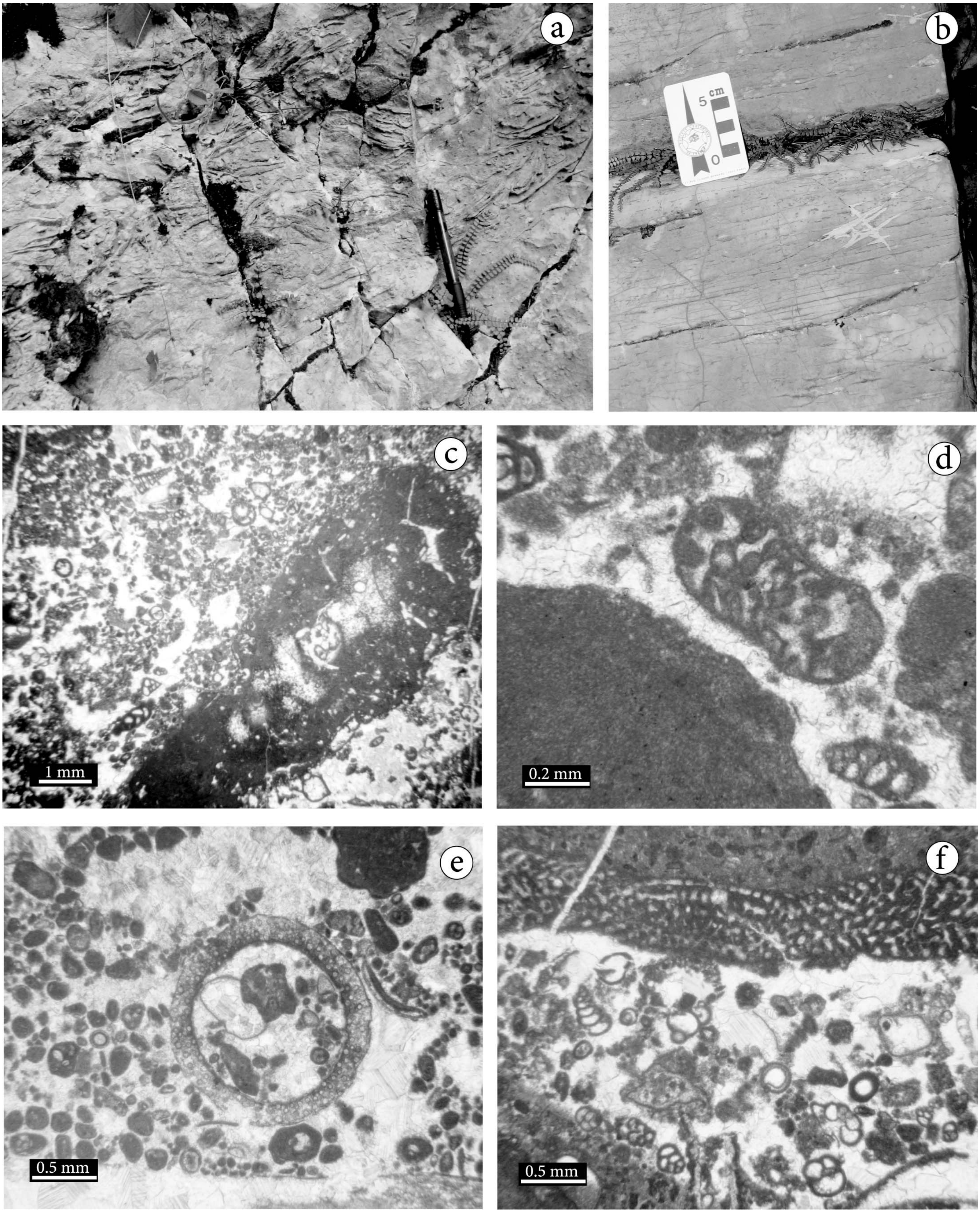


Fig. 3 - Kovk at Trnovski gozd: *a*) Field photograph of micritic limestone containing numerous bivalves typical of lithiotid facies; *b*) Field photograph of micritic limestone with laminoid fenestrae; *c*) Packstone with peloids, foraminifers and intraclast enveloped in sponges (sample TG3-10.90); *d*) ?*Spiraloconulus* sp. within peloidal grainstone (sample TG4-5.60); *e*) Peloidal grainstone with fragment of dasycladalean algae (sample TG6-0.40); *f*) *Orbitopsella primaeva* (Henson) and small foraminifers within peloidal packstone (sample TG6-7.80). – *Sezione di Kovk a Trnovski gozd:* a) *Foto di affioramento del calcare micritico con numerosi bivalvi, tipici della facies a lithiotidi;* b) *Foto di affioramento di calcare micritico con fenestrae;* c) *Packstone con peloidi, foraminiferi e intraclasti incrostati da spugne (campione TG3-10.90);* d) ?Spiraloconulus *sp. in grainstone a peloidi (campione TG4-5.60);* e) *Grainstone a peloidi con un frammento di alghe dasicladali (campione TG6-0.40);* f) Orbitopsella primaeva *(Henson) e piccoli foraminiferi in packstone a peloidi (campione TG6-7.80).*

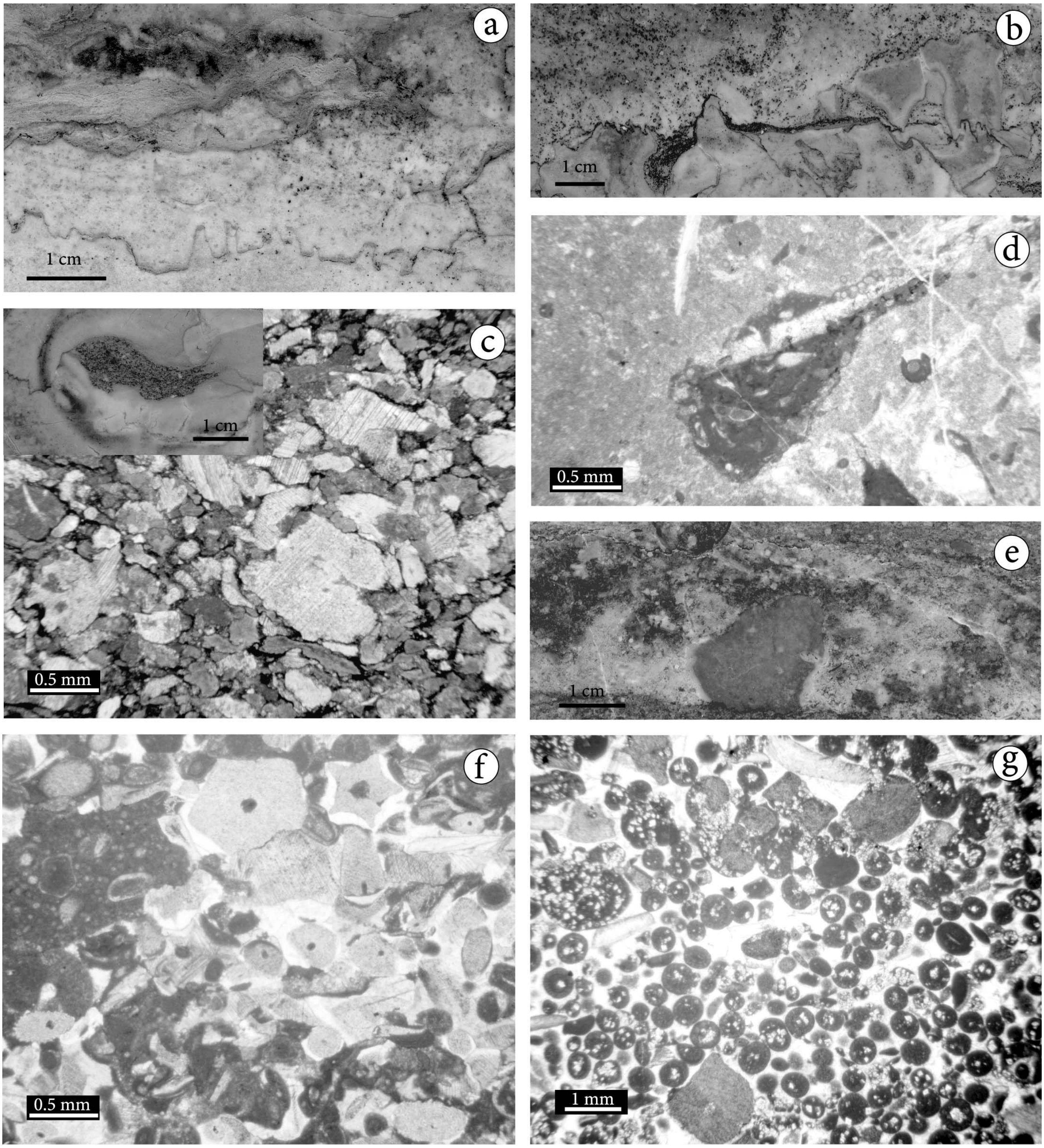


Fig. 4 - Kovk at Trnovski gozd: *a*) Mineralized hardground with stylolites and marly limestone layers (sample TG7-15.50); *b*) Irregular hardground with a dissolution surface; dark dots are glauconite grains (sample TG7-17.95); *c*) Thin section showing glauconite grains (dark gray on photograph), echinoderm fragments and limestone lithoclasts, forming irregular patches (top left corner) within micritic limestone (sample TG7-17.85); *d*) Microfacies immediately above the hardground surface: wackestone with fragments of brachiopod shells, some encrusted by foraminifers (sample TG7-18.25); *e*) Red micritic limestone clasts within crinoidal-ooidal limestone (sample TG7-19.70a); *f*) Microfacies of crinoidal-ooidal limestone: packstone with fragments of crinoids and limestone lithoclasts (sample TG7-19.70); *g*) Microfacies of the upper part of the crinoidal-ooidal limestone: ooids are more abundant than fragments of crinoids. Dolomite crystals are present within the ooids.

– *Sezione di Kovk a Trnovski gozd:* a) *Hardground mineralizzata con stiloliti e strati di calcare marnoso (sample TG7-15.50);* b) *hardground irregolare, con una superficie di dissoluzione; i puntini scuri sono granuli di glauconite (campione TG7-17.95);* c) *Sezione sottile che mostra i granuli di glauconite (grigio scuro nella foto), frammenti di echinodermi e litoclasti di calcare, che formano tasche irregolari (angolo in alto a sinistra) nel calcare micritico (calcare TG7-17.85);* d) *Microfacies immediatamente al di sopra dell'hardground: wackestone con frammenti di gusci di brachiopodi, alcuni incrostati da foraminiferi (campione TG7-18.25);* e) *Clasti di calcare micritico rosso all'interno del calcare a crinoidi ed ooidi (campione TG7-19.70a);* f) *Microfacies del calcare a crinoidi ed ooidi: packstone con frammenti di crinoidi e litoclasti di calcare (campione TG7-19.70);* g) *Microfacies della parte superiore del calcare a crinoidi ed ooidi: gli ooidi sono più abbondanti dei frammenti di crinoidi. Negli ooidi ci sono cristalli di dolomite.*

bachian cyclothems are widely known across the Tethys area (e.g. on the Trento Carbonate Platform, GIANNETTI & MONACO, 2004) and were also studied on the DCP (BUCKOVIĆ *et alii*, 2001, 2005).

Transition from the peritidal limestone to the peloidal grainstone with oncoids is interpreted as a transgressive trend, since this transition implies a change of depositional environment from the inner platform to higher-energy shoals (cf. BURCHETTE & WRIGHT, 1992; REY, 1997; RUIZ-ORTIZ *et alii,* 2004). Oncoids of similar origin as the ones in the peloidal grainstone were reported from the upper part, Massone Member, of the Calcari Grigi Formation of the Trento Platform in the Southern Alps. The Massone Member contains abundant sponge fauna (AVANZINI & BROGLIO LORIGA, 1996), and is comparable to the peloidal grainstone of Trnovski gozd.

The condensed interval of brownish-reddish limestone with multiple ferruginous hardgrounds records a drastic shift from a shallow-water environment to a deeper setting of the outer platform. Extremely reduced sedimentation rates reflected in mineralized surfaces and appearance of glauconite indicate drowning of the DCP margin, which may have been induced by tectonics, sea-level rise and/or productivity perturbations (cf. DI STEFANO & MINDSZENTY, 2000).

The overlying crinoidal-ooidal grainstone records a recovery of carbonate production in a high-energy outer-platform environment. Increased amount of ooids upsection indicates a shallowing-upward trend. The uppermost beds of oolitic limestone are comparable to the San Vigilio Oolite Formation of the Trento Platform (BARBUJANI *et alii*, 1986).

STRATIGRAPHY OF RUMIJA (SW DCP MARGIN)

We studied three different sections in the Rumija region: Livari, Tejani and Strbina (fig. 2). Livari, the thickest succession, is more than 250 m thick, and includes the entire Early Jurassic. Tejani is located only 3 km from Livari, but the sections are significantly different. At Livari the lower part is composed predominantly of cherty limestones, but at Tejani it consists exclusively of oolitic limestones. The overlying deposits at both localities are almost identical and are composed of marly limestone alternating with marl, and bioclastic limestone. Strbina is a short 30 m thick succession of platform carbonates containing bivalves typical of lithiotid facies at its base.

DESCRIPTION: LIVARI

Four main lithostratigraphic units were recognized within the Livari section: 1) micritic limestones; 2) resedimented limestones subdivided into three subunits; 3) marly limestone alternating with marl; and 4) bioclastic limestone with brachiopods.

Micritic limestone

At Livari, the Upper Triassic Dachstein limestone is overlain by 40 m of mudstone to wackestone with most beds about 20 cm thick. The limestone contains peloids and rare foraminifers. The otherwise monotonous succession begins with a few beds of packstone with peloids, intraclasts, echinoderm fragments, foraminifers and rare ooids. The most common foraminifers are lagenids (*Lingulina* sp., *Lenticulina* sp.), *Frondicularia* sp. and *Trocholina* sp. also occur. *Involutina turgida* KRISTAN-TOLMANN and *Involutina liassica* (JONES) (fig. 5a) were identified in the first few meters, while *Glomospira* sp., *Ophthalmidium* sp., and *Agerina martana* (FARINACCI) were found in the upper part of this unit.

Resedimented limestones

Three subunits of resedimented limestones, with a total thickness of 180 m, occur above the micritic limestone; the most common bed thickness is between 10 and 50 cm. The first subunit is 60 m thick, composed of fine- to medium-grained resedimented limestones with 50% replacement chert layers and nodules. Only a few beds show normal grading. Packstone to wackestone mostly contains peloids and echinoderm fragments, also foraminifers, ooids and in places abundant sponge spicules (fig 5b). Foraminifers include textulariids, *Lenticulina* sp. (fig. 5c), *Glomospira* sp., *Frondicularia* sp., *Ophthalmidium* sp., *Haplophragmoides* sp. and *Agerina martana*. Within this first subunit of resedimented limestone two distinct marly intervals appear. The first one is 1 m thick and occurs at 40 m of the subunit; the second is thicker (1.75 m) and forms the very top of this subunit.

The second subunit, 45 m thick, consists mostly of 25 to 60 cm thick beds of coarse-grained packstone (matrix often recrystallized into sparite) and entirely lacks chert. The limestone contains mostly ooids, but also echinoderm fragments and peloids. The most common ooids are single- and double-layered with radial cortex. Foraminifers and fragments of green algae are mostly found as nuclei of ooids, but sporadically as individual grains. The foraminifers are *Ophthalmidium* sp. and ?*Mesoendothyra* sp. (fig. 5d).

The third subunit, 75 m thick, is composed of fine- to medium-grained packstones with chert, which are lithologically almost identical to the first subunit. Packstone with peloids and echinoderm fragments predominates. The main differences in comparison with the first subunit are larger amounts of echinoderm fragments, lack of ooids and smaller amount of foraminifers (fig. 5e). Reduction of chert content is observed within the last 30 m of the succession. The third subunit contains six marly-limestone intercalations, but only one of them is thicker than half a meter and divides the subunit into two parts, which are 35 and 40 m thick respectively.

Marly limestone alternating with marl

The contact with the underlying deposits is tectonic. This unit is at least 5-10 m thick and consists of marly limestone alternating with marl. Sponge spicules, foraminifers, ostracodes and rare radiolarians are present.

Bioclastic limestone

This lithostratigraphic unit is at least 30 m thick. The brownish-reddish bioclastic limestone contains skeletal debris, which include fragments of echinoderms, filaments and brachiopods. It is gradually replaced upwards

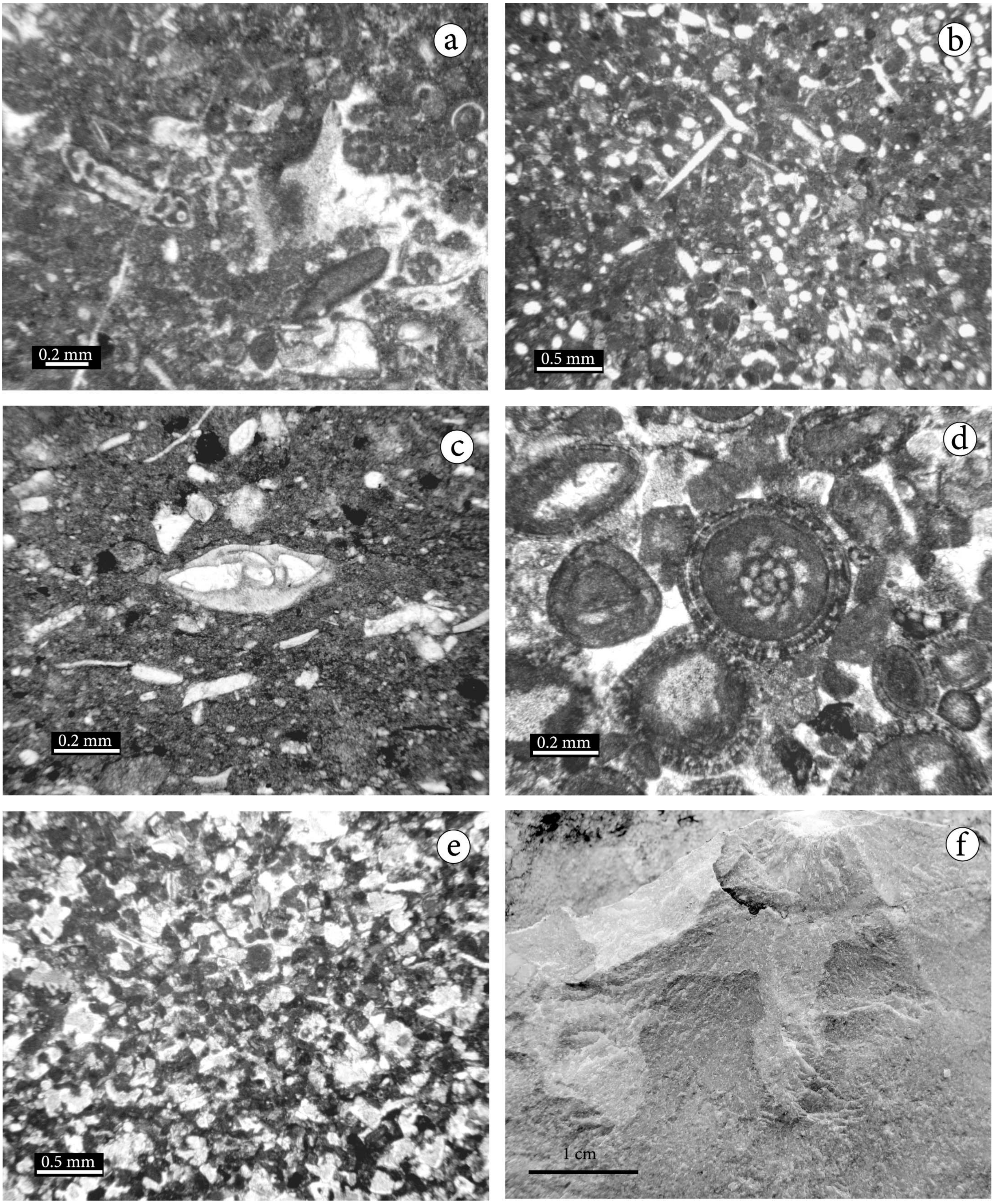


Fig. 5 - Livari at Rumija: *a*) Peloidal packstone containing *Involutina liassica* (JONES) (sample L1-2.70); *b*) Peloidal packstone with abundant sponge spicules (sample L1-61.35); *c*) *Lenticulina* sp. within a marly limestone layer (sample L1-81.70); *d*) Ooids within oolitic packstone, one of them containing ?*Mesoendothyra* sp. (sample L1-104.70); *e*) Typical microfacies of resedimented limestone: packstone containing peloids and echinoderm fragments (sample L1-177.85); *f*) Irregular ferruginous mineralization near the top of the section.
– *Sezione di Livari a Rumija:* a) *Packstone a peloidi con* Involutina liassica *(JONES) (campione L1-2.70);* b) *Packstone a peloidi con abbondanti spicole di spugna (campione L1-61.35);* c) Lenticulina *sp. in uno strato di calcare marnoso (campione L1-81.70);* d) *Ooidi in un packstone oolitico, uno di essi ha a nucleo* ?Mesoendothyra *sp. (campione L1-104.70);* e) *Microfacies tipica dei calcari risedimentati: packstone con peloids e frammenti di echinodermi (campione L1-177.85);* f) *Mineralizzazione ferruginosa irregolare, vicino al top della sezione.*

by fine- to medium-grained resedimented limestone with chert layers and nodules. Only 1 m below the first appearance of chert, an irregular mineralization with Fe-Mn occurs (fig. 5f).

Description: Tejani

At Tejani only a few meters of micritic limestone are exposed above the Upper Triassic Dachstein limestone. A 50 m covered interval extends above this. The first exposed bed is medium- to coarse-grained oolitic limestone. The section is composed of 100 m of thick-bedded coarse-grained grainstone containing ooids (fig. 6a, 6b) and is completely devoid of chert. Due to karstification of this limestone it is difficult to determine the bed thickness but most beds appear several meters thick. Among the thicker beds, a few thinner ones were recognized with evident cross-stratification. Ooids are the most common grains. Algal fragments, foraminifers and echinoderm fragments also occur, both as nuclei of ooids and as independent grains. Most grains are up to 2 mm in size, with a few fragments of crinoids up to 1 cm large. The most abundant algae are dasycladalean and udoteacean green algae, but fragments of solenoporacean red algae are also present. The following foraminifers were found: textulariids, *Ophthalmidium* sp., *Agerina martana* and ?*Mesoendothyra* sp.

Overlying the thick-bedded oolitic limestone is a 30 m thick unit of marly limestone alternating with marl. It is lithologically identical to the marly limestone unit at Livari. This marly limestone contains foraminifers, sponge spicules, and radiolarians. At Livari the lower contact is tectonic, whereas at Tejani it is stratigraphic and very sharp.

Transition from the marly limestone alternating with marl to the brownish-reddish bioclastic limestone is gradual and a coarsening-upward trend is observed. A 30 m thick unit of brownish-reddish bioclastic packstone to wackestone with abundant brachiopods (fig. 6c) also contains echinoderm fragments, foraminifers, lithoclasts of oolitic limestone and intraclasts, some with encrusting foraminifers (fig. 6c). Among the foraminifers *Lenticulina* sp., *Lingulina* sp. and *Glomospira* sp. are abundant. Above a very distinct hardground with Fe-Mn mineralization (fig. 6e) 2 m of medium-grained packstone follow, which is lithologically similar to the bioclastic packstone below the hardground, except that the grains are smaller and peloids are abundant.

The Lower Jurassic succession at Tejani is topped by 12 m of coarse-grained oolitic grainstone, which contains fragments of green algae and corals, among them *Cladophyllia minor* Beauvais, foraminifers including *Protopeneroplis striata* Weynschenk, and lithoclasts of oolitic limestone.

Description: Strbina

The Strbina section was measured from the topmost bed, containing bivalves typical of lithiotid facies. For the underlying limestone we will use the term lithiotid limestone (i.e. Trnovski gozd). This limestone is a thick-bedded bioclastic wackestone to packstone, with average bed thickness 60 to 80 cm. The lithiotid shells are not oriented and are around 10 cm large (fig. 7a). Beds above the lithiotid limestone (S2) are texturally the same-wackestone to packstone. They include gastropods and some intraclasts and bioclasts enveloped with sponges forming oncoids of a few cm in diameter. Foraminifers are abundant, mostly lituolids and textulariids, and some encrusting foraminifers. In addition to this predominant facies, thin beds of peloidal limestone occur, which also contain small amount of ooids. The following foraminifers were recognized: *Siphovalvulina* sp., *Ammobaculites* sp., *Everticyclammina* sp., *Haurania deserta* Henson, *Orbitopsella praecursor* (Gümbel) and *Paleomayncina termieri* (Hottinger) (fig. 7b, c).

Part of the section does not permit detailed measurement. The next exposed beds (S1) are wackestone to packstone with intraclasts of a few centimeters in size. The most abundant are sponge oncoids with gastropods or algal fragments as nuclei. Some intraclasts are encrusted by foraminifers or microproblematica, i.e. *Thaumatoporella* sp. (fig. 7d). Above a macroscopically indistinct discontinuity surface, grainstone is present, which contains peloids and micritic ooids (fig. 7e), then wackstone with sponge oncoids follows again. A 50 cm thick interval exhibits pseudonodular bedding. The overlying limestone bed is the thickest (2.5 m) and contains larger amount of grains, which are a few centimeters large. The most common are again sponge oncoids (fig. 7f), fragments of corals and algae together with limestone lithoclasts. The whole succession ends with 10 m of thick-bedded (bed thickness is 1-2 m) peloidal grainstone. This grainstone also contains small, single-layered ooids (average size is 0.2 mm), foraminifers, and fragments of corals. The following foraminifers are present: textulariids, *Spihovalvulina* sp., *Glomospira* sp., *Amijella amiji* (Henson), and *Agerina martana* (Farinacci). Among the coral fragments *Astraeomorpha* sp., *Epismilia* cf. *mauretaniensis* Beauvais and *Apocladophyllia* cf. *gozdensis* Turnšek (fig. 7g) were identified.

Age

In these sections most of the collected fossils, including foraminifers, are rather long ranging, and thus do not allow a precise age assignment. The following biostratigraphic constraints are important:

1) *Involutina turgida* Kristan-Tolmann and *Involutina liassica* (Jones) define the micritic limestone at Livari as Lower Jurassic. The Triassic-Jurassic boundary is

Fig. 6 - Tejani at Rumija: *a*) Field photograph of succession Tejani; *b*) Oolitic grainstone with foraminifers and echinoderm fragments as nuclei (sample T1-48.20); *c*) Field photo of bioclastic limestone containing numerous brachiopods. This sample is from the Repsa section, located 5 km from Tejani; *d*) Intraclast encrusted with foraminifer within bioclastic limestone (sample T2-24.65); *e*) Thin section right above a very distinct hardground surface, which shows a clast containing numerous ferruginous mineralizations (sample T2-44.10).

– Sezione di Tejani a Rumija: a) *Foto di affioramento della successione di Tejani;* b) *Grainstone oolitico con foraminiferi e frammenti di echinodermi al nucleo (campione T1-48.20);* c) *Foto di affioramento di calcare bioclastico con numerosi brachiopodi. Questo campione viene dalla sezione di Repsa, a 5 km da Tejani;* d) *Intraclasto incrostato da foraminifero in un calcare bioclastico (campione T2-24.65);* e) *Sezione sottile di un campione prelevato immediatamente al di sopra di una hardground molto evidente. Notare il clasto con mineralizzazioni ferruginose (campione T2-44.10).*

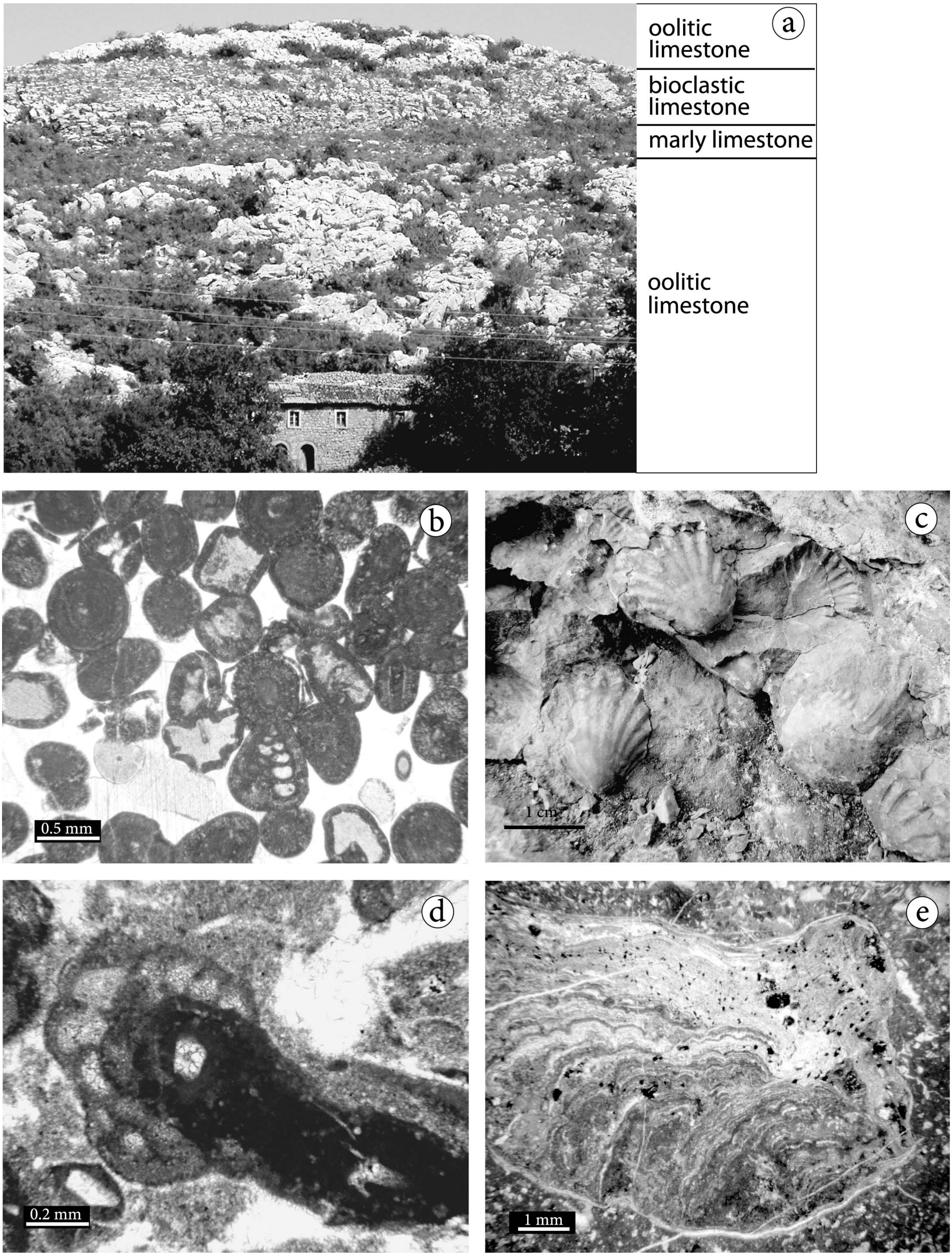

a
oolitic limestone
bioclastic limestone
marly limestone
oolitic limestone
b
0.5 mm
c
1 cm
d
0.2 mm
e
1 mm

Fig. 6.

placed at the contact between thick-bedded limestone with stromatolites (Dachstein limestone) and micritic limestone, which contains the above mentioned foraminifers in the lowest part.

2) Foraminifers in resedimented limestones at Livari and oolitic limestone at Tejani are rare; the only stratigraphically important species is *Agerina martana*, which extends from the Hettangian to the Pliensbachian (Radoičić, 1966; Chiocchini *et alii*, 1994).

3) Several samples of marly limestone were processed with diluted acetic acid for extraction of microfossils. The sample R8 from the Tejani section yielded very rare radiolarians and more abundant sponge spicules (megascleres and rhaxes prevail) (fig. 8). The following radiolarian species were identified: *Hsuum lucidum* Yeh, *Parahsuum* cf. *edenshawi* (Carter), *Parahsuum* cf. *longiconicum* Sashida, and *Praeconocaryomma decora* gr. Yeh. All four identified radiolarian species are common in the Pliensbachian and Toarcian deposits worldwide (Goričan *et alii*, 2006). According to Yeh (1987), *Hsuum lucidum* (together with its synonym *Hsuum validum* Yeh) does not appear below the upper Pliensbachian.

4) At Strbina the bivalves typical of lithiotid facies in the first bed and foraminifers *Orbitopsella praecursor* (Gümbel) together with *Paleomayncina termieri* (Hottinger) in the lower part of the section (S2) indicate a Carixian age (Septfontaine, 1984; Bassoullet, 1997). In the upper part of the section (S1) the foraminifer *Agerina martana* (Farinacci) suggests that the top of the section is not younger than the Pliensbachian (Chiocchini *et alii*, 1994). Additionally, the corals *Epismilia mauretaniensis* Beauvais and *Apocladophyllia gozdiensis* Turnšek are known from the Domerian (Turnšek *et alii*, 2003), which is also the most probable age according to superposition.

5) The uppermost lithostratigraphic unit at Tejani contains the foraminifer *Protopeneroplis striata*, which provides evidence that the oolitic grainstone cannot be older than Aalenian (Bassoullet, 1997). A Middle to Late Jurassic age is also characteristic of the coral *Cladophyllia minor* Beauvais, found in the oolitic grainstone.

Brachiopods have not been paleontologically addressed in this study. However, an earlier study at the locality Livari (Martelli, 1906) suggests an early Middle Jurassic age for the bioclastic limestone containing abundant brachiopod fauna.

In addition, if we consider general trends in sedimentary evolution, it seems obvious that the marly limestone alternating with marl at Livari and Tejani indicates the deepest depositional environment of both successions. We therefore believe that sedimentation of marly limestone coincides with the peak transgression in the early Toarcian (Hallam, 1988), which is in agreement with available biostratigraphic data. The overlying bioclastic limestone with abundant brachiopods at Livari and Tejani is therefore ?middle Toarcian to Aalenian in age, which is supported by data of Martelli (1906). The 220 m thick succession between the Dachstein limestone and marly limestone at Livari ranges from the Hettangian to the Pliensbachian, but a more precise age assignment of individual subunits is presently not possible.

Depositional environment and correlations

Sedimentation of the Lower Jurassic micritic limestone above the Upper Triassic Dachstein limestone at Livari and Tejani was caused by drowning of the marginal areas of the Dinaric Carbonate Platform around the Triassic-Jurassic boundary that primarily occurred due to tectonic subsidence (Radoičić, 1987a). Backstepping of the platform was also reflected in the adjacent Budva Basin, where the Triassic-Jurassic boundary is marked by an abrupt facies change from micritic limestone to lime-poor siliceous mudstone (Goričan, 1994). Termination of shallow-water sedimentation may have been amplified by the end-Triassic biotic crisis and perturbation of the global C-cycle at the Triassic-Jurassic boundary (Galli *et alii*, 2005).

Resedimented limestones at Livari were accumulated in a low-energy, deeper-water environment on the outer ramp. There are no coarse-grained limestones present. We observed no channels or lateral changes of bed thickness along a few hundred meters long outcrop. Only a few beds exhibit normal grading. Therefore, probable mechanisms of deposition of the resedimented limestones are very low-density turbidity currents. Formation of chert nodules in turbidites is common, because rapid burial of the transported siliceous tests, in our case sponge spicules, prevents dissolved silica from passing from the sediment into overlying sea water (Bustillo & Ruiz-Ortiz, 1987). Oolitic packstone, the second subunit within the resedimented limestone, was formed by resedimentation of ooids from the ooidal shoals and is apparently the most proximal facies of the entire unit.

On the other hand, a thick unit of oolitic grainstone at Tejani represents sediments deposited in a high-energy environment of an open platform. Cross-stratification indicates a high-energy tidal- or wave-dominated setting. Oolitic grainstone at Tejani is best correlated with the second subunit of the resedimented limestones, i.e. oolitic packstones, at Livari (see fig. 2). The inferred correlation would imply that there exists a stratigraphic gap between the oolitic grainstone and marly limestone at Tejani. One should nevertheless bear in mind that the Lower Jurassic oolite shoals were probably laterally limited and mobile (Radoičić, 1982), and consequently, the oolitic units at Tejani and Livari are not necessarily exact time equivalents.

The lithiotid facies at Strbina represents Pliensbachian shallow-water deposits of the inner part of the

Fig. 7 - Strbina at Rumija: a) Field photograph of lithiotid bivalves within the thick-bedded wackestone; b) *Orbitopsella praecursor* (Gümbel) (sample S2-4.60); c) *Paleomayncina termieri* (Hottinger) (sample S2-4.60); d) *Thaumatoporella* sp. encrusting pelletal intraclast (sample S1-16.80); e) Polished sample of a hardground surface; lower part consists of fractured micritic limestone, the upper part of oolitic grainstone (sample S1-17.40); f) Thin section of an oncoid (top left corner), formed by encrusting sponges and bioclast as nucleus (sample S1-18.40); g) Coral *Apocladophyllia* cf. *gozdensis* Turnšek (sample S1-20.50).

– *Sezione di Strbina a Rumija:* a) *Foto di affioramento di bivalvi lithiotidi in un wackestone a strati spessi;* b) Orbitopsella praecursor *(Gümbel) (campione S2-4.60);* c) Paleomayncina termieri *(Hottinger) (campione S2-4.60);* d) Thaumatoporella *sp. che incrosta un intraclasto peloidale (campione S1-16.80);* e) *Campione lucidato di una superficie di hardground; la parte inferiore consiste di calcare micritico fratturato, la parte superiore consiste di grainstone oolitico (campione S1-17.40);* f) *Sezione sottile di un oncoide (angolo in alto a sinistra), formato da spugne incrostanti e da un bioclasto come nucleo (campione S1-18.40);* g) *il corallo* Apocladophyllia *cf.* gozdensis *Turnšek (campione S1-20.50).*

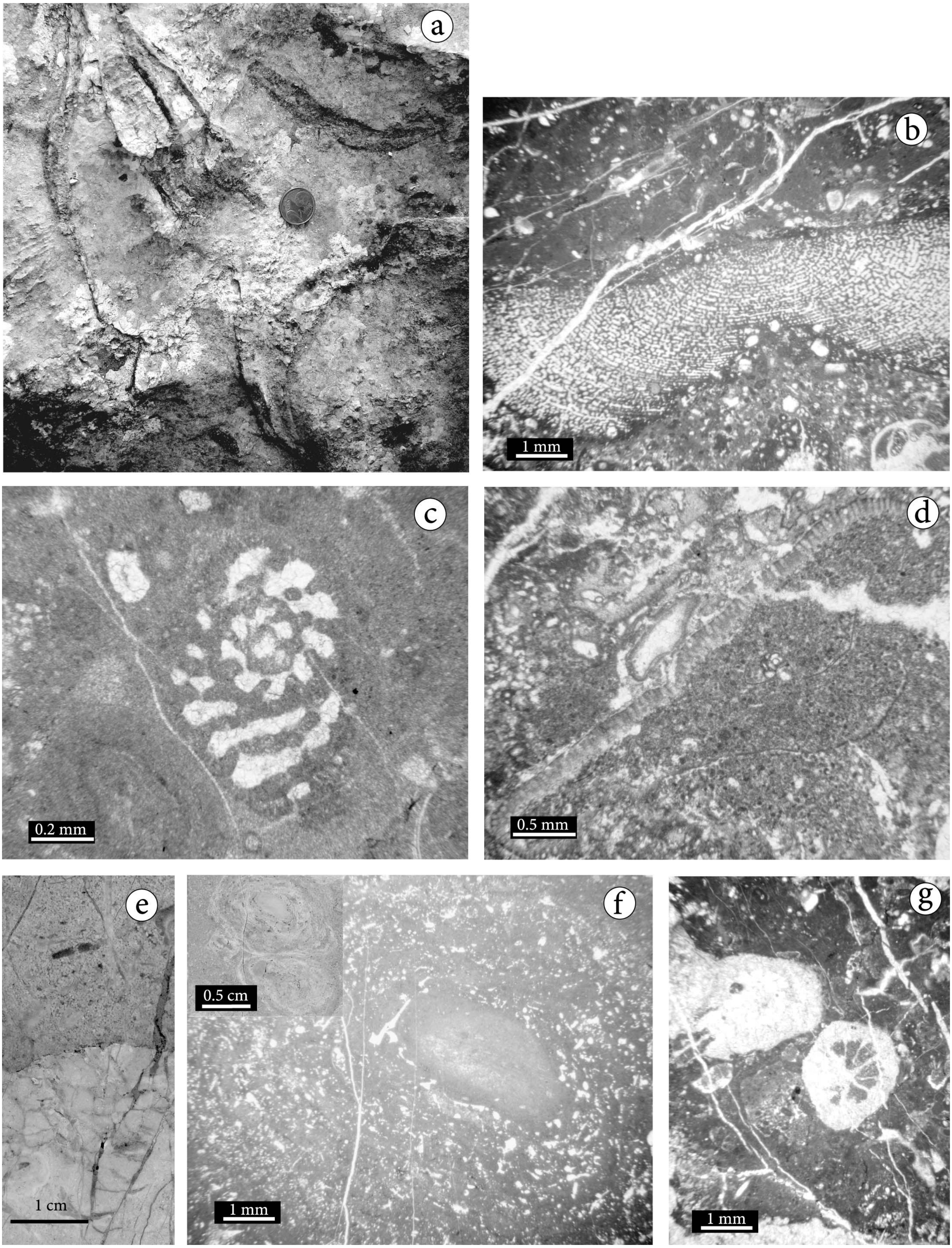


Fig. 7.

carbonate platform. Transition from the lithiotid limestone to the wackestone and packstone with intraclasts, followed by peloidal grainstone, is interpreted as a transition from the shallow-water environment of the inner platform into a higher-energy environment of an open platform, similar to the succession of Trnovski gozd.

Marly limestone alternating with marl indicates the deepest depositional environment of both the Livari and the Tejani successions. The marly limestone was deposited in a quiet-water environment, below storm-wave base. The change from a high-energy environment (oolitic limestone) into a deeper-water, low-energy environment (marly limestone) is especially evident at Tejani. Decrease of carbonate production probably occurred during the early Toarcian sea-level rise combined with productivity perturbations and the Toarcian Oceanic Anoxic Event (JENKYNS, 1988). However, only light-coloured brownish to yellowish marls were deposited during this time, which shows that marine waters at the SW DCP margin were relatively well oxygenated.

Transition from the marly limestone into bioclastic limestone with brachiopods and echinoderms shows a coarsening and thickening-upward trend, which is correlative with the first order Toarcian-Aalenian regression (GRACIANSKY *et alii*, 1998). Hardgrounds occurring at Livari and Tejani probably precipitated around the maximum regression. Hardgrounds indicate reduced sedimentation rates caused by minimum carbonate productivity and/or sweeping of sediment by strong bottom currents.

CORRELATION BETWEEN N AND SW MARGINS OF THE DCP AND COMPARISON WITH OTHER TETHYAN EXAMPLES

From the three studied sections in Montenegro, the Early Jurassic platform-to-basin transition can be reconstructed. The most complete data were obtained for the Pliensbachian-Toarcian interval. Sediments of this age, in addition, can be correlated with the section at Trnovski gozd in Slovenia (fig. 2). Only one section (Livari) records a complete sedimentary evolution from the Triassic-Jurassic boundary to the Aalenian.

At Livari the Dachstein limestone is overlain by Lower Jurassic micritic limestone, and then by resedimented limestones. A similar stratigraphic succession has so far never been described in the Dinarides. The NE margin of the DCP in Croatia lacks evidence of the Early Jurassic margin due to tectonic reductions and coverage of the marginal area with younger sediments (DRAGIČEVIĆ & VELIĆ, 2002). On the other hand, resedimented limestones with chert are well known in typical basinal settings, i.e. Budva Basin in the SW (GORIČAN, 1994) and Slovenian Basin in the N (COUSIN, 1981; BUSER, 1989; ROŽIČ, 2006). Regionally, a succession comparable to Livari is known from the westerly facing carbonate ramp in the Betic Cordillera of Southern Spain (Barranco del Pardo, section 3, in RUIZ-ORTIZ *et alii*, 2004). The beginning of the deep-water sedimentation is not contemporaneous in the two areas (T-J boundary in Montenegro; late Sinemurian-early Carixian in Spain), but cherty limestone with a middle package of oolitic-crinoidal grainstone at del Pardo is lithologically comparable to the resedimented limestones of Livari.

In the Pliensbachian the facies distribution on the SW margin of the DCP (Montenegro) was as follows: shallow-water limestone with bivalves typical of lithiotid facies accumulated in the inner platform (Strbina), oolitic grainstone in the high-energy environment of the open platform (Tejani) and resedimented limestones with chert in the most distal deep-water environment of an open platform (Livari). Lack of boulder- or even pebble-sized grains at Livari does not fit the flat-topped carbonate platform/steep slope model presented by SCHEIBNER & REIJMER (1999). The probable geometry of the Pliensbachian platform was a ramp, with similar facies distribution as proposed by RUIZ-ORTIZ *et alii* (2004) for the Upper Member of the Gavilán Formation: 1) micritic limestones with bivalves typical of lithiotid facies in the inner platform; 2) oolitic grainstones with crinoids in a high-energy open platform; and 3) peloidal packstones and cherty limestones in low-energy open platform setting.

Shallow-water limestones with bivalves typical of lithiotid facies at Strbina (Montenegro) match the peritidal limestones of Trnovski gozd (Slovenia). Lithiotid limestones were the most widespread facies of the DCP during the Pliensbachian (see fig. 25 in DRAGIČEVIĆ & VELIĆ, 2002). Peritidal limestone of Trnovski gozd and lithiotid limestone of Strbina are comparable to numerous Tethyan localities (references in BUSER & DEBELJAK, 1996). The nearest example is the Rotzo Member of the Calcari Grigi Formation of the Trento Plateau (FUGAGNOLI & BROGLIO LORIGA, 1998). Both successions show cyclical sedimentation and contain identical fauna and flora. On the Trento Plateau cycles are subtidal and thickening upwards, and fossils include lithiotid bivalves, lituolid foraminifers and green algae.

Peloidal grainstone with oncoids from Trnovski gozd is correlative with wackestone to packstone containing intraclasts at Strbina. It is further correlative to the ?Pliensbachian-lower Toarcian Massone Oolite, which contains ooids, oncoids, bioclasts including lithiotid bivalves, and is rich in chaetetids (AVANZINI & BROGLIO LORIGA, 1996; FUGAGNOLI & BROGLIO LORIGA, 1998). The Massone Oolite is characteristic of the western and central part of the Trento Plateau (FUGAGNOLI & BROGLIO LORIGA, 1998).

The condensed interval with multiple ferruginous hardgrouds at Trnovski gozd records a shift from shallow-water environments to deeper-water settings. This interval is correlated with marly limestone containing sponge spicules, foraminifers and radiolarians at Livari and Tejani in Montenegro. Sedimentation of marly limestones in Montenegro and formation of multiple hardgrounds at Trnovski gozd is related to the maximum transgression in the early Toarcian (HALLAM, 1988) and regional drowning of carbonate platforms. The early Toarcian drowning episode is platform-wide and is characterized by several tens of meters of dark heavily bioturbated marly limestone («spotted limestone») in the internal parts of the DCP (e.g. DOZET, 1999; VLAHOVIĆ *et alii*, 2005) and mostly by shale in adjacent basins – Perbla Formation in Slovenian Basin (COUSIN, 1981) and base of Lastva Radiolarite in the Budva Basin (GORIČAN, 1994). The elevated clay content is well recorded also in a deep-platform environment (Tejani, Livari). Only a restricted area of the platform edge seems to have been subjected to permanent winnowing that prevented sedimentation of

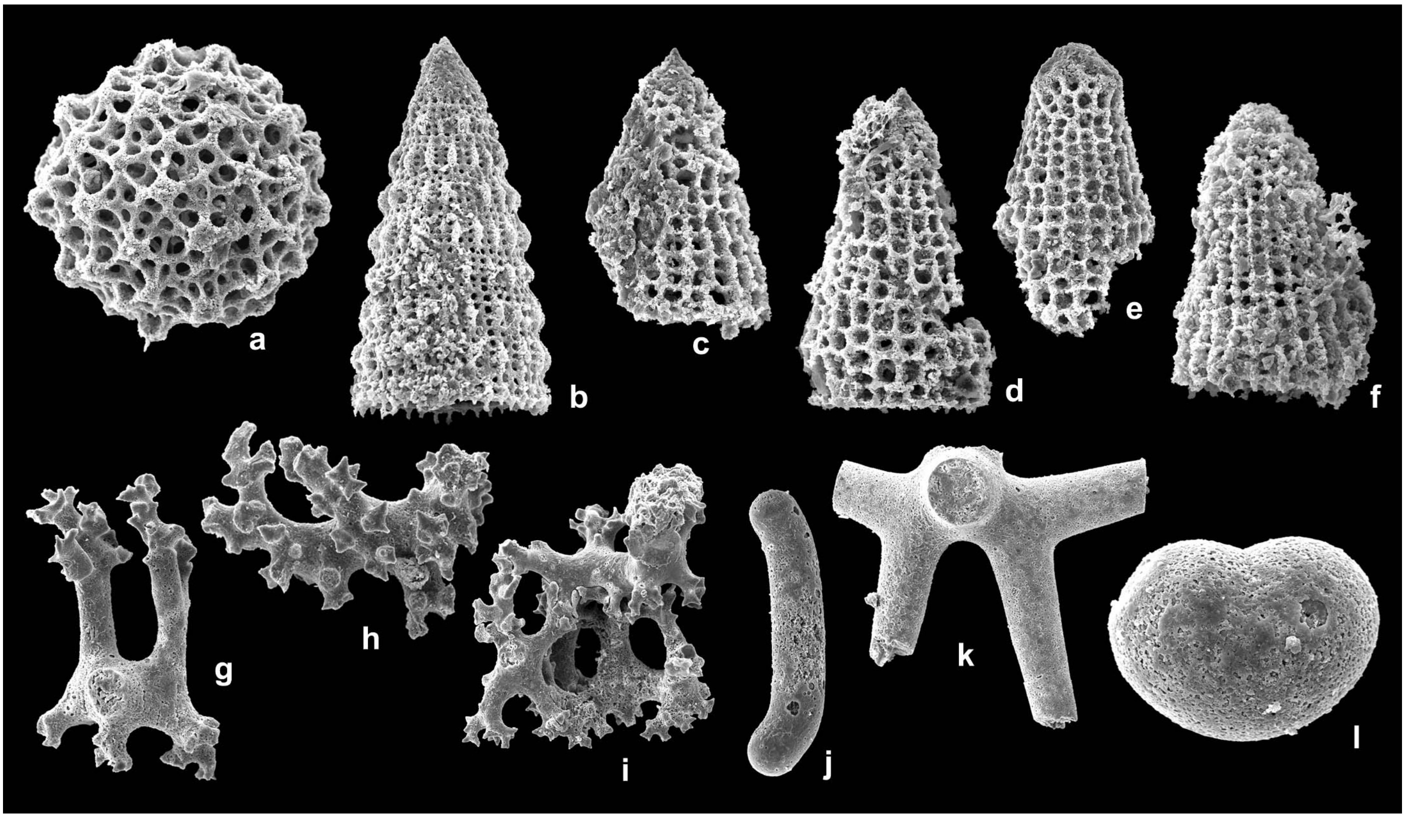


Fig. 8 - Radiolarians (*a-f*) and sponge spicules (*g-l*) from sample R8 (base of marly limestone, Tejani section). SEM negative number and magnification are given for each illustration: *a*) *Praeconocaryomma decora* gr. YEH, R8-061206, 200×; *b*) *Hsuum lucidum* YEH, R8-061212, 200×; *c, d*) *Parahsuum* cf. *longiconicum* SASHIDA, R8-061222, R8-061225, 200×; *e*) *Parahsuum* cf. *edenshawi* (CARTER), R8-061224, 200×; *f*) *Parahsuum* sp., R8-061202, 300×; *g, h, i*) lithistid desmas; *g*) R8-061233, 150×; *h*) R8-061231, 150×; *i*) R8-061234, 100×; *j, k*) other megascleres; *j*) R8-061240, 100×; *k*) R8-061238, 80×; *l*) rhax, R8-061243, 300×.

– Radiolari (a-f) *e spicole di spugna* (g-l) *del campione R8 (base del calcare marnoso, sezione di Tejani). Per ogni illustrazione vengono forniti il numero di identificazione della foto al SEM e l'ingrandimento:* a) Praeconocaryomma decora *gr. YEH, R8-061206, 200×;* b) Hsuum lucidum *YEH, R8-061212, 200×;* c, d) Parahsuum *cf.* longiconicum *SASHIDA, R8-061222, R8-061225, 200×;* e) Parahsuum *cf.* edenshawi *(CARTER), R8-061224, 200×;* f) Parahsuum *sp., R8-061202, 300×;* g, h, i) *lithistid desmas;* g) *R8-061233, 150×;* h) *R8-061231, 150×;* i) *R8-061234, 100×;* j, k) *altre megasclere;* j) *R8-061240, 100×;* k) *R8-061238, 80×;* l) *rhax, R8-061243, 300×.*

clay and resulted in condensed facies with hardgrounds (Trnovski gozd). Hardgrounds of Pliensbachian-Toarcian age are common in the Tethys area (e.g. DI STEFANO *et alii*, 2002), but most of them occur in pelagic settings. However, the formation of hardgrounds is controlled by local bathymetry and thus is often diachronous, which is also clearly evident from the correlation of Kovk at Trnovski gozd with Livari and Tejani sections. In addition to sea level rise, tectonic subsidence could have played an important role in drowning of the DCP margins. Early Jurassic tectonic subsidence was recognized regionally (WINTERER *et alii*, 1991). Locally it was determined as Pliensbachian on the Julian High (ŠMUC, 2005; ŠMUC & GORIČAN, 2005; ČRNE *et alii*, 2007) and on the Trento Plateau (WINTERER & BOSELLINI, 1981) in the Southern Alps, and could therefore also be of importance on the DCP margin. However, very deep water is not essential for termination of carbonate production (MALLARINO *et alii*, 2002). Productivity perturbations are known from carbonate platforms of the central-northern Apennines (GALLUZZO & SANTANTONIO, 2002) and of the High Atlas in Morocco (BLOMEIER & REIJMER, 1999) and may as well be the cause of DCP margin drowning. Marly limestone and condensed facies with hardgrounds are correlative to the lower and middle part of the San Vigilio Group of the Trento Plateau (BARBUJANI *et alii*, 1986); micritic limestones with sponge spicules and radiolarians of the Misone and Tenno Formations overlie the Calcari Grigi. A deepening trend in the late Pliensbachian-early Toarcian is observed on the western side of the Trento Plateau, where a continuous sedimentation without major hiatuses occurred.

The crinoidal-ooidal limestone with brachiopods at Trnovski gozd is correlated with brownish-reddish bioclastic limestone containing abundant brachiopod fauna at Livari and Tejani in Montenegro. The studied bioclastic limestones at all three successions exhibit a shallowing-upward trend, which we relate to the late Toarcian-Aalenian regression. Correlative carbonates of the Trento Plateau are the Red encrinites (BECCARELLI-BAUCK, 1988), directly overlying the Tenno Formation.

The last few almost exclusively oolitic beds at Trnovski gozd are correlated with the beginning of the oolitic grainstone sedimentation at Tejani. At Trnovski gozd the oolitic grainstone continues upsection, which indicates a complete recovery of the carbonate production after the incipient drowning. Oolitic grainstones of Trnovski gozd and Tejani are comparable to the San Vigilio Oolite, known from the western part of the Trento Plateau.

CONCLUSIONS

1) For the first time a transect on the SW margin of the DCP at Rumija in Montenegro is described.

a) A continuous Lower Jurassic succession of the DCP margin is presented (section Livari). It consists of: i) micritic limestone, overlying the Dachstein limestone; the contact approximately marks the T-J boundary; ii) calcareous fine-grained turbidites with chert, containing a middle subunit of chert-free oolitic limestone; iii) marly limestone reflecting the early Toarcian maximum transgression; and iv) bioclastic limestone with abundant brachiopods.

b) On the basis of three sections (Strbina, Tejani, Livari), the Pliensbachian platform-to-basin facies distribution in Montenegro is reconstructed as follows: lithiotid limestone in the inner platform, oolitic limestone in mid-ramp and resedimented limestones with chert in outer-ramp setting. Our data fit well with the ramp model established for the Early Jurassic in the Betic Cordillera of Southern Spain (Ruiz-Ortiz *et alii*, 2004).

2) The Kovk section, at Trnovski gozd in Slovenia, is lithologically almost identical to the most proximal succession of Montenegro, Strbina, which contains lithiotid limestone. Equivalents of sections at Livari and Tejani do not crop out in Slovenia and have neither been reported from the NE margin of the DCP, facing internal Dinaric domains. On the basis of data from Montenegro the geometry of a slightly southwestward dipping Lower Jurassic carbonate ramp is now demonstrated for the first time in the Dinarides.

3) Successions at the N and SW margin of the DCP contain several matching lithostratigraphic units and exhibit the same first order transgressive-regressive trends: i) transition from lithiotid limestone into peloidal grainstone with oncoids indicates a transgressive trend on both margins in the Pliensbachian; ii) platform drowning and precipitation of hardgrounds at Trnovski gozd and sedimentation of deeper-water marly limestone at Rumija are related to the lower Toarcian maximum transgression; and iii) the overlying crinoidal-ooidal limestone at Trnovski gozd and bioclastic limestone with brachiopods at Rumija both show a shallowing-upward trend and are overlain by oolitic limestone.

4) The studied successions are correlative with formations of the western part of the Trento Plateau: lithiotid limestone and peloidal limestone with oncoids correspond to the Calcari Grigi Formation (Rotzo and Massone members); marly limestone/condensed facies with hardgrounds, bioclastic limestone and oolitic limestone to the San Vigillio Group-Misone and Tenno Formations, Red encrinites and San Vigilio Oolite.

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