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THE MIDDLE JURASSIC TO LOWER CRETACEOUS SUCCESSION OF THE PONIKVE KLIPPE: THE SOUTHERNMOST OUTCROPS OF THE SLOVENIAN BASIN IN WESTERN SLOVENIA

BOŠTJAN ROŽIČ [1], ŠPELA GORIČAN [2], ASTRID ŠVARA [1] & ANDREJ ŠMUC [1]

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Abstract. The Slovenian Basin was a Mesozoic deep-water paleogeographic domain located north of the Dinaric Carbonate Platform. Due to a considerable amount of southward-directed thrusting and subsequent erosion, the marginal parts of this basin are only sparsely preserved. The southernmost remains of the Slovenian Basin in western Slovenia are found in the Ponikve Klippe, where we studied a Middle Jurassic (? Aalenian) to Lower Cretaceous (Albian) succession. We dated the succession with radiolarians, calpionellids, and benthic foraminifers.

The succession is divided into three formations. The first is the Middle Jurassic to Lower Tithonian Tolmin Formation, composed of radiolarian cherts, siliceous limestone, and calciturbidites. The second formation is the Upper Tithonian-Berriasian Biancone limestone, which consists of pelagic limestone with calpionellids and one interstratified calciturbidite. The third formation, the Lower flyschoid formation, rests upon a prominent, regionally recognized erosional unconformity. The formation begins with calcareous breccia and continues with finer-grained calciturbidites that alternate with marl/shale and chert. Only the lower part of this formation was investigated and dated to the late Aptian to early Albian.

The correlation of the studied section with the previously described successions of the Slovenian Basin shows that the Jurassic part of the section clearly exhibits a more marginal setting, whereas the Cretaceous part of the section correlates well with the central basinal succession. This inversion was related to the late Aptian tectonic event that was also responsible for the considerable submarine erosion and deposition of the basal breccia of the Lower flyschoid formation.

Introduction

The Slovenian Basin was a Mesozoic deep-water paleogeographic unit situated between the south-lying Dinaric (or Adriatic, sensu Vlahović et al. 2005) Carbonate Platform and the north-lying Julian Carbonate Platform (Buser 1989, 1996). The latter drowned during the Jurassic and first turned into a submarine plateau

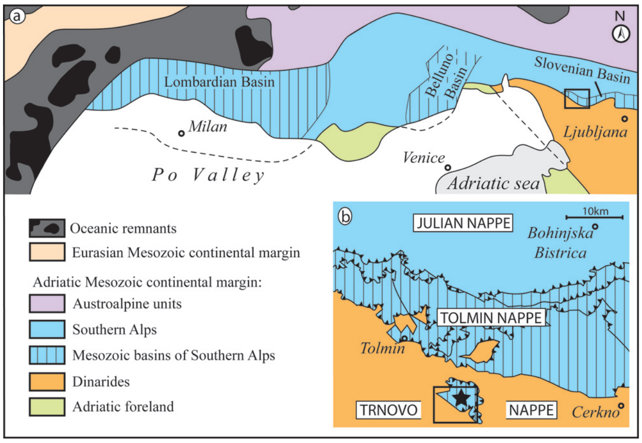

Fig. 1 - a) General location of the studied area within the South-Alpine realm; the boxed area is enlarged in Figure 1b (Channell & Kozur 1997 with modifications from Bosellini et al. 1981; Martire 1992; and Placer 1999); b) geotectonic map of the South-Alpine-Dinaric transition (modified from Buser 1987), with a star marking the position of the studied section; Julian Nappe with successions of the Julian Carbonate Platform, Tolmin Nappe composed of the Slovenian Basin successions, Trnovo Nappe with successions of the Dinaric (Adriatic) Carbonate Platform. Internal tectonical elements within Tolmin Nappe separate lower-order thrust units (simple line: neotectonic strike-slip faults; line with triangles: South-Alpine thrust-faults); the boxed area is enlarged in Figure 2.

1 Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Privoz 11, SI-1000 Ljubljana, Slovenia. E-mail: bostjan.rozic@ntf.uni-lj.si
2 Ivan Rakovec Institute of Paleontology, ZRC SAZU, Novi trg 2, SI-1000 Ljubljana, Slovenia. E-mail: spela@zrc-sazu.si

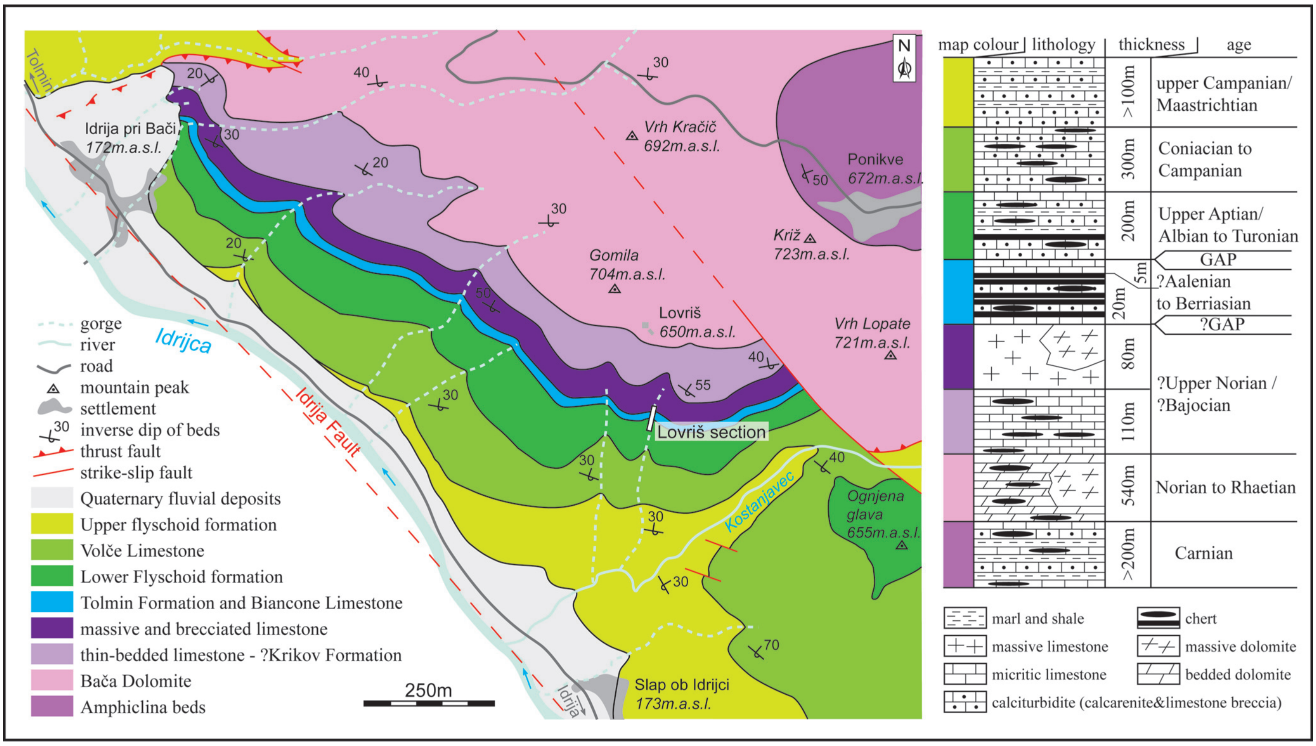

Fig. 2 - Geological map with schematic stratigraphic column of the Ponikve Klippe.

known as the Julian High. This paleotopographic difference with the Slovenian Basin was diminished at the end of the Jurassic (Buser 1996; Šmuc 2005; Šmuc & Rožič 2010). In present-day western Slovenia (Fig. 1a, b), the successions of the Slovenian Basin belong to the Tolmin Nappe, which is overthrust by the Julian Nappe, composed of Julian Carbonate Platform successions. These two south-vergent nappes originated during the Miocene and form the eastern continuation of the Southern Alps. To the south, the Slovenian Basin successions are thrust over the Dinarides, which are characterized by slightly older southwest-vergent thrusting and composed of Dinaric Carbonate Platform successions (Buser 1986, 1987; Placer 1999, 2008). The general sedimentary evolution of the Slovenian Basin has been well known for decades (Cousin 1970, 1973, 1981; Caron & Cousin 1972; Buser 1989, 1996). However, detailed work in the last decade has considerably improved our understanding of this rather complex paleogeographic unit (Rožič 2005, 2009; Rožič & Popit 2006; Rožič et al. 2009; Gale 2010; Rožič & Šmuc 2011; Oprčkal et al. 2012; Gale et al. 2012; Goričan et al. 2012a, b; Rožič et al. 2012). The main Mesozoic paleogeographic units are today bound to the individual thrust-units and the transitional areas between the units are tectonically highly obliterated, not exposed due to overthrusting, or not preserved due to erosion. Consequently, spatial paleogeographic reconstruction of the slopes (i.e., shape, inclination, channel-cut vs. apron fed, etc.) between the units remains questionable and mainly unresolved. Some light was shed on the basin's northern slope by the study of newly discovered Jurassic successions of marginal blocks in the Mt Kobla area (Rožič & Šmuc 2009). Conversely, the southern transition with the Dinaric Carbonate Platform remains practically unstudied.

All previously mentioned studies were performed in the Tolmin Nappe, a continuous basinal facies belt found today in the foothills of the Julian Alps extending eastward from Tolmin town. These successions all show continuous basinal successions characteristic of inner basinal domains. To the south, they are clearly limited by the east-west trending South-Alpine thrust front (Placer 1999). Nevertheless, a succession of the Slovenian Basin reappears southward in the Ponikve Klippe, which represents the only erosional remnant of the Tolmin Nappe preserved today south of the South-Alpine thrust front (Buser 1987; Placer 1999, 2008). The succession that composes this structural unit is believed to have originated in the southernmost still-preserved part of the Slovenian Basin. The Middle Jurassic to Lower Cretaceous part of an Upper Triassic – Upper Cretaceous succession is fully exposed in the gorge southwest of the village of Ponikve and was studied in detail with the aim of reconstructing the sedimentary evolution of the basin's southern margin and correlating the investigated section with the rest of the Slovenian Basin.

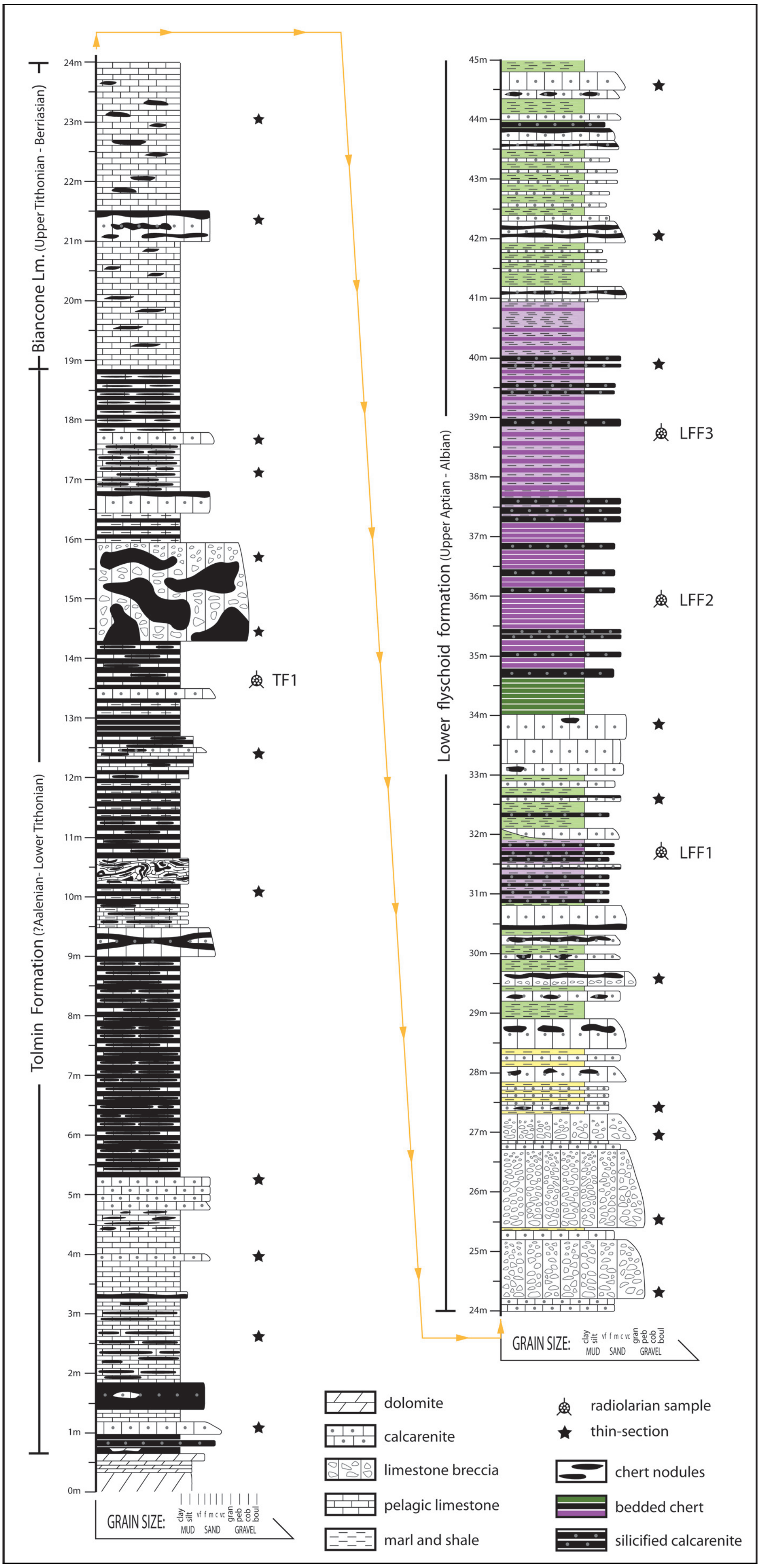

Fig. 3 - The Lovriš section, with the position of thin sections and radiolarian samples.

Geological setting

The studied section (Lovriš section, Fig. 2) is located in the Ponikve Plateau, which is named after its largest village and situated between deeply incised valleys of the Bača River towards the north and the Idrijca River towards the southwest. Structurally, the area surrounding the Ponikve Plateau (see Fig. 1b) belongs to the Trnovo Nappe of the Dinarides (Placer 1999, 2008), which is characterized by Triassic and Jurassic shallow-water carbonates of the Dinaric Carbonate Platform. These platform carbonates end with a prominent gap and are overlain by Coniacian-Campanian calcareous turbidites (the Volče Limestone) or directly by the Maastrichtian Upper flyschoid formation (Ogorelec et al. 1976; Buser 1986, 1987). The Ponikve Plateau and its southwestern slopes are composed of the structurally higher Ponikve Klippe, composed of basinal succession. This structural unit was previously part of the Tolmin Nappe and today represents its only erosional remains south of the South-Alpine thrust front that extends along the Bača River. The Ponikve Klippe is the lower limb of an overturned anticline (Buser 1986, 1987); all strata are in overturned position and dip towards north to northeast (Fig. 2). The contact between the Ponikve Klippe and the underlying Trnovo Nappe is dissected by neotectonic strike-slip faults, among which the NW-SE dextral Idrija Fault is the most prominent.

The stratigraphy of the Ponikve Klippe (Fig. 2) consists of several lithostratigraphic units that characterize the entire area of the Tolmin Nappe. Names and ages of these units are given according to previous studies in this broader area (Caron & Cousin 1972; Cousin 1973; Buser 1986; Rožič 2009). The succession of the Ponikve Klippe starts with Carnian "Amphiclina beds", a formation characterized by alternating micritic limestone with chert and shale, whereas calcarenites (calciturbidites) occur sporadically. The Norian-Rhaetian is characterized by the 540-m-thick Bača Dolomite Formation, which is characterized by bedded dolomite with chert nodules that laterally pass into massive dolomite. With a sharp contact, the Bača Dolomite is overlain by a 100-m-thick succession of thin-bedded micritic limestone with chert nodules of uncertain chronostratigraphic position. The facies is very similar to the Hettangian to Pliensbachian Krikov Formation from the southern part of the Slovenian Basin (Rožič 2009; Goričan et al. 2012b), but could also correlate with the Upper Norian to Rhaetian Slatnik Formation known from the northernmost part of the basin (Rožič et al. 2009; Gale et al. 2012). This formation is overlain by 80-m-thick, partly brecciated and dolomitized massive limestone that contains abundant Late Triassic coral-reef fauna and yielded Sevatian-early Rhaetian conodonts in the topmost part. This formation is known so far only from the Ponikve Klippe (Rožič et al. 2013) and is still under research. With a sharp contact, this massive limestone is overlain by the 18-m-thick, Middle Jurassic to Lower Tithonian Tolmin Formation, which is composed of thin-bedded radiolarian chert, siliceous limestone, and calciturbidites. The Jurassic ends with an Upper Tithonian-Berriasian Biancone limestone formation only 5 m thick and composed of calpionellid-bearing micritic limestone. The Lower Cretaceous is marked by an important, regionally documented gap that spans from the Berriasian to the upper Aptian or lower Albian. The overlying Lower flyschoid formation is 200 m thick, generally starts with calcareous breccia, and, up section, is marked by alternating marl and calciturbidites that usually contain replacement-chert nodules. Red thin-bedded cherts occur at the base of the formation. In the upper part, the formation passes through upper Cenomanian-Turonian red marly limestone (also known in the literature as *Globotruncana* limestone or Scaglia Rossa) to the Coniacian-Campanian Volče Limestone Formation, which is 300 m thick and composed of alternating micritic (pelagic) limestone and calciturbidites with chert nodules. The succession ends with the ?upper Campanian-Maastrichtian Upper flyschoid formation, which closely resembles the Lower flyschoid formation but lacks any silicification and additionally contains limestone breccia megabeds up to a few metres thick. In the studied section, the Tolmin Formation, Biancone limestone formation, and basal part of the Lower flyschoid formation were investigated.

Lovriš Section

The investigated section is located in the gorge that cuts the southwestern slope of the Ponikve Plateau near the Lovriš Farm (Fig. 2, N 46° 07‘ 51“, E 13° 48‘ 24“). The section covers 45 m of the succession and is in overturned position. Three distinctive formations are recognized in the section that encompass the Middle Jurassic to Albian interval with a prominent gap within the Lower Cretaceous (Fig. 3, Pl. 1, fig. 1).

Tolmin Formation

The Tolmin Formation is underlain by massive dolomite that shows a few thin beds in the topmost part (Fig. 3, Pl. 1, fig. 2) and laterally passes into massive limestone. Above the dolomite, three 10-cm-thick black highly siliceous beds occur, the middle one exhibiting a calcarenitic primary texture. They are followed by a 20-cm-thick graded calcarenite bed and further upwards by an equally thick interval of thin-bedded grey biomicritic limestone. This basal part ends with 40 cm of calcarenite that is almost entirely silicified (Pl. 1, fig. 2). The next 3 m are composed of grey thin-bedded biomicritic limestone, with occasional chert nodules and a single thin bed (10 cm) of graded calcarenite. Upwards, four amalgamated 10-cm calcarenite beds are present. The following 9 m are dominated by thin-bedded alternating

PLATE 1

Photographs from the Lovriš section (for all figures in this plate note that the entire succession is in overturned position)

Fig. 1 - The Lovriš section consists of the Tolmin Formation, Biancone limestone formation, and the basal interval of the 200-m-thick Lower flyschoid formation.

Fig. 2 - Sharp contact between the stratigraphically older massive limestone (and dolomite) and the thin-bedded Tolmin Formation marked by an arrow.

Fig. 3 - Strongly silicified, 1.75-m-thick, graded limestone breccia of the Tolmin Formation with the top of the bed consisting of completely silicified calcarenite (seen at the base of the photograph).

Fig. 4 - Erosional contact (arrow) between the Biancone limestone and the basal limestone breccia and calcarenites of the Lower flyschoid formation. Downward, i.e. stratigraphicaly upward, the calciturbidites start to alternate with marl/shale and chert.

Fig. 5 - Alternating violet cherts, shale, and strongly silicified calciturbidites (Lower flyschoid formation). The arrow points to a load cast or a sole mark at the base of the 10-cm-thick calciturbidite bed, which provides an additional evidence for the overturned position of the succession.


1
2
3
4
5
massive limestone
Tolmin Formation
Biancone Limestone
Lower flyschoid formation
5m
10m
20m
30m
35m
40m
45m

dark grey siliceous biomicritic limestone and black chert. Occasionally limestone is slightly marly. At 10.5 m, a 0.5-m-thick slumped interval is recognizable. The entire interval contains three beds (50, 10, and 20 cm) of graded calcarenite. The section continues with the most prominent bed of the unit, a 1.75-m-thick limestone breccia that grades into coarse calcarenite (Pl. 1, fig. 3). This bed is strongly silicified, where chert occurs as irregularly shaped large nodules or selectively replaces larger bioclasts. The formation continues for the next 3 m and is dominated by alternating thin-bedded dark-coloured cherts, siliceous limestone, and, just above a breccia, also marly limestone. Two calcarenite beds occur in this interval. The lower bed is 40 cm thick and replaced by chert in the upper portion of the bed, whereas the upper bed is 20 cm thick and graded. The boundary with the overlying Biancone limestone formation is placed at 18.8 m of the section, where chert beds disappear.

The finest-grained sediments of the Tolmin Formation are thin-bedded wackestone, rarely lime mudstone. Occasionally parallel or slightly wavy laminae are distinguishable. Grains are biogenic and belong predominantly to radiolarians that exhibit a variable degree of calcification. Ostracods occur sporadically. Silicification is poor at the base of the unit and becomes very intense upwards, where radiolarian cherts are also interstratified.

Two main microfacies are distinguished within coarse- to medium-grained calcarenites. At the base of the formation, these beds are grainstone composed of ooids, lithoclasts, fossils, pellets/peloids, and rarer intraclasts (Pl. 2, fig. 1). Within the ooids, two groups are outlined: the largest ooids are strongly micritized and tangential, whereas the smallest ones are rarer and mostly show a radial-fibrous structure. Occasionally, grapestones composed of ooids appear. Fossils are echinoderms and rarer fragmented bivalve shells, recrystallized calcisponges (often a few millimetres in size), and foraminifers, among which trocholinas predominate. Lithoclasts are divided into five groups: A) fine- to medium-grained packstone/grainstone with pellets/peloids, intraclasts, and rarer ooids and fossils, B) mudstone/wackestone with calcified radiolarians and spicules, thin-shelled bivalves, and pellets, C) poorly sorted packstone with dominant pellets and rare large intraclasts, fossils, or ooids, D) medium-grained grainstone with intraclasts, and E) medium-grained, often recrystallized packstone that occasionally shows fenestral structure and is composed of pellets, intraclasts, and rare foraminifers.

The second coarse- to medium-grained microfacies occurs in the upper part of the formation (above 9 m of the section, Fig. 3). It is grainstone/packstone composed of intraclasts and bioclasts (Pl. 2, fig. 2). Intraclasts represent up to 70% of all grains and are micritic or show some internal structure, revealing either a shallow-water or a deep-water (mud-chips) origin of these grains. Some grains are well rounded, isometric, and predominantly micritic with small oval sparitic fields in the centre and could belong to *Tubiphytes* sp. Ooids are very rare and small-sized (up to 200 μm). Fossils represent up to 40% (usually 30%) of all grains and are dominated by echinoderms, typically with syntaxial cement overgrowths. Other rare bioclasts are benthic foraminifers. Sporadic calcispheres (or calcified sponge spicules/radiolarians) and red algae fragments occur in some beds.

There is no apparent difference in composition within the fine-grained calcarenite throughout the formation. This microfacies forms thin beds or upper portions of graded beds. It is packstone composed of pellets/peloids (? very fine intraclasts) and calcified radiolarians (Pl. 2, fig. 3). When laminated, some laminae in the finest parts of beds are the previously described wackestone. At the very top of a bed at 11.1 m of the

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PLATE 2

Microfacies of Tolmin and Biancone formations.

Fig. 1 - Tolmin Formation; coarse-grained grainstone with micritized tangential ooids, rare small radial-fibrous ooids, pellets, and bioclasts with *Trocholina sp*. (in the upper right corner); 1.0 m of the section.

Fig. 2 - Tolmin Formation; coarse-grained grainstone with intraclasts, peloids, micritized ooid (left margin of the photograph), and bioclasts, mainly echinoderms and benthic foraminifers (?*Mohlerina* sp.); 17.7 m of the section.

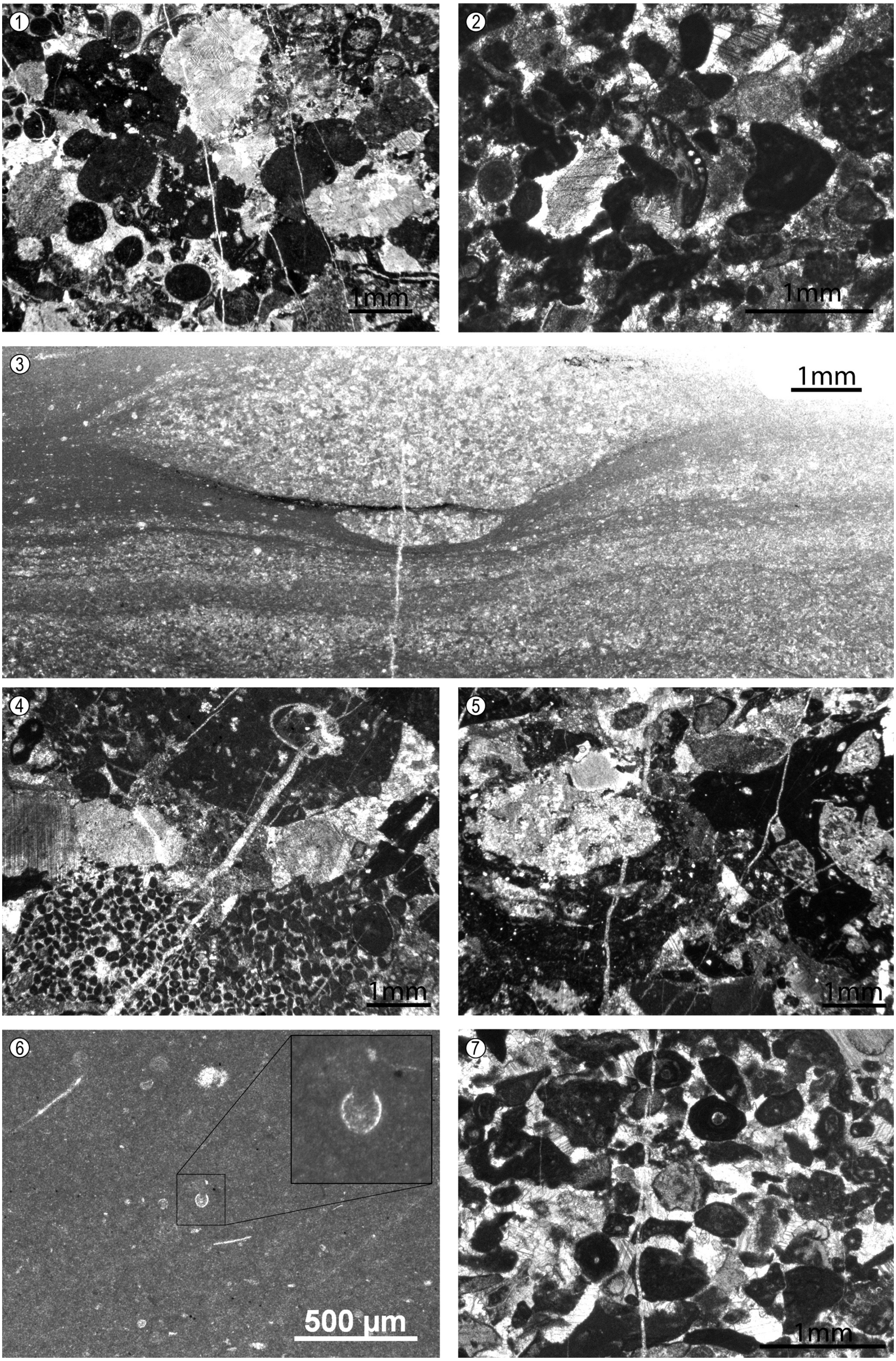
Fig. 3 - Tolmin Formation; slightly compacted packstone burrow between wrapped laminae of alternating wackestone and packstone. Grains in wackestone are bioclasts with predominant calcitized radiolarians, whereas packstone is fine-grained and consists of pellets/small intraclasts and bioclasts including numerous calcified radiolarians; 10.1 m of the section.

Fig. 4 - Tolmin Formation; rudstone with bio/intraclastic grainstone matrix (as in fig. 2) and two clasts of: a) wackestone with large bioclasts and intraclasts (above) and b) coarse-grained grainstone composed of intraclasts, peloids, and ooids (below); 14.4 m of the section.

Fig. 5 - Tolmin Formation; rudstone with bio/intraclastic grainstone matrix (as in fig. 2) and two clasts showing intergrowth of recrystallized calcisponges and microbialites; 14.4 m of the section.

Fig. 6 - Biancone Limestone; mudstone with calcified radiolarians, calpionellids, and fragmented thin-shelled bivalves; *Calpionella alpina* Lorenz is enlarged in the upper right corner; 23.0 m of the section.

Fig. 7 - Biancone Limestone; coarse-grained grainstone similar in composition to bio/intraclastic grainstone of the Tolmin Formation (this plate, fig. 2) with additionally present *Tubiphytes* sp. grains; 21.3 m of the section.


1
1mm
2
1mm
3
1mm
4
1mm
5
1mm
6
500 µm
7
1mm

section, a rounded portion of fine-grained packstone, 8 mm in size, is enclosed in the wackestone (Pl. 2, fig. 3). The shape is ellipsoidal and laminae in surrounding wackestone are wrapped around the grain. The base of the body is separated by thin micritic film and could belong to an additional smaller packstone body, or the film could originate from a small-scale dissolution seam. These bodies are interpreted as slightly compacted burrow, but could also be a sand-ball originating from the disintegration of load cast from the overlying bed.

The limestone breccia bed (around the 15th metre of the section, Fig. 3) is a rudstone with some clasts up to 10 cm in size (Pl. 2, fig. 4). The texture is bimodal with a matrix of the previously described bio/intraclastic calcarenite and larger clasts. In the calcarenitic matrix, bivalve shells and some foraminifers were also observed. Within the lithoclasts six main groups are outlined: A) fine-grained packstone with pellets, peloids, benthic foraminifers, echinoderms, calcispheres (? calcified sponge spicules), a single *Thaumatoporella*, and unrecognizable bioclastic debris, B) wackestone with relatively large (up to 550 μm) peloids and bioclasts, mostly echinoderms (Pl. 2, fig. 4), C) mudstone with calcified radiolarians, thin-shelled bivalves, and rare small lagenid foraminifers, D) grainstone with small (up to 200 μm) intraclasts, peloids (Pl. 2, fig. 4), and ooids, some strongly micritized, E) recrystallized packstone with pellets and fenestral structure, and F) coarse-grained grainstone with irregularly shaped intraclasts, microbialites, recrystallized calcisponges, and rare pellets. At the base of the bed, large bioclasts are abundant. Predominantly they belong to diverse calcisponges (stromatoporoids) that occasionally show intergrowth with microbialites and encrusting foraminifers (Pl. 2, fig. 5).

Biancone limestone formation

The Biancone limestone formation is 5.2 m thick (Fig. 3) and characterized by thin-bedded micritic light-grey limestone with rare chert nodules. It contains a 50-cm-thick calcarenite bed. The contact with the overlying unit is sharp (Pl. 1, fig. 4).

The thin-bedded limestone is wackestone, rarely mudstone, occasionally exhibiting parallel lamination. Grains are calcified radiolarians and calpionellids (Pl. 2, fig. 6). Other rare grains are thin-shelled bivalves, small benthic foraminifers of the genus *Lenticulina*, and calcified sponge spicules.

In structure and composition, the calcarenite bed closely resembles the coarse- to medium-grained calcarenite of the underlying formation. More abundant are spherical, concentrical grains with small oval sparitic centers. Usually, these grains are up to 200 μm large and mostly belong to *Tubiphytes* sp. (Pl. 2, fig. 7). Some larger grains show curved concentric lamination and could be oncoids.

Lower flyschoid formation

The Lower flyschoid formation is 200 m thick (Fig. 3), of which the basal 21 m are well exposed and were studied in the Lovriš section. The formation begins with a 3.3-m-thick basal interval dominated by graded limestone breccia and subordinate calcarenites (Pl. 1, fig. 4). Below the second thick breccia bed, a very thin interval of yellowish-brown marl is present. The next 5.3 m are composed of alternating calcarenites and marl, the latter changing in colour from yellowish-brown to green, violet, and green again. At 31.8 m of the section, a thin bed of violet chert occurs that yielded datable radiolarians. Calcarenites in this interval are often silicified. Usually, they contain chert nodules, whereas in the violet interval they are completely replaced by dark-grey to black vitreous chert. The section continues with three calcarenite beds (20, 40, and 40 cm) that exhibit only minor silicification. The following 7 m are chert-dominated: all calcarenites are completely replaced by black vitreous chert and are interlayered with thin-bedded chert at the beginning of the interval, whereas marl and shale start to occur after 3.5 m (Pl. 1, fig. 5) and become dominant at the last metre of the interval. With the exception of the first, greenish 0.6 m, the entire interval is violet-coloured. The last 4 m of the studied section are alternating green

PLATE 3

Microfacies of Lower flyschoid formation.

Fig. 1 - Chert; SEM photomicrograph of HF-etched rock surface showing the high proportion of sponge spicules and rare radiolarians (sample LFF 1).

Fig. 2 - Coarse-grained grainstone with intraclasts and bioclasts, mostly echinoderm plates, fragmented bivalve shells, and orbitolinas; 26.9 m of the section.

Fig. 3 - Large *Orbitolina* in grainstone with some small lithoclasts to the right of the foraminifer; 25.5 m of the section.

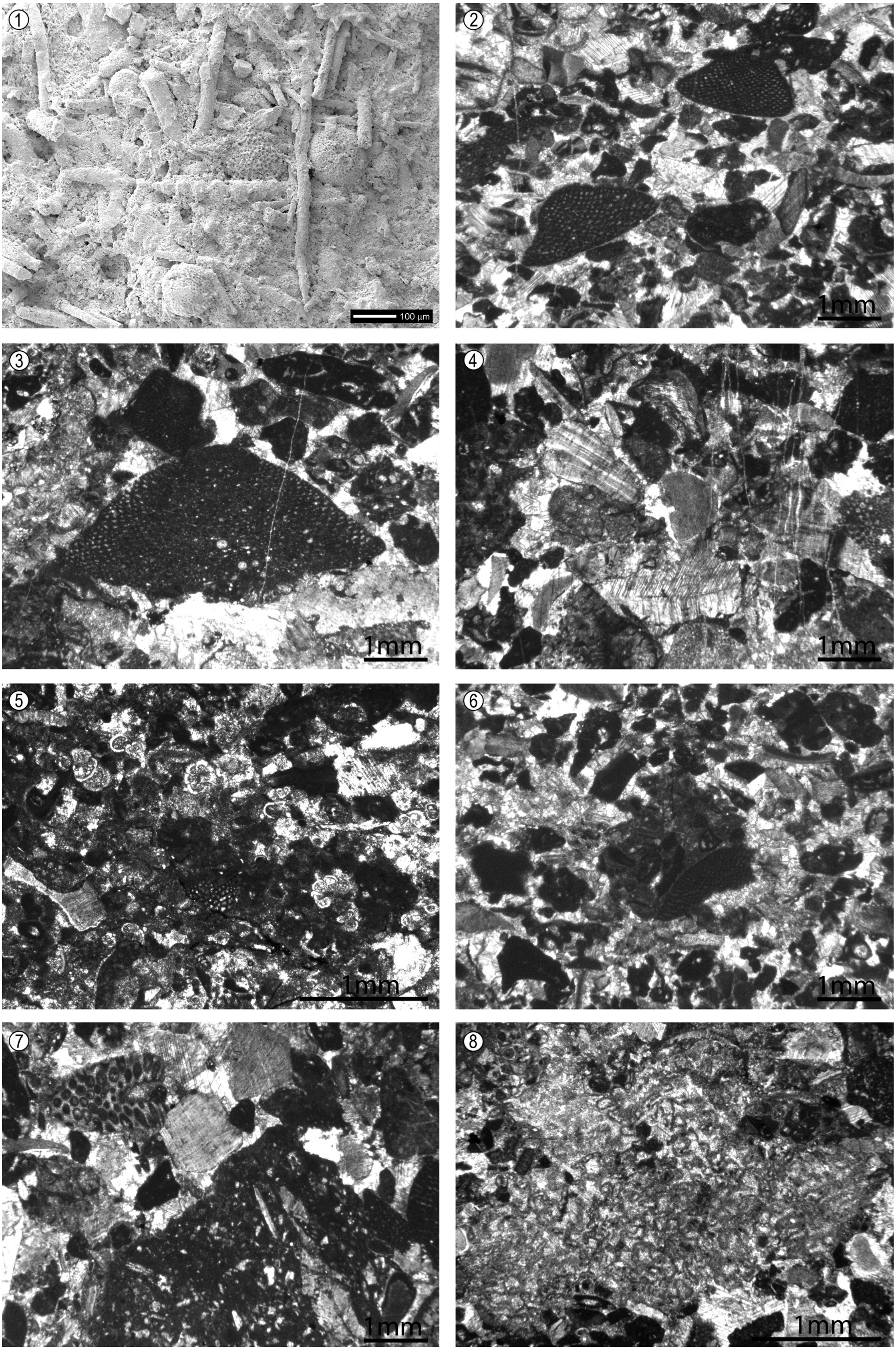
Fig. 4 - Diverse types of fragmented bivalve and brachiopod shells in grainstone; 25.5 m of the section; 25.5 m of the section.

Fig. 5 - Fine-grained packstone with intraclasts, pellets, and bioclasts, among which echinoderm plates and planktonic and benthic foraminifers are recognized; 27.4 m of the section.

Fig. 6 - Coarse-grained grainstone with a packstone lithoclast composed of a large *Orbitolina* fragment, other benthic foraminifers, and intraclasts; 32.6 m of the section.

Fig. 7 - Rudstone with grainstone matrix, large dasycladacean algae, and a wackestone lithoclast composed of pellets and bioclasts with recognizable small pelagic foraminifers at the lower-left end of the grain; 25.5 m of the section.

Fig. 8 - Calcisponge as a large clast in the rudstone described in a previous figure; 26.9 m of the section.


1
100 µm
2
1mm
3
1mm
4
1mm
5
1mm
6
1mm
7
1mm
8
1mm

marl and calcarenites that are often graded and partially silicified.

At the base and the top of the formation, the fine sediments are marl, whereas between 30.5 and 41 m of the section they turn into alternating chert and shale. Chert beds are composed mostly of sponge spicules, radiolarians being less abundant (Pl. 3, fig. 1).

Calcarenites are grainstone composed of intraclasts and fossils (Pl. 3, fig. 2), each representing approximately half of all grains. Intraclasts are mostly well rounded and elongated. Often they show internal recrystallization to microsparite. The internal structure is locally recognizable and includes either peloids/pellets or oval pores filled with sparite (? calcified radiolarians). Oncoids with poorly visible, dense micritic internal structure occur sporadically. Among fossils, echinoderms predominate. Benthic foraminifers are also common and belong to the genera *Orbitolina* (Pl. 3, figs. 2, 3), *Textularia*, *Lenticulina*, and miliolids. Further bioclasts are bivalves with three main types of shells; two types exhibit prismatic structure, where crystal axes are oriented either perpendicular or parallel to the shell walls and one type has fibrous structure (Pl. 3, fig. 4). The last group at least partially belongs to brachiopods. Other fossils are fragments of red algae, bryozoans, calcisponges, and other unrecognizable biogenic debris. Some small lithoclasts are also present and correspond to clasts in limestone breccia that are described in the next paragraph (Pl. 3, fig. 6). In the upper part of the graded calcarenite, the texture turns into packstone and pelagic foraminifers start to occur (Pl. 3, fig. 5).

The limestone breccia forms the base of the formation, is poorly sorted, and grades into coarse-grained calcarenite. It is rudstone composed mostly of diverse lithoclasts, intraclasts, and fossils. Fossils and intraclasts are very similar in composition to those occurring in the previously described calcarenite. Among the fossils, echinoderms predominate, whereas other frequent grains are bivalve shells and foraminifers, among which large orbitolinas stand out. Additionally, large, i.e. pebble-sized calcisponges and dasycladacean algae occur (Pl. 3, fig. 7), the first being particularly frequent in the basal breccia bed (Pl. 3, fig. 8). The lithoclasts are divided into four main groups: A) wackestone to packstone with diverse fossils, mostly bivalves, foraminifers (*Orbitolina* and *Textularia*), echinoderms, and some pellets (Pl. 3, fig. 6), B) wackestone with pelagic bioclasts: either ammonites, ? calcified radiolarians, or globigerinas (Pl. 3, fig. 7), C) fine-grained packstone with pellets, small intraclasts, and rare echinoderms and bivalves, and D) rare clasts of medium-grained grainstone with ooids, intraclasts, and oncoids cemented by rim and mosaic sparite.

Biostratigraphy

The biostratigraphy of the studied section is based on planktonic fossils, namely radiolarians (Pl. 4) and calpionellids. It is further constrained by benthic fossils found in the coarse-grained beds.

In the Tolmin Formation, radiolarians are common but very poorly preserved; determinable radiolar-

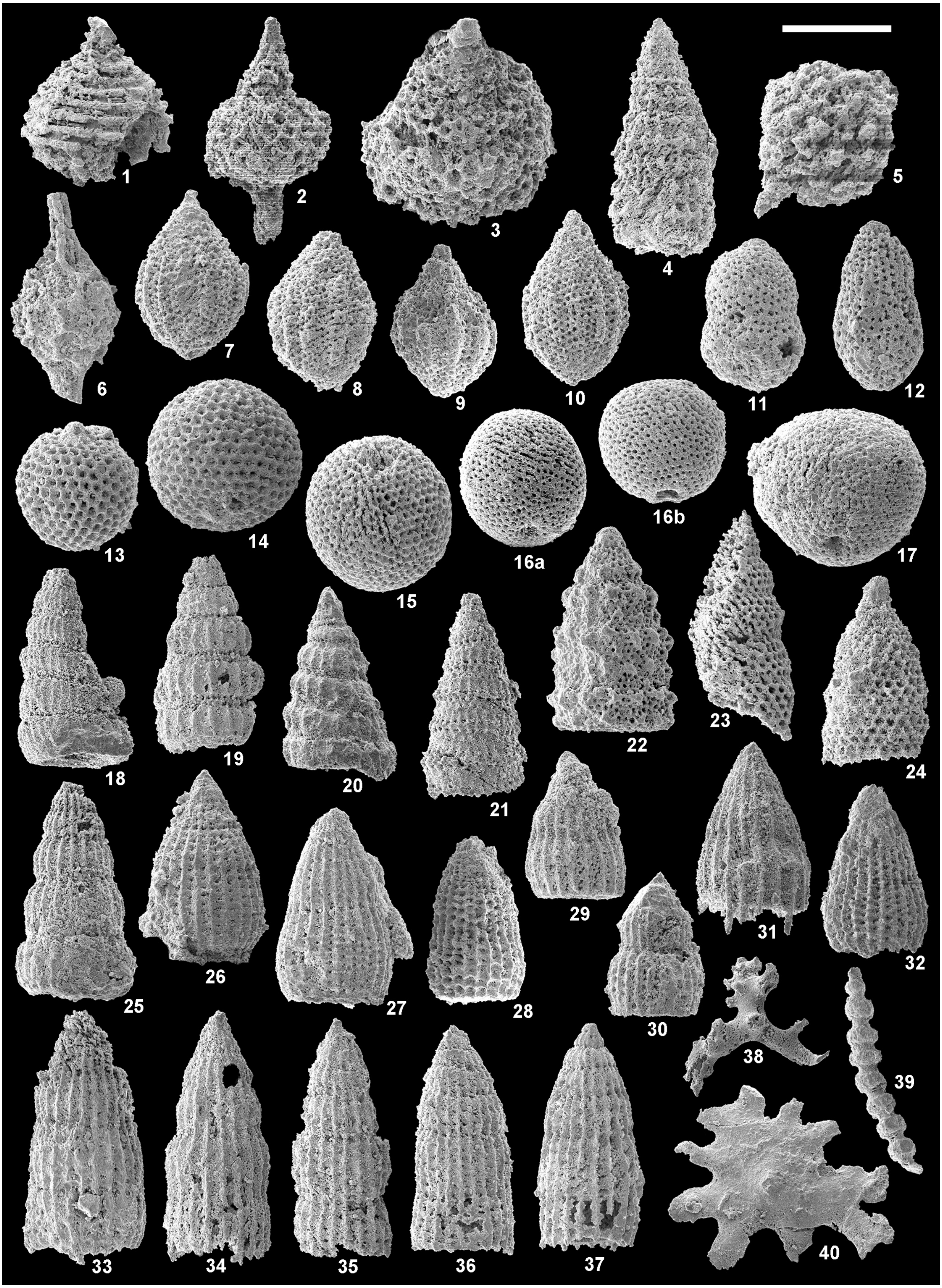
PLATE 4

Radiolarians and sponge spicules from the Lovriš section. For each illustration, the sample number, scanning electron micrograph number, and magnification (length of scale bar) are indicated. Rock samples, residues, and illustrated specimens are stored at the Ivan Rakovec Institute of Paleontology ZRC SAZU, Ljubljana.

Figs 1-5 - Upper Jurassic radiolarians from the Tolmin Formation. 1) *Mirifusus dianae minor* Baumgartner, TF 1, nº 120102, scale bar 200 μm. 2) *Spinosicapsa*? sp. (lateral spines probably broken off), TF 1, nº 120121, scale bar 133 μm. 3) *Palinandromeda crassa* (Baumgartner), TF 1, nº 120104, scale bar 200 μm. 4) *Transhsuum brevicostatum* (Ožvoldova), TF 1, nº 120117, scale bar 133 μm. 5) *Emiluvia orea* Baumgartner, TF 1, nº 120108, scale bar 133 μm.

Figs 6-37 - Aptian-Albian radiolarians from the Lower flyschoid formation. 6) *Pantanellium* sp., LFF 1, nº 120203, scale bar 100 μm. 7-10) *Turbocapsula costata* (Wu), 7 - LFF 1, nº 120209; 8- LFF 1, nº 120207; 9 -LFF 2, nº 120312; 10 - LFF 2, nº 120310; scale bar 100 μm. 11) *Diacanthocapsa betica* O'Dogherty, LFF 3, nº 120403; scale bar 80 μm. 12) *Diacanthocapsa* sp., LFF 2, nº 120320; scale bar 80 μm. 13,14) *Cryptamphorella conara* (Foreman), 13 - LFF 2, nº 120326; 14 - LFF 3, nº 120426; apical view; scale bar 100 μm. 15-17) *Holocryptocanium barbui* Dumitrica, 15 - LFF 1, nº 120227, apical view; 16 a,b) LFF 2, nº 120317, nº 120316, apical and antapical views of the same specimen; 17) LFF 3, nº 120427, apical view; scale bar 100 μm. 18) *Pseudodictyomitra lodogaensis* Pessagno, LFF 3, nº 120414; scale bar 80 μm. 19) *Pseudodictyomitra* sp., LFF 2, nº120321; scale bar 100 μm. 20) *Pseudodictyomitra* cf. *hornatissima* (Squinabol), LFF 1, nº 120218, scale bar 100 μm. 21) *Svinitzium* sp., LFF 3, nº 120404; scale bar 100 μm. 22) *Xitus clava* (Parona), LFF 1, nº 120211, scale bar 100 μm. 23) *Stichomitra*? *communis* Squinabol, LFF 2, nº 120306; scale bar 100 μm. 24) *Stichomitra*? *mediocris* (Tan), LFF 3, nº 120421; scale bar 100 μm. 25) *Archaeodictyomitra* cf. *communis* (Squinabol), LFF 1, nº 120201, scale bar 100 μm. 26-32) *Thanarla brouweri* (Tan), 26 - LFF 1, nº 120219; 27 - LFF 3, nº 120440; 28 - LFF 1, nº 120223; 29 - LFF 2, nº 120318; 30 - LFF 1, nº 120213; 31 - LFF 3, nº 120439; 32 - LFF 3, nº 120415, scale bar 100 μm. 33-37) *Archaeodictyomitra montisserei* (Squinabol), 33 - LFF 2, nº 120303; 34 - LFF 3, nº 120433; 35 - LFF 3, nº 120419; 36 - LFF 3, nº 120435; 37 - LFF 3, nº 120428, scale bar 100 μm.

Figs 38-40 - Sponge spicules from the Lower flyschoid formation. 38) Lithistid desma, LFF 2, nº 120336, scale bar 200 μm. 39) Cricorhabd, LFF 2, nº 120338, scale bar 200 μm. 40) Phyllotriaene, LFF 1, nº 120230, scale bar 200 μm.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Species Samples	range (in UAs)	LFF 1	LFF 2	LFF 3
Archaeodictyomitra communis (Squinabol) (Pl. 4, fig. 25)	1-9	cf.	cf.	
Archaeodictyomitra montisserei (Squinabol) (Pl. 4, figs. 33-37)	10-20		X	X
Cryptamphorella conara (Foreman) (Pl. 4, figs. 13-14)		X	X	X
Diacanthocapsa betica O'Dogherty (Pl. 4, fig. 11)	4-9			X
Diacanthocapsa sp. (Pl. 4, fig. 12)			X	
Holocryptocanium barbui Dumitrica (Pl. 4, figs. 15-17)		X	X	X
Pantanellium sp. (Pl. 4, fig. 6)		X		
Pseudodictyomitra hornatissima (Squinabol) (Pl. 4, fig. 20)	1-9	cf.		
Pseudodictyomitra lodogaensis Pessagno (Pl. 4, fig. 18)	1-9			X
Pseudodictyomitra sp. (Pl. 4, fig. 19)			X	
Svinitzium sp. (Pl. 4, fig. 21)				X
Stichomitra? *communis* Squinabol (Pl. 4, fig. 23)	5-21		X	
Stichomitra? *mediocris* (Tan) (Pl. 4, fig. 24)	1-14			X
Thanarla brouweri (Tan) (Pl. 4, figs. 26-32)	1-11	X	X	X
Turbocapsula costata (Wu) (Pl. 4, figs. 7-10)	6-9	X	X	
Xitus clava (Parona) (Pl. 4, fig. 22)	1-8	X		

Tab. 1 - Occurrence of radiolarian species in the Lower flyschoid formation. The stratigraphic ranges according to the zonation of O'Dogherty (1994) are indicated. The Unitary Associations (UAs) 6-9 belong to the Costata Subzone (middle and upper Aptian, possibly also part of the lower Albian), and the UAs 10-11 belong to the Romanus Subzone (middle Albian).

ians were found in only one sample. The productive sample TF 1 (Fig. 3) is a 4-cm-thick highly siliceous greenish-grey limestone bed containing a layer of black replacement chert in the middle part. The sample was treated first with acetic acid and then with diluted (9%) hydrofluoric acid. The most abundant radiolarians are Favosyringiinae without lateral spines (Pl. 4, fig. 2), which could not be determined at the species level due to the poor preservation. The other identified taxa are (ranges in Unitary Association Zones (UAZ) according to Baumgartner et al. (1995) are given in brackets): *Emiluvia orea* Baumgartner (UAZ 8-11), *Transhsuum brevicostatum* (Ožvoldova) (UAZ 3-11), *Mirifusus dianae minor* Baumgartner (UAZ 9-20), and *Palinandromeda crassa* (Baumgartner) (UAZ 7-10) (Pl. 4, figs. 1, 3-5). Based on the co-occurrence of *Mirifusus dianae minor* and *Palinandromeda crassa* the sample is assigned to the UAZ 9 (middle-late Oxfordian) or UAZ 10 (late Oxfordian-early Kimmeridgian) of Baumgartner et al. (1995). Various sponge spicules also occur in this sample but are relatively rare.

The Biancone limestone formation is dated by calpionellids, among which *Calpionella alpina* Lorenz was recognized. Compiled biostratigraphic data and correlation with the central Slovenian Basin (see the chapter on correlation) date this unit to the Late Tithonian to Berriasian time-interval.

From the Cretaceous cherts and siliceous mudstones of the Lower flyschoid formation, siliceous microfossils were extracted using hydrofluoric acid only. Sponge spicules, including lithistid desmas and other megascleres, are much more abundant than radiolarians in all samples (Pl. 4, figs. 38-40, Pl. 3, fig. 1). The preservation of radiolarians is moderate and the diversity is low. Three samples were selected for a more detailed analysis (see Fig. 3 for stratigraphic position). Their radiolarian content is listed in Table 1 and illustrated in Plate 4 (figs. 6-37). Cryptocephalic and cryptothoracic nassellarians (*Cryptamphorella*, *Holocryptocanium*) are the most abundant. Archaeodictyomitridae (*Archaeodictyomitra*, *Thanarla*) are also common but all other taxa are rare.

The Cretaceous samples were dated with the zonation of O'Dogherty (1994). Two subzones of his zonation that span the middle Aptian to middle Albian are applicable to our samples: the Costata Subzone (the upper subzone of the Turbocapsula Zone) and the Romanus Subzone (the lower subzone of the subsequent Spoletoensis Zone). The Costata Subzone corresponds to the middle and upper Aptian and possibly extends to the lower Albian, while the Romanus Subzone is placed in the middle Albian (O'Dogherty 1994). A relatively long interval of uncertainty and also a discontinuity in the radiolarian record characterize the boundary between the Turbocapsula and Spoletoensis zones, or between the Costata and Romanus subzones (see fig. 11 in O'Dogherty 1994).

The lowermost sample, LFF 1, contains *Turbocapsula costata* (Wu), which is restricted to the Costata Subzone, and *Xitus clava* (Parona), which makes its last occurrence in the Costata Zone. It also contains *Pantanellium*, which last appears in the late Aptian (O'Dogherty et al. 2009). In the next sample, LFF 2, *Turbocapsula costata* (Wu) was found together with *Archaeodictyomitra montisserei* (Squinabol), whose FAD was established in the Romanus Subzone. The youngest sample, LFF 3, is also characterized by a "mixed" assemblage with species of both subzones: *Archaeodictyomitra montisserei* (Squinabol) is associated with *Diacanthocapsa betica* O'Dogherty and *Pseudodictyomitra lodogaensis* Pessagno, which do not extend above the Costata Subzone. Such "mixed" assemblages are not unusual (e.g. Goričan & Šmuc 2004) and may correspond to the missing early Albian interval in O'Dogherty's zonation. In all samples, including the highest sample, LFF 3, *Thanarla brouweri* (Tan) is common. This species does not range above the Romanus Subzone and thus indicates that the samples are certainly not younger than the middle Albian.

The presented radiolarian dating in the Lower flyschoid formation is in accordance with previous dating by Caron and Cousin (1972), who, on the basis of planktonic foraminifers, assigned the lowermost part of the formation to the Albian (or possibly Aptian) in several sections of the central Slovenian Basin. In the Lovriš section it seems likely that the sample LFF 1 is late Aptian and the younger samples LFF 2 and LFF 3 are early Albian in age. Nevertheless, one should keep in mind that the radiolarian biochronology of the Aptian-Albian transition has not yet been sufficiently elaborated worldwide and that the upper two samples of the Lovriš section were in fact not correlated to an established radiolarian zone but were assumed to correspond to a gap between two zones. The Aptian-Albian age is also proved by abundant orbitolinas that occur in the coarse-grained beds of the formation.

Depositional environment

Although there are prominent differences between the three formations, they share important common characteristics: they all consist of beds originated by two distinctive processes. Most of the studied succession consists of pelagic/hemipelagic sediments, as indicated by thin beds/laminae composed of mud-sized material with some pelagic fossils. These deposits are interstratified with coarse-grained limestone beds that represent a second, less abundant but also prominent depositional mechanism. These beds usually exhibit a partial Bouma sequence (normal grading, laminations) and were deposited by turbidity currents. The overall succession records sedimentation in a marginal basinal environment that was rather proximal to the source area, that is, the Dinaric Carbonate Platform. Because both distinctive types of deposits were controlled by different factors, they are discussed separately. Namely, the background sediments record regional or even global changes in climate, production, oceanography, etc., whereas resedimented carbonates reflect changes on the adjacent platform that can be of rather local character.

Background pelagic/hemipelagic sediments

The background (inter-turbidite) sediments of the Tolmin Formation are characterized by a high-silica content. The beds are predominantly calcareous only in the basal 5 m; upwards, radiolarian cherts become dominant. They become slightly more calcareous and marly in the uppermost 4 m of the unit. Parallel lamination in these beds indicates sorting of sediment, probably by bottom currents. Minor slumping of the semi-consolidated material also occurs and implies gentle inclination of the basin floor. Radiolarian cherts are the most common Middle and Upper Jurassic pelagic sediments of all Tethyan basins. Their deposition is related to high surface productivity and lack of terrigenous or periplatform input (for a recent review on radiolarites see Baumgartner 2013).

An abrupt increase in micrite defines the boundary with the overlying Biancone limestone formation. The mid-Tithonian change to almost purely calcareous pelagites is also regional in extent. Comparisons of the Tolmin and Biancone formations with coeval pelagic deposits of the neighbouring deep-water basins in the Southern Alps and Dinarides have been thoroughly discussed in our previous papers (Rožič 2009; Goričan et al. 2012a).

Silica-rich sediments start to prevail again in the upper Aptian-Albian, but an obvious difference in composition exists between the Jurassic cherts of the Tolmin Formation and the Cretaceous cherts of the Lower flyschoid formation. The Jurassic cherts are almost entirely composed of radiolarians, whereas in the Cretaceous cherts, sponge spicules prevail and radiolarians are rare. A very high proportion of sponge spicules was claimed as a general characteristic of the Cretaceous cherts in the Slovenian Basin (Buser 1986). This change from plankton- to benthos-dominated siliceous deposits indicates that in the late Early Cretaceous the depositional environment became shallower or was at least closer to the shelf (cf. Kiessling 1996). Similarly to the Jurassic cherts, we relate the chert-dominated part of the Lower flyschoid formation to high seawater fertility (cf. Baumgartner 2013 and references therein).

The sediments of the Lower flyschoid formation are further characterized by a high clay content in the siliceous interval. The origin of clay is attributed to the warm and humid greenhouse climate in the late Early Cretaceous (review in Skelton 2003), which enhanced erosion of continental areas, introducing prominent terrigenous input. Clay-rich sediments were widespread in Tethyan basins. Cretaceous radiolarian cherts intercalated with a high proportion of shale are characteristic of the Dinarides and Hellenides, e.g., they characterize the Bijela Radiolarite in the Budva Zone (Goričan 1994) and the Katafito Formation in the Pindos-Olonos Zone (Neumann & Zacher 2004). Successions of chert and shale extend further east to Iran (Neghareh Khaneh Formation in Robin et al. 2010) and Oman (Nayid and Qumayrah formations, upper part of the Musallah Formation in Béchennec et al. 1993). Westwards, in the Southern Alps and Apennines, the late Early Cretaceous deposits (Scaglia Variegata and Marne a Fucoidi formations, Puez Marl Member of the Puez Formation) are more calcareous but similarly exhibit an increased clay input especially during Albian times (Lukeneder 2010 and references therein).

Calciturbidites

The composition of calciturbidites reflects the sedimentary environment on the adjacent Dinaric Carbonate Platform, which was a source area of the resedimented material. Middle Jurassic platform sedimentation is characterized by high ooidal production followed by a poorly dated drowning event marked by the superposition of thin-bedded micritic limestone and calcarenite with chert nodules on the platform margin (Buser 1978, 1986). In the late Oxfordian, the Dinaric Carbonate Platform became rimmed by an extensive barrier reef that thrived until the end of the Kimmeridgian (Turnšek 1997). Its demise coincides with a tectonically induced regional uplift, which caused a subaerial exposure of the inner areas of the Dinaric Carbonate Platform (Dozet et al. 1996; Tišljar et al. 2002). Carbonate production was re-established in the Late Kimmeridgian or Early Tithonian with sedimentation of bedded limestone with *Clypeina jurassica* Favre (Buser 1986). Although the onset of the Tolmin Formation in the Lovriš section lacks an exact biostratigraphic dating, the composition of calciturbidites at the base of the formation indicates that these beds originated during the main ooid-producing episode, broadly acknowledged as Middle Jurassic in age. Upwards, calciturbidites lack debris of reef-building organisms as well as ooids and originated either before or after the prominent reefal episode. The exception is the thick limestone-breccia bed, which contains quite abundant grains of reef-building organisms such as calcisponges and microbialites. In addition, this breccia contains a large amount of various lithoclasts, suggesting erosion of the platform and slope limestones. Platform-derived lithoclasts are peloidal/bioclastic packstone, peloidal/intraclastic/ooidal grainstone, pelletoidal packstone with fenestrae, and intraclastic/bioclastic grainstone, whereas bioclastic wackestone indicates erosion of open-shelf or slope limestones. This breccia was presumably originated by the tectonic uplift of the Dinaric Carbonate Platform and destruction of the marginal reef, which is in accordance with the middle Oxfordian-early Kimmeridgian age obtained in the TF1 radiolarian sample just below the breccia bed.

In contrast to pelagic sedimentation that shows an end-Jurassic turnover, the sedimentary conditions on the Dinaric Carbonate Platform persisted into the Early Cretaceous (Buser 1986), which is directly reflected in the composition of the single calciturbidite of the Biancone limestone formation, which closely resembles older, previously discussed beds.

The change to the Lower flyschoid formation is characterized by a prominent basinal unconformity that covers most of the Lower Cretaceous (Caron & Cousin 1972). Re-establishment of sedimentation around the Aptian-Albian boundary is explained by intensified regional tectonics that resulted in normal faulting at the basinal margins (Rožič 2005). Coeval tectonic activity is thought to have generated the quick lateral facies changes reported from the Dinaric Carbonate Platform, especially from the present-day Istria (Croatia), which belonged to its northern part (Fuček et al. 2003; Velić et al. 2003; Vlahović et al. 2002, 2003; Husinec & Jelaska 2006).

When compared to the Jurassic strata, components of the calciturbidites in the Lower flyschoid formation reveal significantly changed sedimentary conditions in their source area; i.e. the Dinaric Carbonate Platform. Apart from similarities (intraclasts and echinoderms), grains consist of distinctly more abundant and diverse bivalve shells as well as benthic foraminifers which include very characteristic orbitolinas. In the Aptian, the Dinaric Carbonate Platform was, at least in western Slovenia, rimmed by an Urgonian-type reef (Turnšek & Buser 1974; Grötsch 1994; Turnšek 1997; Samiee 1999) and patch-reefs lagoon-wards (Koch et al. 1989, 2002). Similarly to the end-Jurassic reefs, main reef-growth predates the prominent regional platform exposure at the Aptian/Albian transition, marked by emersion breccia (Tišljar & Velič 1991; Tišljar et al. 2002; Vlahović et al. 2005; Jurkovšek 2010). The emersion is also reflected in the reef-limestone with paleokarst cave infilling (Grötsch 1994; Samiee 1999). The overlying Albian strata consist of abundant, commonly rock-forming, orbitolinid foraminifers (Šribar 1979; Jurkovšek et al. 1996; Dozet & Šribar 1998; Koch et al. 1998). A few meters-thick interval of rock-forming *Orbitolina (Mesorbitolina) texana* Roemer composes the base of the Povir Formation just above the emersion breccia in the northern part of the Trieste-Komen Plateau (Jurkovšek 2010). Late Aptian and Early Albian orbitolinid limestone is also reported further to the south on the same platform (Velić 1988; Husinec et al. 2000, 2009) as well as on other Tethyan carbonate platforms (Raspini 2012 and references therein). We conclude that, with the possible exception of the basal limestone breccia bed, which contains slightly more abundant calcisponges, the resedimented limestones of the Lower flyschoid formation in the Lovriš section were deposited during the early Albian orbitolinid expansion, which postdated the regionally recognized platform emersion.

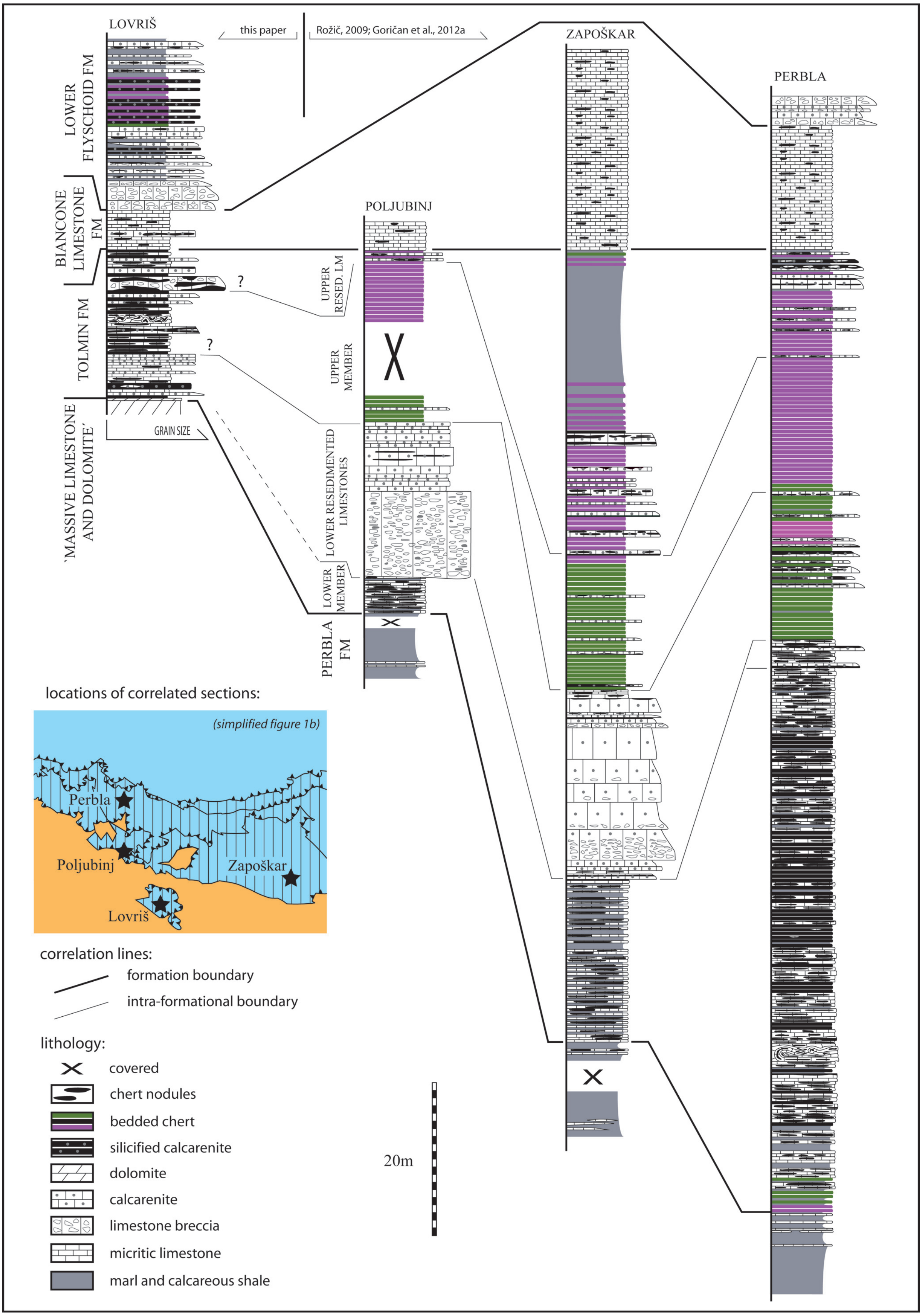

Fig. 4 - Correlation of the Lovriš section with selected sections from the Slovenian Basin (Poljubinj, Zapoškar, and Perbla sections according to Rožič 2009). The Lower flyschoid formation was not included in detailed logs at Zapoškar and Poljubinj sections, where it shows a marl-dominated interval just above the Biancone limestone formation (40 and 5 m in thickness). In the Perbla section, the basal limestone breccia (partly included in detailed logs) is 30 m thick and composed of several thick graded beds. Upwards it passes into a 50-m-thick shale/marl-dominated interval, above which calciturbidites (mostly graded calcarenites) gradually start to predominate (Goričan et al. 2012b).

Correlation with other sections of the Slovenian Basin

During the Middle and Late Jurassic the Slovenian Basin was dominated by thin-bedded (hemi)pelagic sedimentation. The succession lies with gradual contact above the marl-dominated Toarcian Perbla Formation and was defined as the Tolmin Formation (Rožič 2009). It is divided into two members; the lower member consists of siliceous limestone and subordinate cherts, whereas the upper member is characterized by radiolarian chert (Rožič 2009). The turnover to siliceous pelagic sedimentation is dated to the late Bajocian (Goričan et al. 2012a). Two intervals of resedimented limestones occur in the formation (Rožič & Popit 2006; Rožič 2009). The lower interval marks the boundary between the members and is Bajocian to Bathonian, and possibly also early Callovian in age (Rožič 2009; Goričan et al. 2012a, b). It is characterized by ooidal/peloidal calciturbidites that form a succession up to 25 m thick in the southern margins of the basin and become diluted to several calciturbiditic beds interstratified between pelagites in the central part of the basin. This interval correlates well with co-eval deposits in other deep-water paleogeographic domains that surrounded the Dinaric Carbonate Platform (Bosellini et al. 1981; Goričan 1994; Zempolich & Erba 1999; Šmuc 2005; 2012; Šmuc & Goričan 2005). The upper interval is Late Kimmeridgian to Early Tithonian in age and occurs in the southern and central part of the basin as bioclastic/intraclastic calciturbiditic interlayers between radiolarian chert (Rožič & Popit 2006; Rožič 2009; Goričan et al. 2012a,b). Time-equivalent resedimented limestones are known from the Budva Basin located in the southwestern margin of the Dinaric Carbonate Platform (Goričan 1994).

A direct lithological and microfacies comparison between the Tolmin Formation in the Lovriš section and other sections shows that the basal four metres of the formation, which are limestone dominated, correlate with the lower member of the Tolmin Formation. The rest of the formation corresponds to the upper member but shows slightly elevated carbonate content when compared with pure siliceous background sediments in other sections.

The formation in other sections can be up to six times thicker (Fig. 4), which probably indicates that several gaps, undetected in the field, exist within the formation in the Lovriš section. Hidden discontinuities were revealed by radiolarian dating even in distal parts of the basin (Goričan et al. 2012a) and are expected to be more common in the proximal setting. These differences are explained by the proximal position of the Lovriš section with respect to the Dinaric Carbonate Platform.

We also note that the chert layers of the Tolmin Formation are dark grey in the Lovriš section but green and then red in the other sections of the Slovenian Basin (Rožič 2009; see also Fig. 4). The colour is determined by the presence of Fe^{3+} in reddish cherts and Fe^{2+} in grey and green cherts, and can thus be used as an indicator of redox conditions in the depositional/early diagenetic environment. It has been demonstrated that within the same basin, dark-coloured cherts predominantly occur in proximal settings, whereas coeval cherts which were deposited closer to the depocentre are red (Goričan 1994). This spatial distribution of rock colours was explained in relation to the oxygen minimum zone (OMZ) at mid-water depths (Goričan 1994; Goričan et al. 2012a). Grey/green cherts indicate a depositional environment within the OMZ, whereas red cherts may indicate greater depths below the OMZ. The lack of red cherts in the Lovriš section is in agreement with its location in close proximity to the adjacent platform and relatively shallow bathymetry within the basin.

In the Tolmin Formation in the Lovriš section it is impossible to distinguish between lower and upper resedimented limestones because calciturbidites occur throughout the formation. To some degree it correlates only to the Zapoškar section, where calciturbidites are uniformly distributed through the formation (Fig. 4), although these beds are characteristically rare, thin, and very fine-grained in the lower part of radiolarian cherts and become coarser and more abundant upwards, whereas in the Lovriš section calciturbidites are generally coarser. Considering the very rough age determination, we cannot exclude the possibility that in the Lovriš section the chert-dominated interval observed in other sections is considerably reduced or entirely missing. Down-slope sliding of a thick package of semi-consolidated pelagic sediment would not be unusual in such a proximal setting.

The Biancone limestone formation is uniformly developed across the Slovenian Basin including the Lovriš section. Nevertheless, the calciturbiditic bed represents an exception, because such beds are practically absent in more distal basinal sections. Recently, one calciturbidite was reported within the Biancone limestone in the Kneža Valley (Smrkolj 2012), whereas few beds of resedimented limestones are known from the Mirna Valley from eastern Slovenia (Rožič et al. 2010).

During the late Aptian to the Turonian, the Lower flyschoid formation accumulated in the Slovenian Basin (Caron & Cousin 1972). Generally, the formation begins with a basal limestone breccia that passes upwards to marl and shale interbedded with calciturbidites (Caron & Cousin 1972; Cousin 1981; Buser 1986), but the formation exhibits significant lateral variations especially towards the basinal margins. Namely, the westernmost, i.e. proximal, successions (at Mt Mrzli vrh and to some degree also at Tolminske Ravne) consist predominantly of resedimented carbonates, whereas interstratified pelagites are mostly pelagic limestone (Samiee 1999; Rožič 2005; Goričan et al. 2012b). The Lower flyschoid formation of the Lovriš section correlates well with more distal, i.e. classical sections. This is in contrast with the Jurassic tract of the succession, where more calcareous pelagites and abundant calciturbidites in the Tolmin and Biancone limestone formations of the Lovriš section point to a marginal basinal settings. This indicates that the tectonic event that is reflected in the regional erosional unconformity and deposition of basal breccia (Caron & Cousin 1972; Buser 1986) also changed the paleotopography at the platform-basin transition. The retreat of the adjacent carbonate platform was probably greater near the present-day Lovriš section than further west, towards the paleogeographic termination of the Slovenian Basin (cf. Šmuc 2012 and references therein).

Conclusions

The Lovriš section exposes Middle Jurassic to Lower Cretaceous basinal strata of the Ponikve Klippe, which represents the only erosional remains of the Tolmin Nappe south of the South-Alpine thrust front. Due to its specific structural position, the studied succession records the southernmost development of the Slovenian Basin in present-day western Slovenia. The section consists of three formations. It begins with the Middle Jurassic to Lower Tithonian Tolmin Formation, composed of radiolarian chert and siliceous limestone alternating with calciturbidites, i.e. ooidal/bioclastic/lithoclastic calcarenite at the base of the formation and the intraclastic/bioclastic calcarenite within the rest of the formation. With a sharp contact, the Tolmin Formation is overlain by the upper Tithonian-Berriasian Biancone limestone formation, which is composed of typical calpionellid-bearing pelagic limestone with a single calciturbiditic bed equal in composition to the ones in the underlying formation. Above a prominent stratigraphic gap, the section continues with the Upper Aptian to Turonian Lower flyschoid formation. Only the basal part of the formation was studied, and it begins with carbonate breccia and calciturbidites that upwards start to alternate with chert and marl/shale. Lithoclasts, intraclasts, and bioclasts, especially echinoderms, orbitolinas, and bivalve shells, characterize the resedimented limestones. Background sediments of the studied succession record regional changes, whereas resedimented limestones reflect perturbations of sedimentary conditions on the south-lying Dinaric Carbonate Platform. Jurassic resedimented limestones occur throughout the section and indicate the Middle Jurassic main ooid-producing period and reestablishment of open-marine sedimentary conditions after the emersion-related demise of reefs. Resedimentation documented in the Lower flyschoid formation postdates a prominent reef-growth at the platform margin that, similarly to Upper Jurassic reefs, ended due to regional emersion. Correlation of the section with the central part of the Slovenian Basin reveals that the Tolmin Formation and the Biancone limestone exhibit a marginal basinal setting. Conversely, the Lower flyschoid formation shows characteristics of more inner basinal domains, which indicates that a prominent change in the geometry of the marginal area occurred during the late Aptian tectonic event, which also caused submarine erosion and deposition of basal breccia.

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