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The Jurassic Prehodavci Formation of the Julian Alps: easternmost outcrops of Rosso Ammonitico in the Southern Alps (NW Slovenia)

Andrej Šmuc · Boštjan Rožič

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Abstract The Julian Alps are located in NW Slovenia and structurally belong to the Julian Nappe where the Southern Alps intersect with the Dinarides. In the Jurassic, the area was a part of the southern Tethyan continental margin and experienced extensional faulting and differential subsidence during rifting of the future margin. The Mesozoic succession in the Julian Alps is characterized by a thick pile of Upper Triassic to Lower Jurassic platform limestones of the Julian Carbonate Platform, unconformably overlain by Bajocian to Tithonian strongly condensed limestones of the Prehodavci Formation of the Julian High. The Prehodavci Formation is up to 15 m thick, consists of Rosso Ammonitico type limestone and is subdivided into three members. The Lower Member consists of a condensed red, well-bedded bioclastic limestone with Fe–Mn nodules, passing into light-grey, faintly nodular limestone. The Middle Member occurs discontinuously and consists of thin-bedded micritic limestone. The Upper Member unconformably overlies the Lower or Middle Members. It is represented by red nodular limestone, and by red-marly limestone with abundant *Saccocoma* sp. The Prehodavci Formation unconformably overlies the Upper Triassic to Lower Jurassic platform limestone of the Julian Carbonate Platform; the contact is marked by a very irregular unconformity. It is overlain by the upper Tithonian pelagic Biancone (Maiolica) limestone. The sedimentary evolution of the Julian High is similar to that of Trento Plateau in the west and records: (1) emergence and karstification of part of the Julian Carbonate Platform in the Pliensbachian, or alternatively drowning of the platform and development of the surface by sea-floor dissolution; (2) accelerated subsidence and drowning in the Bajocian, and onset of the condensed pelagic sedimentation (Prehodavci Formation) on the Julian High; (3) beginning of sedimentation of the Biancone limestone in the late Tithonian.

Keywords Rosso Ammonitico · Lithostratigraphy · Julian High · Eastern Southern Alps · Jurassic · Trento Plateau

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A. Šmuc (✉) · B. Rožič
Department of Geology,
Faculty of Natural Sciences and Engineering,
University of Ljubljana, Privoz 11,
1000 Ljubljana, Slovenia
e-mail: andrej.smuc@ntf.uni-lj.si

Introduction

During Jurassic times Southern Alps and Dinarides belonged to the southern passive continental margin of the Tethys, that experienced extension related to the rifting. The rifting disintegrated pre-existing carbonate platforms, producing a complex pattern of pelagic basins, escarpment-bounded pelagic plateaus and productive carbonate platforms (Bernoulli et al. 1979, 1990; Bosellini et al. 1981; Winterer and Bosellini 1981; Bertotti 1991; Bertotti et al. 1993; Martire 1992, 1996; Martire et al. 2006). Whereas this evolution is well known in the Western and Central Southern Alps, information on the easternmost Southern Alps is relatively scarce (Aubouin et al. 1965; Cousin 1970, 1973, 1981; Buser 1989, 1996), and it is only recently that the area has been thoroughly investigated (Goričan et al. 2003; Šmuc and Goričan 2005; Črne et al. 2007). Here we focus on a detailed sedimentological and biostratigraphic study of the Jurassic—lowermost Cretaceous successions in the lesser known easternmost part of the Southern Alps: the Julian Alps.

The Julian Alps are a typical example of a Tethyan rifted margin, characterized by a thick pile of Upper Triassic to Lower Jurassic platform limestones overlain by condensed and discontinuous Jurassic to Cretaceous deeper-water deposits of the Julian High.

In this paper we shall, based on new data, discuss the sedimentary evolution of the Julian High. The succession of the Julian High will be compared with the coeval, well investigated successions of the Trento Plateau, in order to attempt an interpretation of the Jurassic to Cretaceous paleogeography, sedimentary evolution and rifting history of this segment of southern Alpine–Dinaric continental margin.

Geological setting

The Julian Alps comprise the north-western part of Slovenia and extend into the easternmost part of Italy (Fig. 1a). Structurally they are part of the Julian Nappe which, along with the Tolmin Nappe to the south, represents the easternmost continuation of the Southern Alps (Fig. 1b). In the Julian Alps the Paleogene Dinarides intersect with the Neogene Southern Alps. The area was first deformed by Dinaric SW-vergent thrusting during Oligocene—early Miocene times, and then by S to SSE-vergent Alpine thrusting since the late Miocene (Doglioni and Bosellini 1987; Doglioni and Siorpaes 1990; Carulli et al. 1990; Bresnan et al. 1998; Placer and Čar 1998; Placer 1999; Mellere et al. 2000; Vrabec and Fodor 2006). Around the Miocene–Pliocene boundary a phase of major strike-slip deformation started in the Julian Alps (Vrabec and Fodor 2006). NW–SE trending dextral strike-slip faults dissect the area, displacing both the Dinaric and South-Alpine fold-and-thrust structures.

In the Jurassic, the Southern Alps and Dinarides belonged to the Adriatic microcontinent, bordered to the north and west by the Alpine Tethys and to the east by the Vardar Ocean (e.g. Stampfli et al. 2001).

Palaeogeographically, from the Late Triassic to the earliest Jurassic, the Julian Alps were a relatively homogeneous carbonate platform: the Julian Carbonate Platform. With Early Jurassic rifting, the platform was dissected into blocks, forming a horst-and-graben structure. Some of these blocks became part of an isolated pelagic plateau named the Julian High (Fig. 2), while other blocks formed hangingwall deeper basins, e.g. the Bovec Trough (Šmuc and Goričan 2005).

In the Julian High the Pliensbachian platform limestones are unconformably overlain by Bajocian to Tithonian strongly condensed limestones of the Prehodavci. In the most condensed sections, the platform limestones are crossed by polyphase Jurassic neptunian dykes and

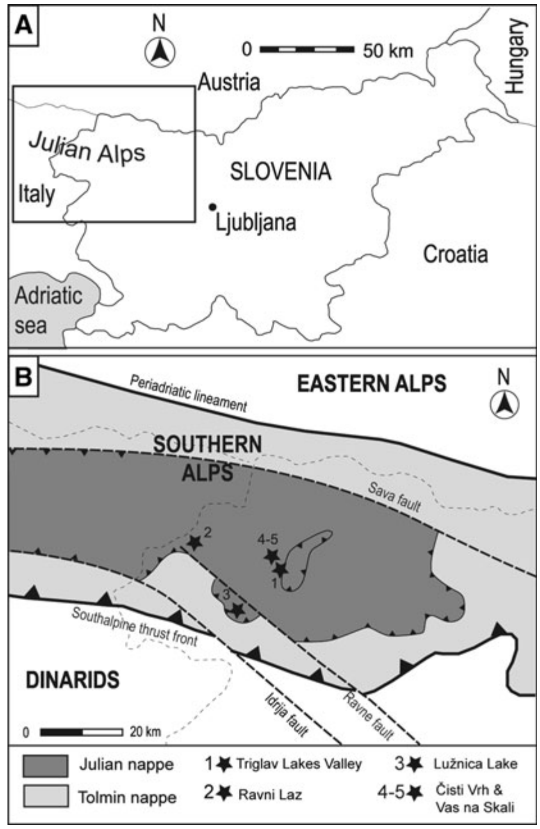


Fig. 1 **a** Location of the Julian Alps. Inset in **a** represents the location of **b**. **b** Main structural elements in NW Slovenia and location of the investigated sections

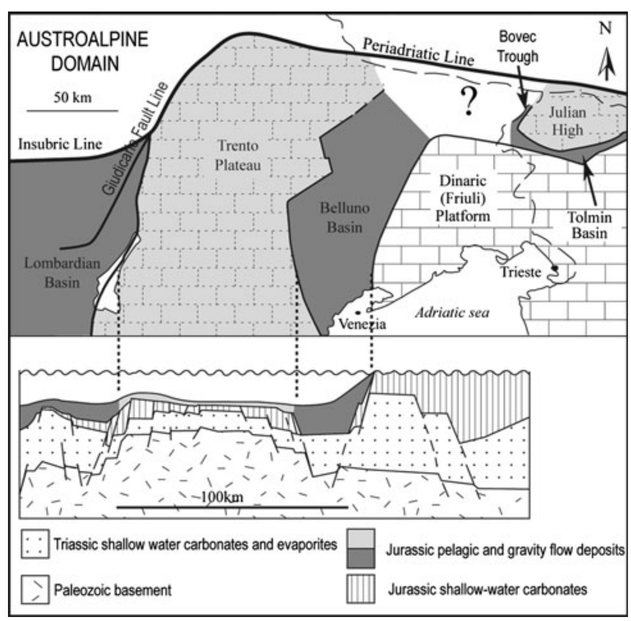


Fig. 2 Present-day position of paleogeographic units (compiled from Bosellini et al. 1981, Martire 1992, Buser 1989, and Placer 1999) and schematic palaeogeographic cross-sections at the end of the Jurassic (Bernoulli et al. 1979)

unconformably overlain by middle Cretaceous Scaglia Variegata or Senonian Scaglia rossa. The areas which are key to an understanding of the Jurassic tectono-sedimentary evolution of the Julian High are the Triglav Lakes Valley, Ravni Laz, Lužnica Lake, Vas na Skali, and Čisti Vrh (Fig. 1b).

Prehodavci Formation

The Prehodavci Formation is a newly described stratigraphic unit in the Julian Alps. The definition of the formation is based on the detailed research of seven selected sections: TV1–TV5 sections (Triglav Lakes Valley), R1 (Ravni Laz) and L1 (Lužnica Lake) sections (Fig. 3). The Vas na Skali and Čisti Vrh areas did not allow detailed measuring due to poor exposure, but still provided additional information on individual stratigraphic units. A location map is given in Fig. 1b.

The formation is named after the Prehodavci saddle in the Triglav Lakes Valley. It consists of condensed limestones of Rosso Ammonitico type subdivided into three members. The Lower Member consists of red, well bedded bioclastic limestone with Fe–Mn nodules passing into light-grey, faintly nodular limestones. The Middle Member consists of thin-bedded red marly limestones. The Upper Member unconformably overlies the Lower or Middle Member. It is represented by red nodular limestone, and by red-marly limestones with abundant *Saccocoma* sp.

The Prehodavci Formation unconformably overlies the Pliensbachian platform limestone of the Julian Carbonate Platform. The contact is marked by an irregular unconformity with oval-shaped depressions, up to 3 m deep and up to 10 m wide, cut into the Lower Jurassic platform limestone (Figs. 4, 5). The Prehodavci Formation is overlain by the upper Tithonian pelagic Biancone (Maiolica) limestone. The formation reaches a maximum thickness of about 15 m.

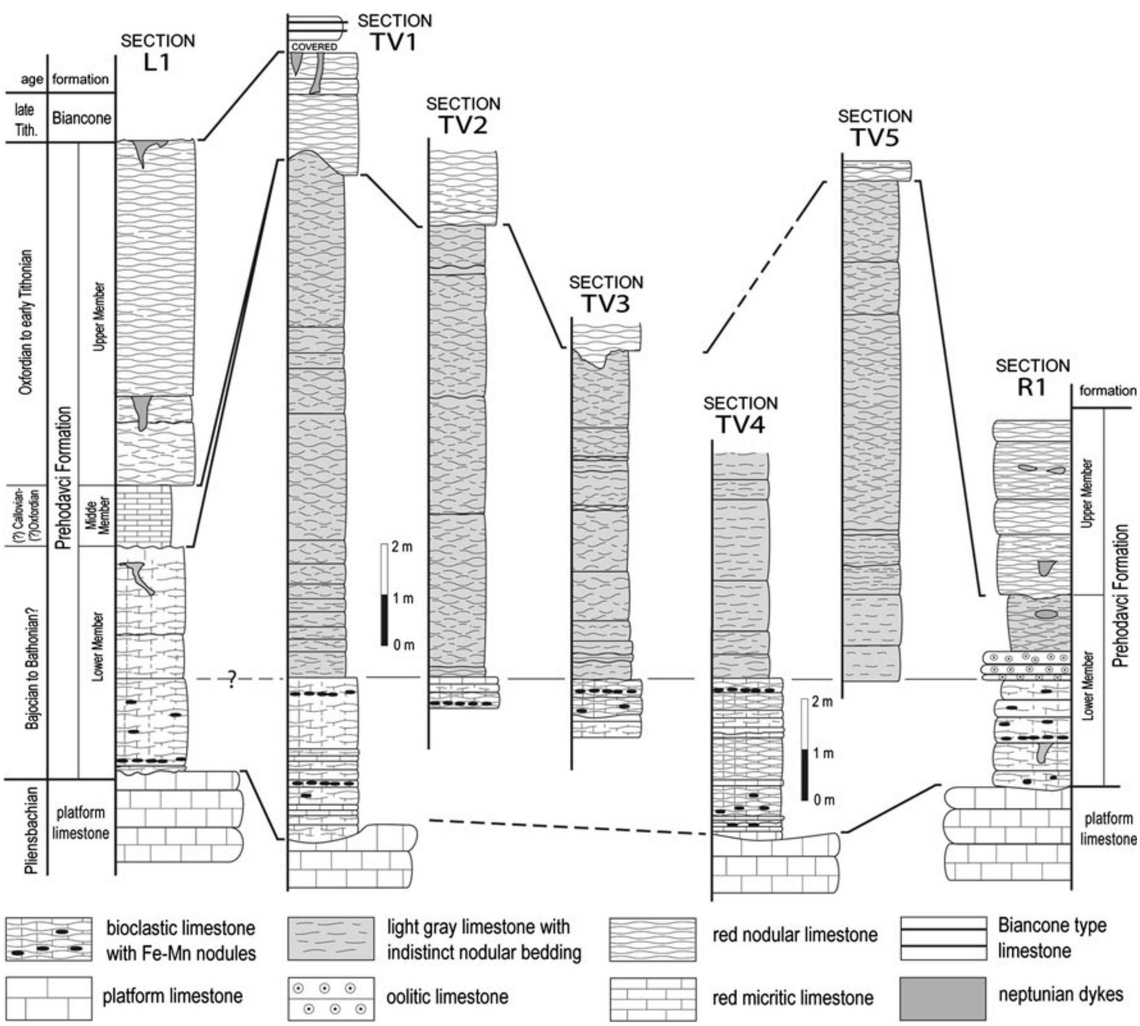


Fig. 3 Stratigraphic sections of the Prehodavci Formation: L1 Lužnica Lake area, TV1–TV5 Triglav Lakes Valley sections, R1 Ravni Laz section

Fig. 4 Unconformity between Lower Jurassic platform limestone and the Prehodavci Formation (*arrows*). Triglav Lakes Valley, section TV1

A Bajocian to Tithonian age of the formation is established, based on ammonite assemblage found by Ramovš (1975), along with planktic foraminifers, *Saccocoma* sp., and on stratigraphic correlation with the Trento Plateau.

The first authors who mentioned Jurassic beds in Julian Alps were Stur (1858), Diener (1884), and Kossmat (1913). Seidl (1929) was the first to give a schematic cross-section of the Jurassic beds in the Triglav Lakes Valley. Salopek (1933) provided the first general description of Jurassic and Lower Cretaceous beds in the Triglav Lakes Valley and reported the following ammonites from the Jurassic beds: *Phylloceras* sp., *Holcophylloceras*? sp., and *Perisphinctes* sp. Ramovš (1975) dated the red nodular limestones in Triglav Lakes Valley as Oxfordian and Kimmeridgian on the basis of the following ammonites: *Euaspidoceras* sp., *Gregoryceras* sp., *Lytoceras* sp., *Paraspidoceras* sp. and *Sowerbyceras* sp. The area of the Triglav Lakes Valley was mapped by Buser (1986) and Jurkovšek (1986) for the Basic Geological Map of Yugoslavia on the 1: 100,000 scale.

Lower Member of the Prehodavci Formation

The Lower Member was investigated at the TV1–TV5, R1, and L1 sections (Fig. 3). It consists of red bioclastic limestone with Fe–Mn nodules, limestone with ooids (found locally), and light-grey nodular limestone. The Lower Member is disconformably overlain by either the Middle or Upper Member of the Prehodavci Formation. The erosional surface separating the Lower and Middle Members is virtually flat, while the contact between the Lower and Upper Members is irregular and cuts up to 1 m deep into the light-grey limestone of the Lower Member.

The bioclastic limestone with Fe–Mn nodules makes up the lowermost part of the Lower Member (Fig. 3). This unit unconformably overlies an irregular discontinuity surface developed on top of the Pliensbachian platform carbonates and displays significant thickness variations, from a few decimeters to 3 m (Figs. 4, 5). The lower part is represented by red, thinly bedded, locally nodular (up to 10 cm) wackestone to packstone (rarely grainstone), with faint cross-lamination. Bedding surfaces locally display Fe–Mn oxide crusts. The limestone is composed of fragments of echinoderms, benthic foraminifers (*Lenticulina* sp.), gastropod protoconchs, juvenile ammonites, disarticulated valves of thin-shelled bivalves, algal fragments (Fig. 6a) and intraclasts of sparite limestone and bioclastic limestone with the same composition as the host rock. Planktic foraminifera (Protoglobigerinids) occur in the middle part of the bioclastic facies. In places, the limestone is composed exclusively of bored echinoderm fragments cemented by syntaxial cement. The bioclastic limestone

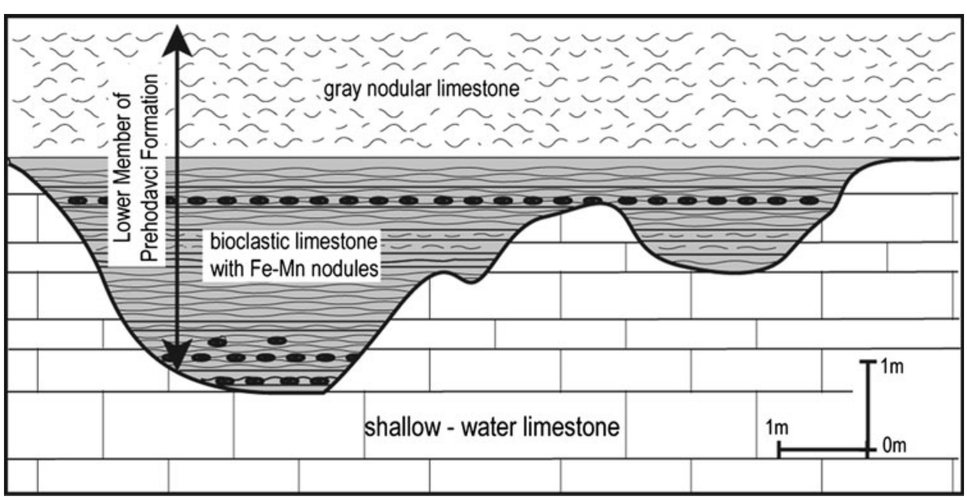


Fig. 5 Sketch of the unconformity between the Lower Jurassic platform limestone and the Prehodavci Formation

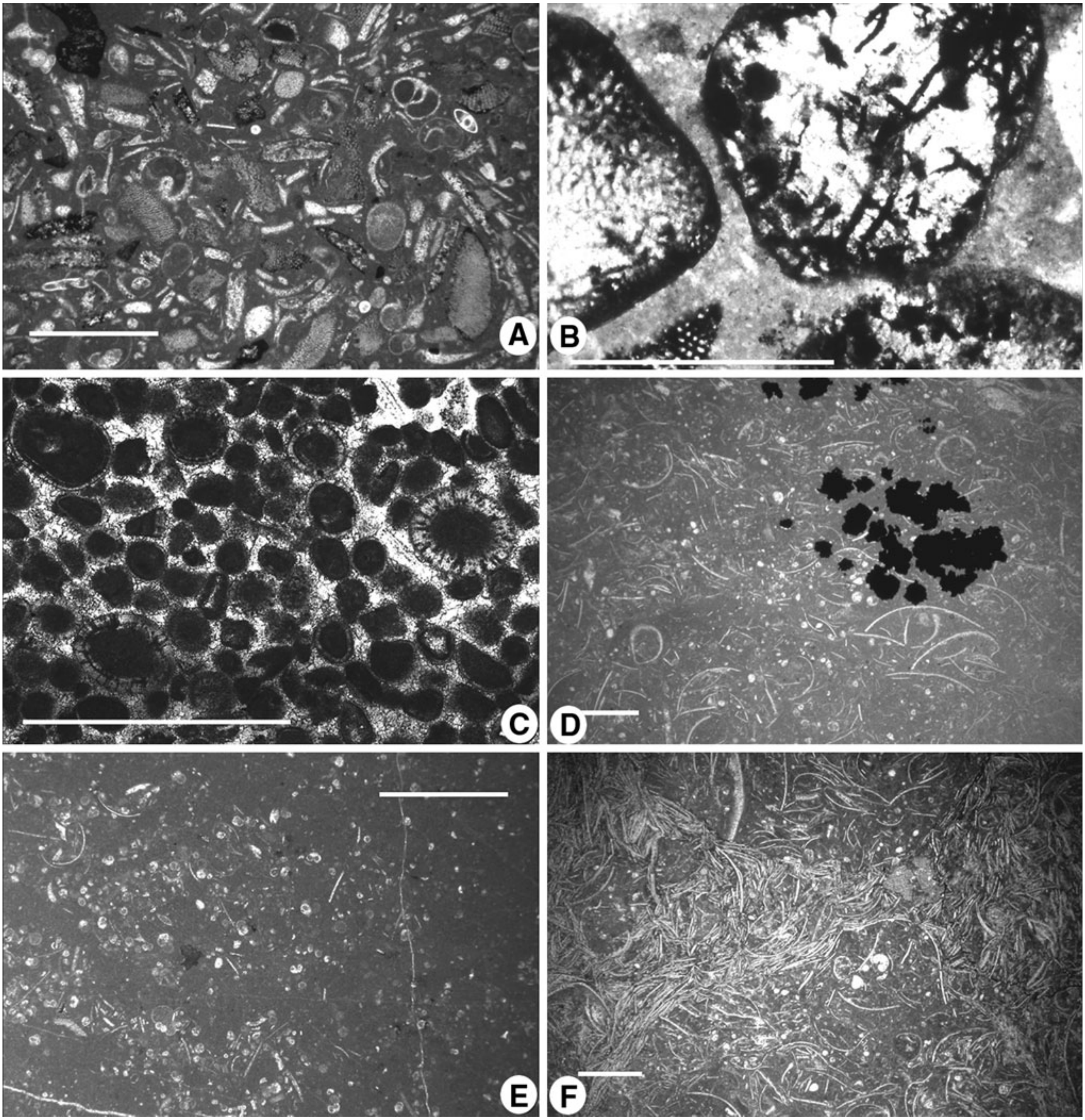


Fig. 6 **a** Lower Member of the Prehodavci Formation: bioclastic limestone with echinoderm fragments, gastropods and thin-shelled bivalve (section TV4). *Scale bar* is 1 mm. **b** Lower Member of the Prehodavci Formation: Fe–Mn encrusted echinoderm fragments (section TV1). *Scale bar* is 0.5 mm. **c** Lower Member of the Prehodavci Formation: limestone with ooids and peloids (section R1). *Scale bar* is 1 mm. **d** Lower Member of the Prehodavci Formation: light gray nodular limestone with calcified radiolarian moulds, thin-shelled bivalve and pyrite concretions (section TV2). *Scale bar* is 1 mm. **e** Middle Member of the Prehodavci Formation: lime mudstone with calcite filled radiolarian moulds (section L1). *Scale bar* is 1 mm. **f** Upper Member of the Prehodavci Formation, red nodular limestone: nodules of wackestone with thin-shelled bivalve and calcified radiolarian moulds embedded in a thin-shelled bivalve-rich matrix forming fitted fabric (section TV1). *Scale bar* is 1 mm

contains a high abundance of Fe–Mn oxides that occur as cryptocrystalline aggregates, as coatings of bioclasts, as individual thin crusts (Fig. 6b), dissolution residues along stylolites, and as individual Fe–Mn nodules (up to 10 cm in diameter) forming a distinct horizon (Fig. 7). Up-section the wacke–packstone grades into thick (up to 40 cm) bedded light-red wackestone that is generally similar in composition, but contains more abundant pelagic

Fig. 7 Fe–Mn nodules in the Lower Member of the Prehodavci Formation, Triglav Lakes Valley

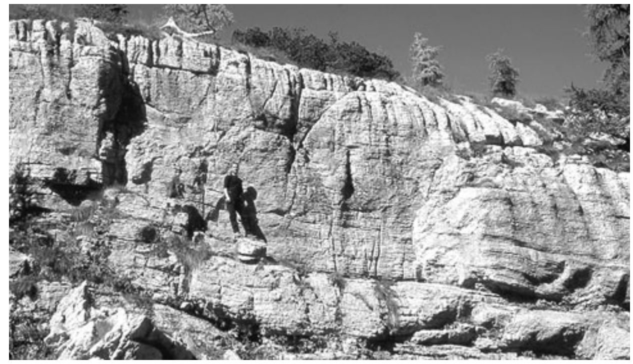


Fig. 8 Lower Member of the Prehodavci Formation: light gray nodular limestone. Triglav Lakes Valley, section TV2

foraminifers, pelagic bivalves and calcite-filled radiolarian molds, while Fe–Mn oxides are missing but pyrite occurs.

At R1 section the lower part of the Lower Member ends with a 40 cm thick package composed of packstone to wackestone with echinoderm fragments, belemnites, and rare planktic foraminifers, calcite-filled radiolarian molds and pelagic bivalves.

Oolitic limestone is only present at the R1 section (Fig. 3), where it conformably overlies the red bioclastic limestone. Oolitic limestone consists of three 10–30 cm thick, horizontally laminated beds of grainstone and packstone composed mainly of partly micritized Bahamian type ooids (Fig. 6c). Other grains are echinoderm and bivalve fragments, and benthic foraminifera. The uppermost bed of the oolitic facies represents a transitional facies to overlying light-grey nodular limestone described below. In the upper part of this bed pelagic bivalves predominate while ooids become scarce and finally absent.

A light-grey nodular limestone is 6–10 m thick and present in Čisti Vrh and in the TV1–TV5 sections (Fig. 3), whereas at the R1 section is only 1 m thick. The lower boundary is conformable and gradual while the upper boundary is sharp and marked by an erosional surface. The facies is characterized by packstone to wackestone and exhibits faint to evident nodular bedding (Fig. 8). Beds are 3–5 cm thick (rarely 10 cm) and marked by thin green clay films. The packstone is composed mainly of disarticulated valves of thin-shelled bivalves (*Bositra* sp.) and calcite-filled radiolarian molds (Fig. 6d). Other grains are aptychi, benthic foraminifera, echinoderm fragments, juvenile ammonites, gastropod protoconchs and pellets. The lower part of the limestone bears protoglobigerinids. In places poorly preserved ammonite moulds are also present. Rarely, ellipsoidal nodules of wackestone composed exclusively of calcite-filled radiolarian molds occur showing sharp and transitional boundaries with the matrix. Distinctive feature is occurence of a few cm thick concentrations of pyrite (Fig. 6d).

Age: The common presence of planktic foraminifera (protoglobigerinids) in the bioclastic limestone with Fe–Mn nodules and also in the light-gray nodular limestone suggests a Middle Jurassic age, most probably Bajocian to Bathonian (cf. Caron and Homewood 1983; Tappan and Loeblich 1988; Darling et al. 1997), for the Lower Member.

Middle Member of the Prehodavci Formation

The Middle Member of the Prehodavci Formation is present only in L1 section (Fig. 3). It is a bedded red marly limestone that disconformably overlies the Lower Member and is disconformably overlain by the red nodular limestone of the Upper Member. The marly limestone is thin, evenly bedded (bed thickness is up to 7 cm) lime mudstone composed of planktic foraminifera (protoglobigerinids), calcite-filled radiolarian molds, benthic foraminifers, and echinoderm fragments (Fig. 6e). The matrix is micrite with a small amount of terrigenous silt-sized mica.

Age: On the basis of the stratigraphic position only a general age assignment is possible: Callovian and Oxfordian.

Upper Member of the Prehodavci Formation

The Upper Member was investigated TV1, 2, 3, 5, R1, and L1 sections (Fig. 3) and at Čisti Vrh and Vas na Skali areas. The Upper Member unconformably overlies the Lower or Middle Member of the Prehodavci Formation. The contact is irregular and cuts up to 1 m deep into the Lower Member (Fig. 9). The Upper Member is a nodular limestone of Rosso Ammonitico type. The exact thickness of this member could not be determined, since the upper

Fig. 9 Irregular contact (*arrow*) between Lower and Upper Member of the Prehodavci Formation. Triglav Lakes Valley, section TV1

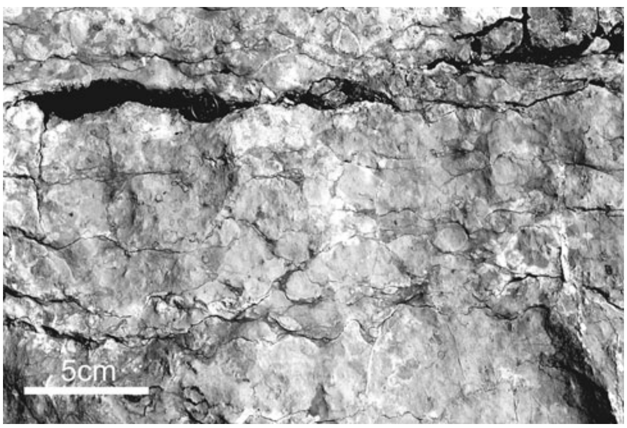


Fig. 10 Upper Member of the Prehodavci Formation: red nodular limestone. Triglav Lakes Valley, section TV1

boundary is not visible in the outcrops, but can be estimated to be no less than 2.5 m at TV sections, 3.5 m at R1 section, and 6 m at L1 section (Fig. 3).

This facies is characterized by red color and a marked nodular aspect in outcrop (Fig. 10). Nodules are up to 10 cm across and are mainly intraclasts, ammonite moulds, and early diagenetic nodules. The intraclasts consist of wackestone to packstone with disarticulated valves of *Bositra* sp., calcite-filled radiolarian molds, fragments of ammonite shells, echinoderm fragments, juvenile ammonites, gastropod protoconchs, benthic foraminifers (*Lenticulina* sp.), and planktic foraminifera (protoglobigerinids) (Fig. 6f). The intraclasts show sharp boundaries with the surrounding matrix. In the upper part of the member, they are also bored, and the borings are coated with Fe–Mn crusts (Fig. 11a). Ammonite moulds are frequent but are usually broken, abraded and coated with Fe–Mn oxides. The early diagenetic nodules have the same composition as the intraclasts but show transitional boundaries with the surrounding matrix that is darker, and more clay-rich. The matrix consists of packstone with fragments of *Bositra* sp., forming fitted fabrics, and rare echinoderm fragments. Stylolites are common and occur within the matrix and at the boundary between matrix and nodules. In R1 section a 70-cm thick package of packstone with bioclasts is present in the upper part of the section, bearing abundant *Saccocoma* sp., belemnite rostra, echinoderm fragments, aptychi, calcite-filled radiolarian molds, and intraclasts.

At Čisti Vrh and Vas na Skali the Upper Member of the Prehodavci Formation is composed of nodules that are wackestones with abundant *Saccocoma* fragments, aptychi, and calcite-filled radiolarian molds (Fig. 11b). Rarely, fragments of echinoderms and detritical grains of quartz are present. The nodules are embedded in a clay-rich packstone matrix with abundant *Saccocoma* sp., and rare calcite-filled radiolarian molds and other echinoderm fragments.

Age: Ammonite moulds are relatively frequent in the upper Member, but they are not well-preserved and very hard to extract from the rock. Ammonite fauna from Upper Member in Triglav Lakes Valley described by Salopek (1933) and Ramovš (1975) points to the Oxfordian. A Late Kimmeridgian to Early Tithonian age for the nodular limestones of the Čisti Vrh and Vas na Skali was assumed based on the occurence of *Saccocoma* sp. (by Sartorio and Venturini 1988). The Oxfordian to early Tithonian age of the Upper Member of the Prehodavci Formation is thus most probable.

Depositional environment of the Prehodavci Formation

The limestones of the Prehodavci Formation represent a typical deposit of an isolated pelagic plateau as is evidenced by characteristic composition of limestones: the presence of mainly pelagic bioclasts (radiolarians, ammonites, pelagic bivalves and planktic foraminifers) and benthos (foraminifers and echinoderms), whereas shallow-water elements are completely missing. Abundant Fe–Mn oxides present in the bioclastic facies of the Lower Member of the Prehodavci Formation suggest extremely reduced sedimentation rates, owing to the strong bottom-currents that were sweeping the ocean floor and thus prevented high sediment accumulation (Martire 1992, 1996). Sedimentation rates were at their lowest when Fe–Mn nodules and encrustations on the bedding planes formed. Additionally the episodic high-energy conditions are indicated by mud-free limestones composed exclusively of bored echinoderm fragments and cemented by syntaxial cement.

Beds of oolitic limestone (Ravni Laz section) composed of the partly micritized Bahamian type ooids in the upper part of the Lower Member of the Prehodavci Formation occur within a typical condensed pelagic platform facies and are allochthonous gravity-displaced deposits (see discussion in chapter 5.2).

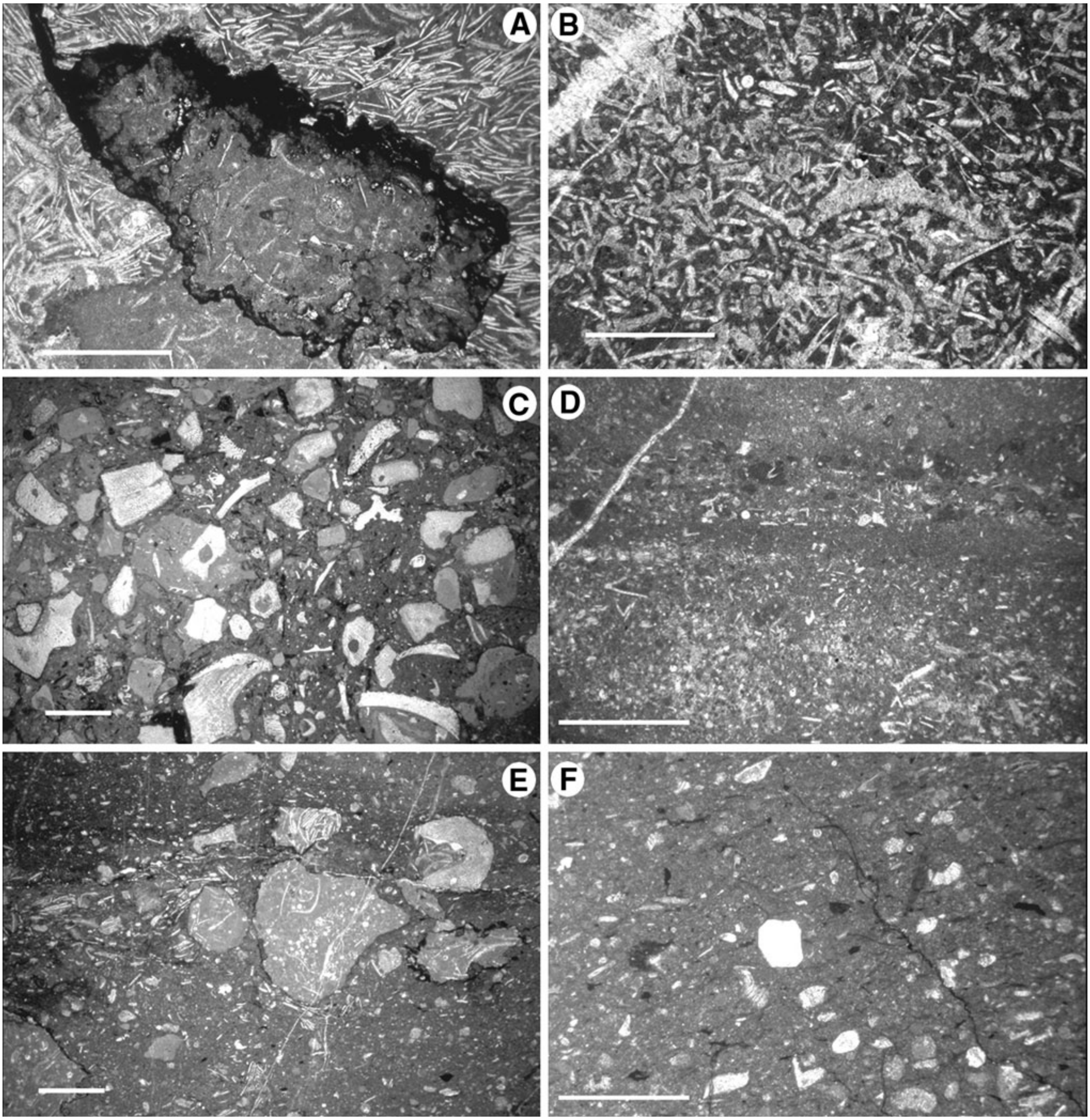


Fig. 11 **a** Upper Member of the Prehodavci Formation: Fe–Mn incrusted intraclast in a thin-shelled bivalve-rich packstone matrix (section TV1). *Scale bar* is 1 mm. **b** Upper Member of the Prehodavci Formation: packstone with *Saccocoma* fragments and aptychi (Vas na Skali area). *Scale bar* is 1 mm. **c** Neptunian dyke: breccia with echinoderm fragments and lithoclasts of wackestone with echinoderm fragments (neptunian dyke infill at Ravni Laz, section R1). *Scale bar* is 1 mm. **d** Neptunian dyke: laminated and normally graded wackestone. In lower part of the photograph wackestone with *Saccocoma* passes upward into wackestone with calpionelids (neptunian dyke infill at Ravni Laz, section R1). *Scale bar* is 1 mm. **e** Neptunian dyke: breccia with lithoclasts of wackestone with thin-shelled bivalves embedded in a wackestone/packstone with thin-shelled bivalves, and rare echinoderm fragments (neptunian dyke infill in Triglav Lakes Valley, section TV1). *Scale bar* is 1 mm. **f** Neptunian dyke: wackestone with echinoderm fragments, thin-shelled bivalves and euhedral quartz grain in the middle of the photo (neptunian dyke infill in Triglav Lakes Valley, section TV1). *Scale bar* is 1 mm

The marly lime mudstone of the Middle Member of the Prehodavci Formation, found only in the Lužnica Lake section, was deposited during a lower hydrodynamic current regime, which permitted deposition of evenly bedded mud-supported sediment. Absence of cementation, that prevented firm ground burrowing, hindered formation

Fig. 12 Neptunian dyke cutting trough an ammonite mould in Upper Member of the Prehodavci Formation. Triglav Lakes Valley, section TV1

of nodular structure (cf. Martire 1996). The presence of silt-sized micas indicates an increased input of terrigenous material at that time.

The Upper Member of the Prehodavci Formation is represented by a nodular facies with various pre-depositional nodules (intraclasts and ammonite moulds) and diagenetic nodules. Ammonite moulds are usually broken, abraded and, together with intraclasts, coated with Fe–Mn oxides. This is evidence for fluctuating current intensity resulting in non-deposition and erosion with intensive boring and mineralization. When current intensity was weaker, deposition of mud-supported sediment was possible and also more selective cementation was present (cf. Martire 1996; Martire et al. 2006). Later the compaction and pressure-dissolution additionally enhanced the textural contrast between nodules and matrix.

Neptunian dykes in the Prehodavci Formation

Neptunian dykes in the Prehodavci Formation are present in all the investigated sections of the Julian High, but their occurrence and the age of the infillings vary from section to section.

Neptunian dykes at Ravni Laz section

At Ravni Laz (Fig. 3), neptunian dykes occur throughout the Prehodavci Formation.

In the Lower Member, the dykes are bed-crossing fractures down to 0.2 m deep and smaller oval cavities with undulating walls that occur in distinct horizons. The dykes are filled with Kimmeridgian to lower Berriasian laminated and graded packstone to mudstone with *Saccocoma* sp. passing into microsparitic-graded limestones with echinoderm fragments, calpionellids (*Calpionella alpina* (Lorenz)), and intraclasts of packstones with *Saccocoma* sp. At places the dykes are filled by a Cretaceous wackestone with globotruncanids.

In the Upper Member the neptunian dykes are up to 10 cm wide and up to 50 cm deep. The dikes are bed-crossing and bed-parallel at places with undulate wall geometries. The dyke infill consists of fine-grained clast-supported breccias (Fig. 11c) with single echinoderm fragments, Fe–Mn encrusted bioclasts and lithoclasts of wackestones to lime mudstones with echinoderm fragments, benthic foraminifera (*Lenticulina* sp., Textularidae) and *Calpionella elliptica* (Cadisch) embedded mudstone matrix. The breccias are of early Berriasian age. The dikes are at places also filled by Late Cretaceous wackestone with planktic globular foraminifers, globotruncanids and rare echinoderm fragments (Fig. 11d). In the upper part of the infills, the limestones become laminated. The laminations consist of up to 5 mm thick packstone laminae and thinner lime mudstone laminae. Packstone is composed exclusively of fragments of globotruncanids.

Neptunian dykes at Lužnica Lake section

At Lužnica Lake (Fig. 3), the neptunian dykes occur in the Lower and the Upper Members. Dikes are represented by subvertical fractures and rarely bed-parallel cavities up to few dm in diameter showing smooth and strait walls. In the Lower Member, the dykes are filled with packstone composed mainly of thin-shelled bivalves and encrusted intraclasts of bioclastic limestone. Other grains include echinoderm fragments and gastropod protoconchs. In the Upper Member of the Prehodavci Formation the fill is an Upper Kimmeridgian to Lower Tithonian packstone composed of numerous filaments, *Saccocoma* sp. fragments and intraclasts of host rock. At places the dikes are filled also with calpionellid mudstone (*Calpionella alpina* (Lorenz)) of Tithonian age.

Neptunian dykes in the Triglav Lakes Valley

Neptunian dykes in the Triglav Lakes Valley are developed only in the uppermost part of the Prehodavci Formation (section TV1) as bed-crossing, up to 50 cm deep and 10 cm wide fractures with a preferential SE–NW orientation, filled with two different generations of breccias (Fig. 12). In places neptunian dykes exhibit a jigsaw structure. The walls of the fractures are usually encrusted with Fe–Mn oxides. A first generation of breccias consists of fragments of ammonite moulds and cm-sized lithoclasts of red wackestone to packstone, with thin-shelled bivalves and calcite-filled radiolarian molds of the red nodular facies. The matrix of the breccia is packstone with pelagic bivalves, rare echinoderm fragments, belemnites and foraminifer (*Lenticulina* sp.) (Fig. 11e). A second generation of breccias is composed of euhedral grains of detritic quartz, lithoclasts of red nodular limestone, packstone with calcified radiolarian moulds, and wackestones with aptychi. The matrix of the breccia is a wackestone with echinoderm fragments, opaque minerals and Fe–Mn incrusted bioclasts (Fig. 11f).

Interpretation of the neptunian dyke formation

The geometry of the neptunian dikes of the Ravni Laz section is characterized by bed-crossing and bed-parallel fractures, smooth walls of the host rock and also by undulating oval cavities. Thus, the formation of the cavities was most probably caused by initial mechanical fracturing of the host rock and also subsequent dissolution in places, the latter causing reshaping of the existing voids. The sedimentary structures such as grading and lamination are result of the minor turbidity currents, which episodically transported the sediment into the open voids.

The dykes at the Lužnica Lake and at the Triglav Lakes Valley were open fractures formed due to brittle fracturing of a well-lithified host rock. The ''jig-saw'' structure that is present at places additionally indicates a mechanical deformation by penetrative fracturing of the host rock (cf. Cozzi 2000). Fe–Mn impregnated walls of the fractures indicate episodes of non-deposition following the fracture formation.

Jurassic sedimentary and palaeogeographic evolution of the Julian High

The Julian Alps are a part of the South-Alpine rifted margin which experienced an extension beginning in latest Triassic and continuing into Jurassic times. The Jurassic successions of the Julian High shed light on the depositional history of the plateau, and they provide data for identification of the main factors controlling sedimentation along this particular segment of the southern Tethyan margin. The time span of individual formations and stratigraphic gaps are graphically given in Fig. 13.

Pliensbachian: demise of the Julian Carbonate Platform and formation of the Julian High

In all investigated sections the Pliensbachian shallow-water limestones of Julian Carbonate Platform are unconformably overlain by the Bajocian to Tithonian condensed Prehodavci Formation, with a stratigraphic gap spanning at least from the Toarcian to Aalenian (Figs. 3, 13). The drowning unconformity is an erosional surface with broad scours up to 3 m deep and 10 m wide cut into platform limestone. They are filled with limestone of the Prehodavci Formation. The morphology of this surface suggests chemical erosion. The dissolution can occur in a meteoric zone indicating an episode of subaerial exposure or it can occur on the sea-floor (Di Stefano and Mindszenty 2000). However, no clear evidence for any of the mentioned scenarios is present. No distinct continental or shallow-water sediments are entrapped in the topographic lows of the unconformity surface, no paleokarst features or cements indicative of vadose-zone precipitation are present. For the time being both of the scenarios (subaerial exposure and karstic dissolution or submarine dissolution) are equally possible.

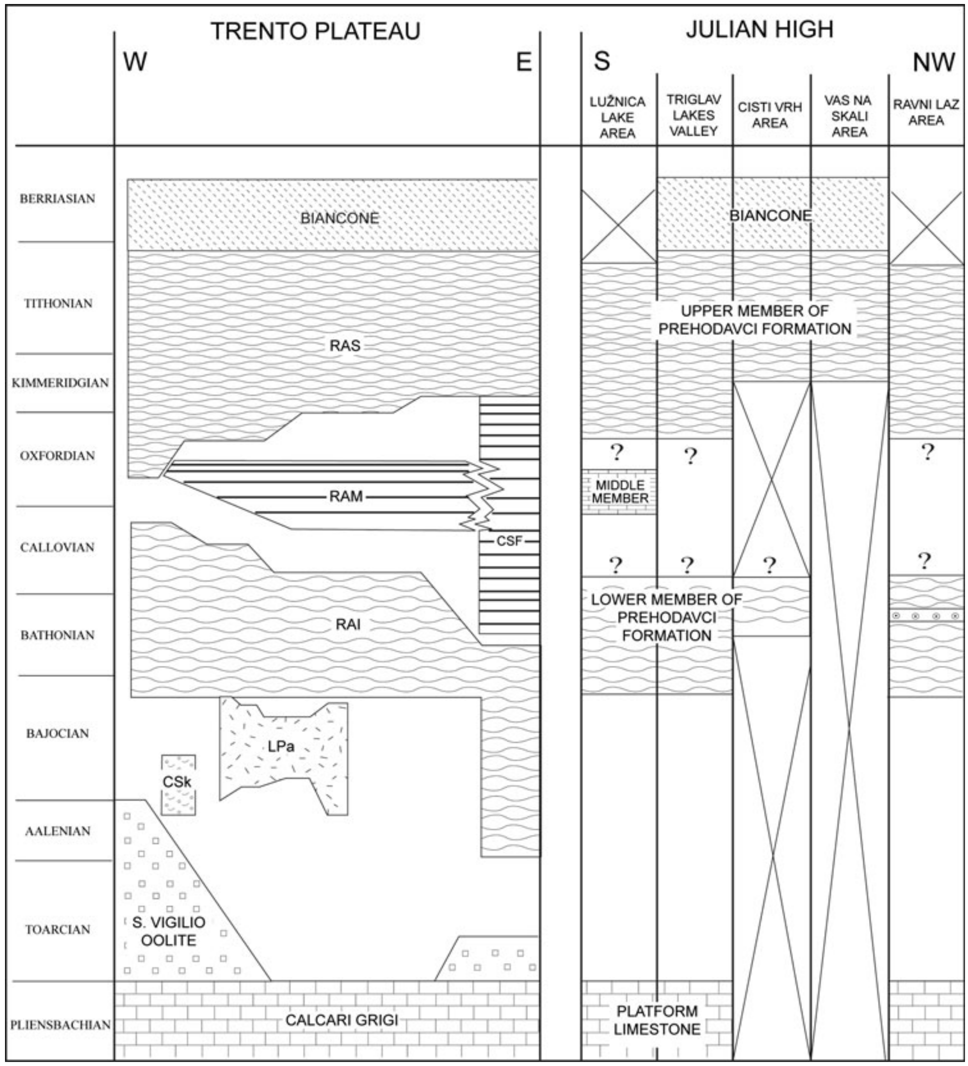
Based on the data from the studied sections, the timing of the demise of the shallow-water sedimentation on the Julian High can only be assigned as post-Pliensbachian to pre-Bajocian. However, in the Julian Alps evidence for tectonically induced subsidence, tilting, and demise of shallow-sedimentation in the Pliensbachian include: (1) Pliensbachian polyphase neptunian dykes in the uppermost part of the Lower Jurassic platform limestone, described from the Mangart structural unit of the Mt. Magart Saddle (see Črne et al. 2007), (2) the contrasting manifestations of drowning on the Julian High with respect to Bovec Trough, where a synchronous deepening-upward facies trend is recognized (Šmuc and Goričan 2005).

On the basis of the present day data we interpret that shallow-water sedimentation on the Julian Carbonate Platform ended as a consequence of a Pliensbachian extensional tectonic phase. The Julian Carbonate Platform was dissected into blocks with different subsidence rates. Some of the fault blocks became deeper basins, e.g. the Bovec Trough (Šmuc and Goričan 2005), while less subsident blocks became part of an isolated pelagic plateau: the Julian High. The area represented by the Triglav Lakes Valley, Ravni Laz and Lužnica Lake sections constitutes the interior portions of the Julian High, where rift related tectonic uplift could have produced a karstic discontinuity surface. An alternative hypothesis is that inner areas of the Julian High were also drowned, and the discontinuity surface was formed by sea-floor dissolution (cf. Di Stefano and Mindszenty 2000). The Early Jurassic extensional tectonic phase that lasted from the middle Hettangian to the late Pliensbachian is recognized across the entire south-Tethyan passive continental margin (Winterer and Bosellini 1981; Sarti et al. 1992; Bertotti et al. 1993; Di Stefano and Mindszenty 2000; Baumgartner et al. 2001; Clari and Masetti 2002; Di Stefano et al. 2002).

Bajocian to Tithonian: sedimentation on the Julian High

The Bajocian saw a major turnover in the style of sedimentation. On the Julian High the sedimentation of the condensed Prehodavci Formation, the typical deposit of

Fig. 13 Ages of the Jurassic and Cretaceous formations and correlation of the sections in the Julian Alps with the Trento Plateau (after Martire et al. 2006)



pelagic plateau began in the Bajocian. Additionally, in the adjacent Tolmin Basin change from carbonate to predominantly siliceous pelagic sedimentation occurred at that time (Rožič 2009), while the Bovec Trough deepened at that time and started to receive resedimented carbonates (Šmuc and Goričan 2005). This major turnover was most probably related to the pulse of accelerated tectonic subsidence in the Bajocian that is also well documented to the west in the Belluno Basin and on the Trento Plateau (Winterer and Bosellini 1981; Martire 1992, 1996; Winterer 1998).

In the Julian High the Prehodavci Formation directly overlies the Pliensbachian platform limestone with a stratigraphic gap encompassing the Toarcian and Aalenian (Figs. 3, 13). Similar stratigraphic gaps, having a maximum extent from the Sinemurian to the early Bathonian, are common on submarine highs in the Mediterranean Tethys. They were documented in the Trento Plateau in the Dolomites (Winterer and Bosellini 1981; Baumgartner et al. 1995; Clari et al. 1995; Martire 1992, 1996; Clari and Masetti 2002; Martire et al. 2006), a number of pelagic plateaus in the Apennines (Santantonio 1993, 1994; Santantonio et al. 1996; Santantonio and Muraro 2002), and on the submarine highs of the Sciacca and Trapanese domains (Di Stefano and Mindszenty 2000; Di Stefano et al. 2002; Baldanza et al. 2002; Martire and Pavia 2004). These stratigraphic gaps are often interpreted as having formed on more elevated areas of structural highs where current activity was strong enough to erode the substrate or totally hinder sedimentation for a long time span (e.g. Clari et al. 1995).

At the Ravni Laz section (R1, Fig. 3) thin beds of limestone containing Bahamian type ooids conformably overlie the bioclastic limestone with Fe–Mn nodules. The occurence of ooid-rich levels within a typical condensed pelagic facies is quite unexpected. In our interpretation these must be held as allochthonous gravity-displaced sediments. A similar situation was reported from the

Sabina Plateau in the Apennines, where Galluzzo and Santantonio (2002) described up to 30 cm thick lenses of posidoniid/oolite calcarenites on the top of the late Bajocian Bugarone inferiore Formation. The occurrence of ooids on a morpho-structural high was interpreted as a result of the overbanking of a turbidity flow that travelled across the adjacent Sabina Basin and eventually impacted on a huge obstacle represented by the marginal palaeoescarpment of the plateau (Galluzzo and Santantonio 2002; Santantonio and Muraro 2002). We believe that the occurrence of ooids within typical condensed limestones of the isolated Julian High can be explained in a similar way.

The Middle Member of the Prehodavci Formation is present only in the Lužnica Lake area while in all other sections this level corresponds to a stratigraphic gap. A similar situation is present in an E–W oriented central belt of the Trento Plateau, where the Middle Member of the Rosso Ammonitico Formation (RAM) is missing (Martire 1996; Martire et al. 2006). Here the absence of RAM is a consequence of an extensional tectonic phase following the deposition of RAI which generated a half graben structure (Martire 1996). During the early Callovian to late Oxfordian the elevated areas were sediment-starved, and sediment was transported into lows and the deeper parts of slopes. On the Julian High, the irregular sea-bottom topography had an influence on the sedimentation, producing lateral thickness variations. The Triglav Lakes Valley and Ravni Laz sections represented more elevated areas that were swept clean, while the Lužnica Lake area was an area where sediment could settle and accumulate.

In the Oxfordian to early Tithonian the red nodular limestones of the Upper Member of the Prehodavci Formation were deposited and cut by Kimmeridgian neptunian dykes (Figs. 3, 13). Presence of the dikes implies the existence of extensional tectonic activity in the Late Jurassic.

Late Tithonian to early Aptian: pelagic sedimentation of the Biancone limestone

At the early/late Tithonian boundary the sedimentation of the condensed Prehodavci Formation was replaced by sedimentation of the pelagic Biancone limestone (Fig. 13) that resulted from normal pelagic sedimentation in a deeper-water environment. The change to the calcareous Biancone formation is also observed in the adjacent Tolmin Basin (Cousin 1981; Buser 1986, 1987; Rožič 2009), in the Southern Alps (Weissert 1979; Winterer and Bosellini 1981; Baumgartner 1987; Baumgartner et al. 1995; Bartolini et al. 1999), and in the Dinarides (e.g. Goričan 1994). In the Dinarides this change is abrupt, while on the Trento Plateau the change is gradual from the Oxfordian into the Early Cretaceous.

Correlation of the Julian High with the Jurassic Trento Plateau

The successions of the Julian High bear some resemblance with those of the Trento Plateau in the Southern Alps, belonging to the same passive continental margin (Bosellini et al. 1981; Winterer and Bosellini 1981; Baumgartner et al. 1995; Martire 1989, 1992, 1996; Clari and Masetti 2002; Martire et al. 2006). A litho- and chronostratigraphic correlation of the stratigraphic successions is graphically shown in Fig. 13.

The Early Jurassic limestones of the Julian Carbonate Platform are time and facies equivalents of the Lower and Middle Members of the Calcari Grigi Formation (Clari and Masetti 2002).

On the Julian High the Pliensbachian platform limestones are separated by a stratigraphic gap from the Bajocian or Bathonian Prehodavci Formation. A correlative stratigraphic gap is present on the Trento Plateau, between the Calcari Grigi Formation and the Lower Member of the Rosso Ammonitico Formation (Winterer and Bosellini 1981; Baumgartner et al. 1995; Martire 1992, 1996; Clari and Masetti 2002; Martire et al. 2006). In the middle part of the Trento Plateau, the gap spans the Toarcian to the Bajocian, whereas in the other parts of the plateau the gap is shorter.

In the Trento Plateau the thin and discontinuous formations not present on the Julian High occur between shallow-water deposits and the base of the Rosso Ammonitico. They include Calcare di Campotorondo, Calcari a Skirroceras, Lumachella a Posidonia alpina, and other crinoidal–ooid limestones.

The Lower Member of the Prehodavci Formation is partly time-equivalent to the Lower Member of the Ammonitico Rosso Formation (RAI), which consists of pseudonodular, mineralized and bioclastic limestones (cf. Martire 1992, 1996; Martire et al. 2006). The bioclastic limestone of the Lower Member of the Prehodavci Formation with Fe–Mn nodules and encrustations is similar to the mineralized facies of the RAI dated as Middle-Late Bathonian (Martire 1992; Martire et al. 2006). The light-grey bioclastic nodular limestone in the upper part of the Lower Member of the Prehodavci Formation is the facies equivalent to the bioclastic facies present in the upper part of the RAI (Martire 1992, 1996; Martire et al. 2006).

The red, evenly bedded limestone of the Middle Member of the Prehodavci Formation is present only in Lužnica Lake section, where it disconformably overlies the Fe–Mn mineralized facies of the Lower Member. Age diagnostic fossils are missing, therefore only a broad age assignment between the Callovian and the Kimmeridgian is possible. This facies is a facies equivalent to the white-to-pink lime mudstone with radiolarian moulds found in the thin-bedded limestone facies of the Middle Member of the Rosso Ammonitico Formation (RAM). The RAM was dated as latest Callovian to middle Oxfordian across most of the Trento Plateau (Martire et al. 2006) and as middle? Oxfordian to early Kimmeridgian for an ''anomalous'' section at Ceniga (Beccaro 2006). The Middle Member of the Prehodavci Formation is entirely made of carbonates, while the RAM consists of thin-bedded cherty limestone and abundant chert (Martire 1992, 1996; Martire et al. 2006).

The Upper Member of the Prehodavci Formation correlates with the Upper Member of the Rosso Ammonitico Formation (Martire 1992, 1996; Baumgartner et al. 1995), that ranges from late middle Oxfordian to the Tithonian (Rabeschini section) or from latest early Kimmeridgian to Tithonian (Kaberlaba section) (Martire et al. 2006).

The Biancone Limestone is present both in the Julian High and the Trento Plateau.

The successions of the Triglav Lakes Valley and Ravni Laz, being those where the Middle Member of the Prehodavci Formation is missing, are similar to the successions in the middle sector of the Trento Plateau where the RAM is missing.

Conclusions

In the Jurassic the Julian Alps belonged to the passive southern Tethyan continental margin; they preserve a record of rifting history, platform drowning and subsequent deeper-water deposition. The Jurassic successions of the Julian Alps correlate with regional tectonics and major palaeogeographic changes as follows:

1. Early Jurassic platform deposits of the Julian Alps were deposited on the Julian Carbonate Platform and represent a continuation of shallow-water sedimentation from the Late Triassic.
2. In the Pliensbachian, shallow-water sedimentation on the Julian Carbonate Platform ended as a result of extensional tectonic phase. The platform was dissected into blocks with different subsidence rates, forming the deeper-water Bovec Trough and a structural high named the Julian High. The Julian High was uplifted above sea level resulting in the formation of a karstic discontinuity surface. An alternative hypothesis is that the Julian High also drowned, and the discontinuity surface was formed by sea-floor dissolution.
3. Accelerated subsidence in the Bajocian caused submergence and/or deepening of the Julian High. Foundering into deeper water was coincident with the onset of the condensed Prehodavci Formation in the Bajocian.
4. The occurrence of Kimmeridgian neptunian dykes on the Julian High implies the existence of extensional tectonic activity in the Late Jurassic.
5. In the late Tithonian sedimentation of the Biancone limestone became ubiquitous across the Bovec Trough, Julian High, in the Tolmin and Belluno basins, and on the Trento Plateau.

The condensed successions of the Julian High can be correlated with those known on the Trento Plateau. In particularly they show, with few local exceptions, similarities to those parts of the Trento Plateau where the Middle Member of the Ammonitico Rosso (RAM) is missing.

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References

Aubouin, J., Bosellini, A., & Cousin, M. (1965). Sur la paléogéographie de la Vénétie au Jurassique. *Memorie Geopaleontologiche dell'Università di Ferrara, 1*, 148–158.

Baldanza, A., Cope, J.C.W., D'Arpa, C., Stefano, P.D., Marino, M.C., Mariotti, N., Nicosia, U., Parisi, G., Petti, F.M. (2002). Quarry at Contrada diesi—Section I (Early Jurassic–early Tithonian). In: M. Santantonio (Ed.), *General field trip guidebook*. VI international symposium on the Jurassic system, 12–22 September 2002, 69–72.

Bartolini, A., Baumgartner, P. O., & Guex, J. (1999). Middle and Late Jurassic radiolarian palaeoecology versus carbon-isotope stratigraphy. *Palaeogeography, Palaeoclimatology, Palaeoecology, 145*, 43–60.

Baumgartner, P. O. (1987). Age and genesis of Tethyan Jurassic Radiolarites. *Eclogae Geologicae Helvetiae, 80*, 831–879.

Baumgartner, P.O., Bernoulli, D., Martire, L. (2001). Mesozoic pelagic facies of the Southern alps: Palaeotectonics and palaeoceanography. *IAS 2001 Davos: Fieldtrip guide; excursion A1*.

Baumgartner, P.O., Martire, L., Goričan, Š., O'Dogerthy, L., Erba, E., Pillevuit, A. (1995). New Middle and Upper Jurassic radiolarian assemblages co-occurring with ammonites and nanofossils from the Southern Alps (Northern Italy). In: P.O. Baumgartner, L. O'Dogerthy, Š. Goričan, E. Urquhart, A. Pillevuit, P. DeWever (Eds.), *Middle Jurassic to Lower Cretaceous Radiolaria of Tethys: Occurrences, Systematics, Biochronology*. Mémoires de Géologie (Lausanne) *23*, 737–750.

Beccaro, P. (2006). Radiolarian correlation of Jurassic successions of the Rosso Ammonitico Formation in the Southern Alps and Western Sicily (Italy). *Eclogae Geologicae Helvetiae, 99*, 21–33.

Bernoulli, D., Bertotti, G., & Froitzheim, N. (1990). Mesozoic faults and associated sediments in the Austroalpine-South Alpine Passive continental margin. *Memorie della Societa Geologica Italianà, 45*, 25–38.

Bernoulli, D., Caron, C., Homewood, P., Kälin, O., & Stuijvenberg, J. V. (1979). Evolution of continental margins in the Alps. *Schweizerische Mineralogische Petrographische Mitteilungen, 59*, 165–170.

Bertotti, G. (1991). Early Mesozoic extension and Alpine shortening in the western Southern Alps. The geology of the area between Lugano and Menaggio (Lombardy, northern Italy). *Memorie di Scienze Geologiche (Padova), 43*, 17–123.

Bertotti, G., Picotti, V., Bernoulli, D., & Castellarin, A. (1993). From rifting to drifting: Tectonic evolution of the South-Alpine upper crust from the Triassic to the Early Cretaceous. *Sedimentary Geology, 86*, 53–76.

Bosellini, A., Masetti, D., & Sarti, M. (1981). A Jurassic ''Tongue of the ocean'' infilled with oolitic sands: The Belluno Trough, Venetian Alps, Italy. *Marine Geology, 44*, 59–95.

Bresnan, G., Snidarcig, A., & Venturini, C. (1998). Present stata of tectonic stress of the Friulli area (eastern Southern Alps). *Tectonophysics, 292*, 211–227.

Buser, S. (1986). *Basic Geological Map of SFRJ 1:100.000, sheet Tolmin in Videm*. Beograd: Zvezni geološki Zavod.

Buser, S. (1987). Explanatory note to the Basic geological map of SFRJ 1:100.000, sheet Tolmin in Videm. *Zvezni geološki Zavod*, (pp. 103). Beograd.

Buser, S. (1989). Developement of the Dinaric and the Julian Carbonate Platforms and of the intermediate Slovenian Basin (NW Yugoslavia). *Memorie della Società Geologica Italiana, 40*, 313–320.

Buser, S. (1996). Geology of Western Slovenia and its paleogeographical evolution. In: K. Drobne, Š. Goričan, B. Kotnik (Eds.), *International workshop Postojna 1996: The role of impact processes in the geological and biological evolution of planet Earth*, 111–123.

Caron, M., & Homewood, P. (1983). Evolution of early planktic foraminifers. *Marine Micropaleontology, 7*, 453–462.

Carulli, G. B., Nicolich, R., Rebez, A., & Seljko, D. (1990). Seismotectonics of the Northwest External Dinarides. *Tectonophysics, 179*, 11–25.

Clari, P. A., Dela Pierre, F., & Martire, L. (1995). Discontinuities in carbonate successions: Identification, interpretation and classification of some Italian examples. *Sedimentary Geology, 100*, 97–121.

Clari, P. & Masetti, D. (2002). The Trento Ridge and the Belluno Basin. In: M. Santantonio (Ed.) *General field trip guidebook. VI international symposium on the Jurassic system*, 12–22 September 2002, 271–315.

Cousin, M. (1970). Esquisse géologique des confins italo-yougoslaves: Leur place dans les Dinarides et les Alpes meridionales. *Bulletin de la Sociéte géologique de France 7, 6*, 1034–1047.

Cousin, M. (1973). Le sillon slovène: Les formations triasiques, jurassiques at neocomiennes au Nord-Est de Tolmin (Slovéne occidentale, Alpes méridionales) et leurs affinités dinariques. *Bulletin de la Sociéte géologique de France 15, 3–4*, 326–339.

Cousin, M. (1981). Les rapports Alpes-Dinarides. Les confins de l'Italie et de la Yougoslavie. *Société Géologique du Nord, Publ. No 5, vol. 1 of 521 pp.*, *vol. 2 : Annexe of 521 pp*.

Cozzi, A. (2000). Synsedimentary tensional features in Upper Triassic shallow-water platform carbonates of the Carnian Prealps (northern Italy) and their importance as palaeostress indicators. *Basin Research, 12*, 133–146.

Črne, A., Šmuc, A., & Skaberne, D. (2007). Jurassic neptunian dikes at Mt Mangart (Julian Alps, NW Slovenia). *Facies, 53*, 249–265.

Darling, K. F., Wade, C. M., Kroon, D., & Brown, A. J. L. (1997). Planktic foraminiferal molecular evolution and their polyphyletic origins from benthic taxa. *Marine Micropaleontology, 30*, 251–266.

Di Stefano, P., Galacz, A., Mallarino, G., Mindszenty, A., & Vörös, A. (2002). Birth and early evolution of a Jurassic escarpement: Monte Kumenta, Western Sicily. *Facies, 46*, 273–298.

Di Stefano, P., & Mindszenty, A. (2000). Fe-Mn encrusted 'Kamenitza' and associated features in the Jurassic of Monte Kumeta (Sicily): Subaerial and/or submarine dissolution. *Sedimentary Geology, 132*, 37–68.

Diener, C. (1884). Ein Beitrag zur Geologie des Centralstockes der julischen Alpen. *Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt, 34*, 659–705.

Doglioni, C., & Bosellini, A. (1987). Eoalpine and mesoalpine tectonics in the Southern Alps. *Geologische Rundschau, 76*, 735–754.

Doglioni, C., & Siorpaes, C. (1990). Polyphase deformation in the Col Bechei area (Dolomites-Northeastern Italy). *Eclogae Geologicae Helvetiae, 83*, 701–710.

Galluzzo, F., & Santantonio, M. (2002). The Sabina Plateau: A new element in the Mesozoic palaeogeography of central Apennines. *Bollettino della Società Geologica Italiana, 121*, 561–588.

Goričan, Š. (1994). Jurassic and Cretaceous radiolarian biostratigraphy and sedimentary evolution of the Budva Zone (Dinarides, Montenegro). *Mémories de Géologie (Lausanne) 18*, 177 pp.

Goričan, Š., Šmuc, A., & Baumgartner, P. O. (2003). Toarcian Radiolaria from Mt. Mangart (Slovenian-Italian border) and their paleoecological implications. *Marine Micropaleontology, 932*, 1–27.

Jurkovšek, B. (1986). *Basic Geological Map of SFRJ 1:100.000, sheet Beljak in Ponteba*. Beograd: Zvezni geološki Zavod.

Kossmat, F. (1913). Die adriatische Umrandung in der alpinen Faltenregion. *Mitteilungen der Geologischen Gesellschaft in Wien, 6*, 61–165.

Martire, L. (1989). Analisi biostratigraphica e sedimentologica del Rosso Ammonitico Veronese dell'Altopiano di Asiago (VI), PhD thesis, Università di Torino, 166 pp.

Martire, L. (1992). Sequence stratigraphy and condensed pelagic sediments. An example from the Rosso Ammonitico Veronese, northeasters Italy. *Palaeogeography, Palaeoclimatology, Palaeoecology, 94*, 169–191.

Martire, L. (1996). Stratigraphy, facies and synsedimentary tectonics in the Jurassic Rosso Ammonitico Veronese (Altopiano di Asiago, NE Italy). *Facies, 35*, 209–236.

Martire, L., Clari, P., Lozar, F., & Pavia, G. (2006). The Rosso Ammonitico Veronese (Middle-Upper Jurassic of the Trento Plateau): A proposal of lithostratigraphic ordering and formalization. *Rivista Italiana di Palentologia e Stratigrafia 112, 2*, 227–250.

Martire, L., & Pavia, G. (2004). Jurassic sedimentary and tectonic processes at Montagna Grande (Trapanese domain, Western Sicily, Italy). *Rivista Italiana di Palentologia e Stratigrafia 110, 1*, 23–33.

Mellere, D., Stefani, C., & Angevine, C. (2000). Polyphase tectonics trough subsidence analysis: The Oligo-Miocene Venetian and Friulli basin, north-east Italy. *Basin Research 2000, 12*, 159–182.

Placer, L. (1999). Contribution to the macrotectonic subdivision of the border region between Southern Alps and External Dinarides. *Geologija, 41*, 223–255.

Placer, L., & Čar, J. (1998). Structure of Mt. Blegoš between the Inner and Outer Dinarides. *Geologija, 40*, 305–323.

Ramovš, A. (1975). Amoniti v dolini Triglavskih jezer. *Proteus, 37*, 332–340.

Rožič, B. (2009). Perbla and Tolmin formations: Revised Toarcian to Tithonian stratigraphy of the Tolmin Basin (NW Slovenia) and regional correlations. *Bulletin de la Societe Geologique de France 180*, no. 5, 411–430.

Salopek, M. (1933). O gornjoj juri u Dolini sedmerih jezera. *Jugoslavenska akademija znanosti i umjetonosti, 246*, 110–118.

Santantonio, M. (1993). Facies associations an evolution of pelagic carbonate platform/basin systems: Examples from the Italian Jurassic. *Sedimentology, 40*, 1039–1067.

Santantonio, M. (1994). Pelagic carbonate platforms in the geologic record: Their classification, and sedimentary and paleotectonic evolution. *AAPG Bulletin, 78*, 122–141.

Santantonio, M., Galluzzo, F., & Gill, G. (1996). Anatomy and palaeobathymetry of a Jurassic pelagic carbonate platform/basin system. Rossa Mts., Central Apennines (Italy). Geological implications. *Palaeopelagos, 6*, 123–169.

Santantonio, M. & Muraro, C. (2002). The Sabina Plateau, Palaeoescrapment, and Basin–Central Apennines. In: M. Santantonio (Ed.), *General field trip guidebook. VI international symposium on the Jurassic system*, 12–22 September 2002, 271–315.

Sarti, M., Bosellini, A., Winterer, E.L. (1992). Basin geometry and architecture of a Tethyan Passive Margin, Southern Alps. *AAPG Memoir 53: Geology and Geophysics of Continental Margins*, 241–258.

Sartorio, D. & Venturini, S. (1988). Southern Tethyan Biofacies. *AGIP*, 235 pp.

Seidl, F. (1929). Zlatenska Plošča v osrednjih Julijskih Alpah. *Glasnik Muzejskega društva za Slovenijo* 10.

Šmuc, A., & Goričan, Š. (2005). Jurassic sedimentary evolution from carbonate platform to deep-water basin: A succession at Mt Mangart (Slovenian-Italian border). *Rivista Italiana di Paleontologia e Stratigrafia, 111*(2), 45–70.

Stampfli, G.M., Mosar, J., Favre, P., Pillevuit, A., Vannay, J.-C. (2001). Permo-Mesozoic evolution of the western Tethys realm: The Neo-Tethys East Mediterranean Basin Conenction. In: P.A. Ziegler, E. Cavazza, A.H.F. Robertson, S. Crasquin-Soleau (Eds.), *Peri Tethys Memoir 6: Pery-Tethyan Rift/Wrench Basins and passive Margins. Memoires du Museum national d'historie naturelle 186*, 51–108.

Stur, D. (1858). Das Isonzo-Thal von Flitsch abwärts bis Görz, die Umgebungen von Wippach, Adelsberg, Planina und Wochein. *Jahrbuch der kaiserlich-königlichen Geologischen Reichsanstalt, 9*, 324–366.

Tappan, H., & Loeblich, A. R. (1988). Foraminiferal evolution, diversification, and extinction. *Journal of Paleontology, 62*, 695–714.

Vrabec, M., & Fodor, L. (2006). Late Cenozoic Tectonics of Slovenia: Structural styles at the Northeastern Corner of the Adriatic Microplate. In N. Pinter, G. Grenerczy, J. Weber, S. Stein, & D. Medak (Eds.), *The Adria microplate: GPS geodesy, tectonics and hazards* (pp. 151–168). Amsterdam: Springer.

Weissert, H.J. (1979). Die Palaeoozeanographie der südwestlichen Tethys in der Unterkreide. *Mitteilungen aus dem Geologischen Institut der Eidgenössischen Technischen Hochschule und der Universität Zürich, Neue Folge 226*, 174 pp.

Winterer, E. L. (1998). Paleobathymetry of Mediterranean Tethyan Jurassic pelagic sediments. *Memorie della Societa Geologica Italiana, 53*, 97–131.

Winterer, E. L., & Bosellini, A. (1981). Subsidence and sedimentation on Jurassic Passive Continental Margin, Southern Alps, Italy. *AAPG Bulletin, 65*, 394–421.