

THE LOWER TRIASSIC SHALLOW MARINE SUCCESSION IN GORSKI KOTAR REGION (EXTERNAL DINARIDES, CROATIA): LITHOFACIES AND CONODONT DATING

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Abstract. The paper aims to present Lower Triassic lithofacies definition and first conodont fauna of Gorski Kotar region, Croatia. The depositional environment is envisaged as shallow marine realm of a passive continental margin. Sedimentary complex differentiates in predominantly carbonate sedimentation that characterises the beginning of deposition with upward increasing trend of terrigenous influx. Lithofacial units have been defined as oolitic bar facies, lagoonal facies, shoreface-offshore facies, ooid-sandy shoal facies, restricted bay facies and flat-pebble conglomerate facies.

The following conodont taxa were collected: *Ellisonia* sp., *Foliella gardenae*, *Hadrodontina* sp., *Hindeodus parvus*, *Hindeodus* sp., *Pachycladina obliqua*, *Parachirognathus* sp., *Platyvillosus costatus* and *P. hamadai*. The oldest strata yield *Hindeodus parvus* marking lowermost Triassic. The biostratigraphical data enable recognition of the *parvus-isarcicella* zones, *obliqua* Zone and *Platyvillosus* Subzone. The finds of *Hindeodus parvus*, *Platyvillosus costatus* and *P. hamadai* represent their first records in the External Dinarides and enable correlation of the Early Triassic conodont faunas of the Western Tethyan realm.

Riassunto. Questo articolo definisce le litofacies e descrive per la prima volta la fauna a conodonti della regione di Gorski Kotar, Croazia. L'ambiente di deposizione è interpretato come quello di un contesto marino poco profondo su margine continentale passivo. La successione sedimentaria è prevalentemente carbonatica all'inizio, per poi modificarsi verso l'alto per l'incremento di apporti terrigeni. Le associazioni di facies riconosciute sono di barra oolitica, di laguna, di shoreface-offshore, di secca arenitica ed oolitica, di baia confinata, e di conglomerati a ciottoli piatti.

Sono stati identificati i seguenti taxa di conodonti: *Ellisonia* sp., *Foliella gardenae*, *Hadrodontina* sp., *Hindeodus parvus*, *Hindeodus* sp., *Pachycladina obliqua*, *Parachirognathus* sp., *Platyvillosus costatus* e *P. hamadai*. Gli strati più vecchi hanno fornito *Hindeodus parvus*, che indica la presenza della più antica fauna a conodonti del Triassico. Sono

inoltre identificabili le seguenti biozone: zona a *parvus-isarcicella*, a *obliqua* e subzona a *Platyvillosus*. Il ritrovamento di *Hindeodus parvus*, *Platyvillosus costatus* e di *P. hamadai* rappresenta il primo rinvenimento nelle Dinaridi Esterne e ne consente la correlazione con le coeve faune a conodonti della Tetide occidentale.

Introduction

The Lower Triassic sedimentary complex of Gorski Kotar region (sheet Delnice of the Basic Geological Map of SFRY M 1: 100.000) has long been an issue of controversy; for decades the Lower Triassic deposits have been mixed with the Upper Triassic sedimentary complex when, considered as Late Triassic, was even mapped so (Savić & Dozet 1984, 1985). Nevertheless, Šćavničar & Šušnjara (1966, 1967), Đurđanović (1967) and Babić (1968) contributed to the new approach in determining the «Triassic sedimentary rocks», their lithology and facies characteristics and unraveled the litho- and biostratigraphy of Lower Triassic rocks. Đurđanović (1967) found *Meandrospira iulia* at the Rogoznica hill between Lokve and Mrzla Vodica, while Babić (1968) documented *Pseudomonotis (Claraia)* cf. *orbicularis* (Richthofen), *Myacites (Anodontophora) fassaensis* (Wissmann), *Myacites (Anodontophora)* cf. *canalensis* (Catullo), and *Pseudomonotis (Claraia)* cf. *inaequicostata* (Benecke) from red clastic shallow marine deposits in the eastern part of Gorski Kotar. Up till now these were the only biostratigraphic data in Lower Triassic sedimentary rocks of the Gorski Kotar region. More detailed lithologic investigation has been performed

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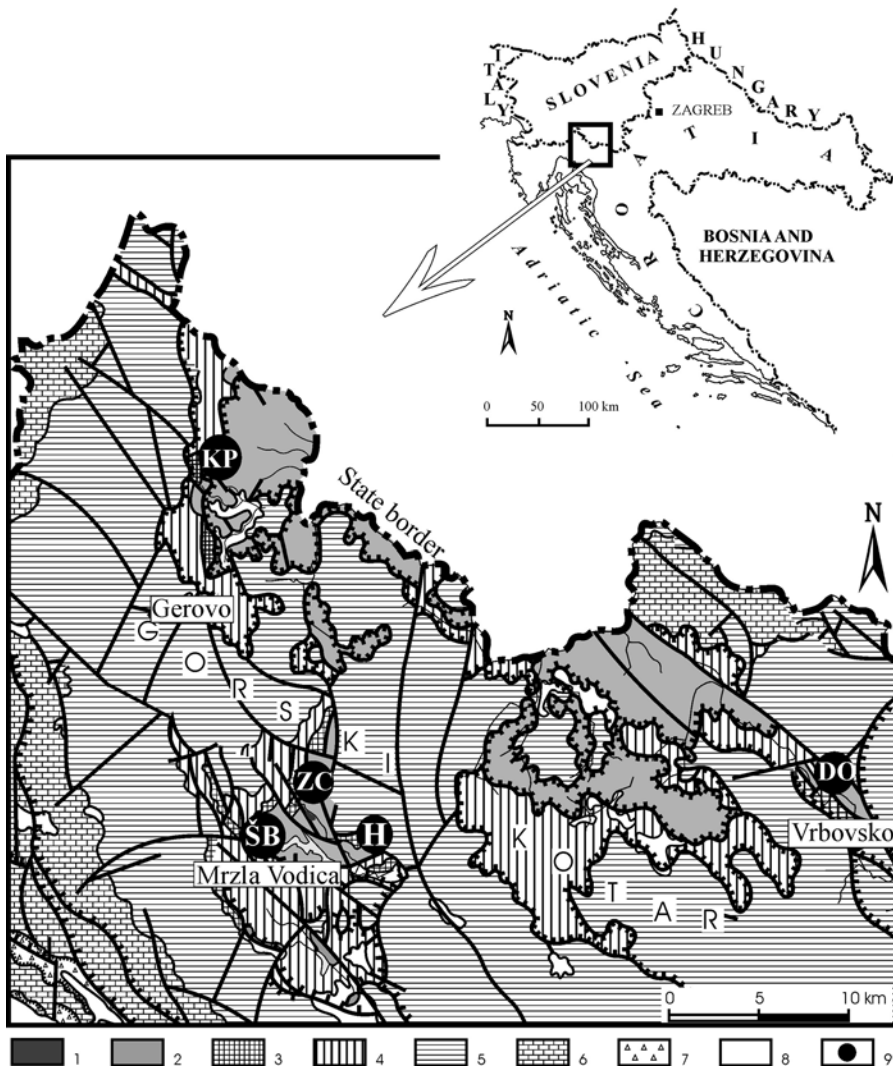


Fig. 1 - Location and geologic map of the Gorski Kotar region; Legend: 1) Carboniferous sandstones, 2) Permian sedimentary complex, 3) Scythian dolomites and clastic rocks, 4) Upper Triassic dolomite (Hauptdolomit), 5) Jurassic carbonates, 6) Cretaceous limestones, 7) Eocene breccias, 8) Alluvium, 9) Sections (modified after Savić & Dozet 1984).

by Šćavničar (1973). The classic division of Lower Triassic deposits to Siusi (Lower) and Campil (Upper) members, as for the rest of the External Dinarides (Šćavničar & Šušnjara 1983; Aljinović 1995; Jelaska et al. 2003), was impossible to apply to Gorski Kotar, thus, the investigations were usually lacking any aid in stratigraphic definition.

Recent sedimentological studies of Aljinović (1997) and Aljinović & Tišljara (2000) resulted in more detailed facies interpretation and better understanding of the facies successions in Lower Triassic depositional environment but still without any chronostratigraphic data. Therefore the revised investigation and sampling focused on biostratigraphic study of five sections (Fig. 1) aiming to establish the age by means of the conodonts. Early Triassic conodonts from Gorski Kotar area, Croatia are documented herein. The conodonts often provide the only chronostratigraphic data. The conodont species *Platyvillosus costatus* and *P. hamadai* represent their first records in the External Dinarides, and *Hindeodus parvus* in the Dinarides in general. Correlation of the Lower Triassic conodont faunas of Gorski Kotar area with those from some

other parts of the Western Tethyan realm can be carried out.

Geological setting

The investigated area of Gorski Kotar is situated in northwestern part of the External Dinarides (Croatia). Because of its location in the zone of major faults (Prelogović et al. 2004), and due to intense overthrusting (Herak 1980), the outcrops of Lower Triassic sediments are scarce and small, which makes the interpretation of sedimentary environment rather difficult (Fig. 1). Lower Triassic deposits are in fault contact with underlying Permian clastic rocks and unconformably overlain by Upper Triassic deposits. Lower Triassic depositional environment is envisaged as shallow marine (passive continental margin) (Jelaska et al. 2003). The Lower Triassic sedimentary complex in Gorski Kotar begins with a predominantly carbonate sedimentation and, going upward, shows increasing terrigenous influx.

The Lower Triassic sedimentary successions were investigated in the central part of Gorski Kotar region

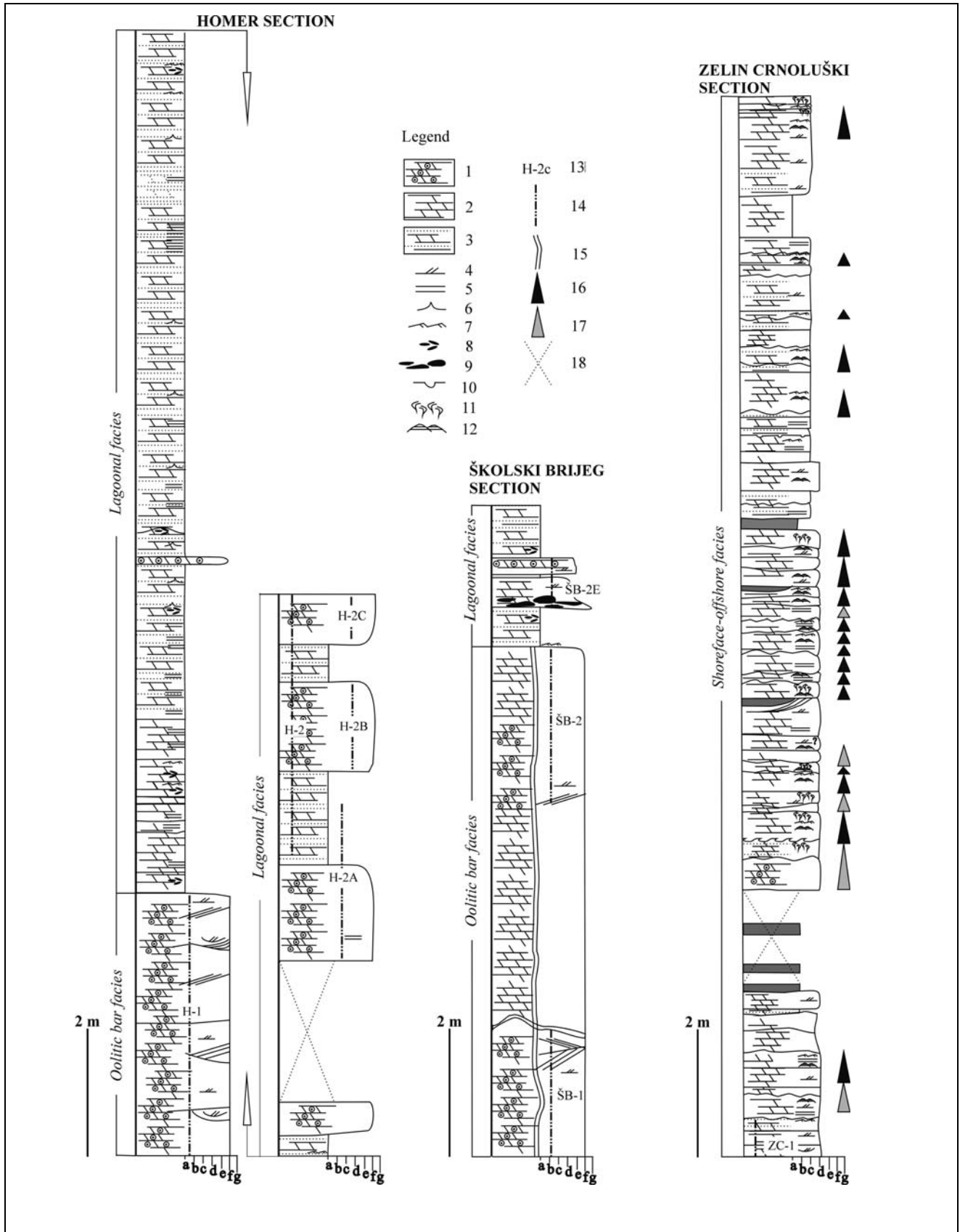


Fig. 2 - Homer, Školski Brijeg and Zelin Crnoluški sections; legend: 1) dolomitised ooid grainstone, 2) macrocrystalline dolomite, 3) intercalations of dolomicrites, sandy dolomicrites and calcarenaceous sandstones, 4) cross-bedding, 5) parallel lamination, 6) wave ripple cross-lamination, 7) current ripple cross-lamination, 8) intraclasts, 9) flat pebbles, 10) gutter-casts, 11) bioturbation, 12) hummocky cross-lamination, 13) conodont sample, 14) sampled interval, 15) barite veins, 16) fining upward sequence, 17) uncertain fining upward sequence, 18) partly covered interval. Grain size: a) mud, b) silt, c) very fine sand, d) fine sand, e) medium sand, f) coarse sand, g) gravel.

(the vicinity of Lokve and Mrzla Vodica), as well as in the marginal parts of the region (vicinity of Gerovo and Vrbovsko). A facies assemblage investigated in the central part of Gorski Kotar region (Homer - H, Školski Brijeg - ŠB, Zelin Crnoluški - ZC sections) differs from those in the marginal parts (Kramarčin Potok - KP, Dobra - DO sections). Therefore the lithofacies investigations were supplemented by conodont studies at each of five localities.

Lithofacies and conodont fauna of investigated sections

Five Lower Triassic sections (Homer-H, Školski Brijeg-ŠB, Zelin Crnoluški-ZC, Kramarčin Potok-KP and Dobra-DO) have been investigated and sampled for conodonts in the Gorski Kotar region. In this chapter, lithofacies analysis of each section is presented as a lithologic column, and supplemented with obtained conodont data. Twenty-five rock samples, with minimum weight of 3.5 kg (Tab. 1) were collected and treated for conodonts. A standard conodont technique with acetic acid was used, followed by gravity enrichment. Only thirteen samples proved to yield conodont elements. In general, the recovered conodonts are rare, except for the *Pachycladina* elements, and their preservation is commonly fragmented. The CAI (Color Alteration Index) (Epstein et al. 1977, Rejebian et al. 1987) of the conodonts is above 5, implying post-depositional temperatures varying between temperature ranges 300-480°C and 490-720°C (Rejebian et al. 1987). Representative conodont specimens were photographed with aid of scanning-electron microscope and illustrated on Pl. 1. All recovered conodont specimens have been deposited at Geološki zavod Slovenije (Geological Survey of Slovenia) under catalogue numbers GeoZS 3636-3638, 3644-3652, 3716-3725.



Fig. 3 - Tabular and trough cross-bedding (2D and 3D dunes) forming oolitic bar facies (Homer section). Pen for scale - 12 cm, encircled.

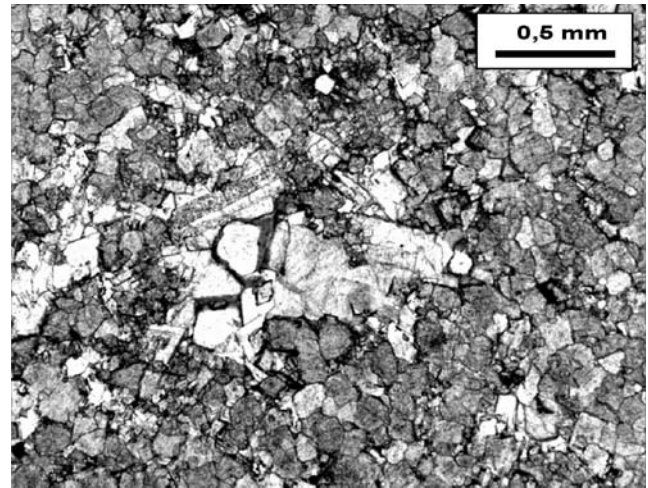


Fig. 4 - Microphotograph of dolomitised oolitic bar facies. Unimodal anhedral to subhedral dolomitic structure suggesting late-diagenetic origin (Školski Brijeg section, ŠB-2). Plane polarised light.

Homer and Školski Brijeg sections

The carbonate and mixed carbonate-siliciclastic Lower Triassic sediments in the central part of Gorski Kotar are best represented by outcrops in the old barite pits Homer - H west of Lokve and Školski Brijeg - ŠB in Mrzla Vodica (Fig. 2). In the sequence, the Palaeozoic sediments are transgressively overlain by the basal, dolomitised, **oolitic bar facies (F-1)** (Fig. 3). The dominant lithofacies characteristic of F-1 is the appearance of thick, tabular foresets and thin, trough cosets that stem from a migration of large 2D and medium 3D dunes (terminology after Ashley 1990) (Fig. 3). The thick tabular foresets of the oolitic sand were interpreted as being deposited by tidal currents intensified during storms, while the thinner planar and trough cosets are the result of post-storm reworking by tidal currents.

Micropetrographically, the rocks of F-1 facies exhibit unimodal to polymodal anhedral or subhedral dolomitic structure, suggesting late diagenetic origin (Fig. 4). Primary carbonate components were usually completely destroyed, except partially preserved ooid "ghosts" (Fig. 5). Facies F-1 has never been documented palaeontologically, possibly because of intense dolomitisation. The oolitic sands exhibit the morphology and position of barrier bars located between the open sea and the landward laying shallow restricted area. The shallow sea behind the barrier was characterized by deposition of mostly carbonate muds, occasionally with varying proportions of siliciclastic terrigenous detritus. These sediments are interpreted as the **lagoonal facies (F-2)**. It consists of thin to medium-bedded (2-30 cm) dolomicrites with interbeds of parallel to ripple cross-laminated sandy dolomites and/or calcarenaceous sandstones. Among the dolomicrites and calcarenaceous sandstones of F-2 facies, some tabular 15-60 cm thick

oid grainstone interlayers occur, exhibiting faint cross-lamination. Dolomicrites, sandy dolomicrites and calcarenaceous sandstones imply quiet and slow accumulation of lagoonal material (mainly carbonate mud, silt-sized intraclasts and pellets), periodically interrupted by terrigenous influx. Interlayers of tabular ooid grainstones are interpreted as back barrier storm layers. In the F-2 facies, a general upward increasing terrigenous influence can be noticed.

For the purpose of conodont analyses, five samples have been processed from the Homer section (Tab. 1). These are: sample H-1 (GeoZS 3637) taken from the basal 4 m thick F-1 facies (Fig. 2) and H-2, H-2A, H-2B, H-2C (GeoZS 3638, 3723, 3724, 3725) from tabular oolitic storm layers of facies F-2. From a total five samples, only two (H-1, H-2) yielded fragments of conodonts.

From the Školski Brijeg section, 4 samples have been collected (Tab. 1). Samples ŠB-1, and ŠB-2 (GeoZS 3636, 3716) from facies F-1 (basal division of the section) and samples ŠB-2E and ŠB-3 (GeoZS 3717-3719) from facies F-2. A single element determined as *Hindeodus parvus* (Kozur & Pjatakova) was obtained from the sample ŠB-1 out of 6 kg weight, and a fragment of *Hindeodus* sp. from the sample ŠB-2.

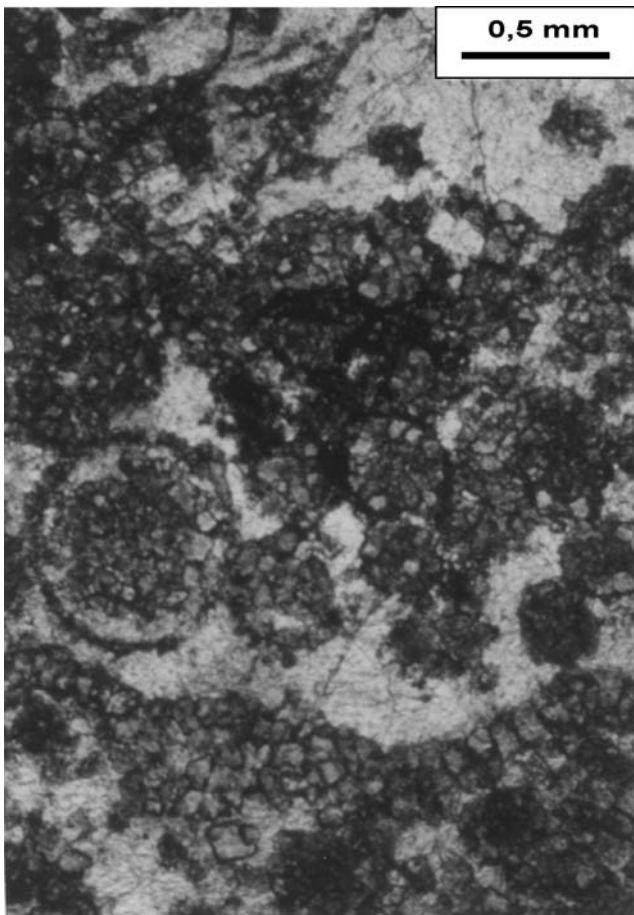


Fig. 5 - Ooid "ghosts" preserved in oolitic bar facies (Školski Brijeg section, ŠB-1). Plane polarised light.

Zelin Crnoluški section

North from Lokve and Mrzla Vodica at the Zelin Crnoluški section - ZC Lower Triassic rocks reveal different sedimentary characteristics from those at the Homer and Školski Brijeg sections (Fig. 2). Oolitic bar facies (F-1) is not covered by lagoonal facies (F-2), but the sediment succession comprises micro- to macro-crystalline dolomites and sandy dolomites with rare tabular or lenticular intercalations of siltites. Aforementioned sediments are organized into fining-upward sequences, consisting usually of cross-bedded dolomites in the lower part, succeeded by hummocky cross-stratified upper part. The cross-bedded interval, composed of tabular or trough wave reworked cross bed sets bounded by erosional surfaces, could represent deposition of a wave or storm influenced shoreface sediments. As shown by Dott & Bourgeois (1982), the close association with the hummocky cross-stratification, imply storm as an important agent in deposition. Described sequences restrict the deposition of primary carbonate grain sediments to inner shelf area, near or below mean fair weather wave base and were interpreted as **shoreface-offshore facies (F-3)**.

The deposition of this facies appeared in a highly agitated storm-wave dominated near-shore zone of an unrimmed shelf. On the contrary, the succession at Homer and Školski Brijeg sections indicate a restricted, rimmed shelf, consisting of ooid barrier bars (facies F-1) and a lagoon facies (F-2). Thus, the deposition of storm influenced shoreface-offshore facies can be explained if we consider the fast transgression by "drowning in place" mechanism (Reinson 1984; Elliot 1986) by which the coast of initial barrier "jumps" landward and forms a new coastal zone of unrimmed (non-barred) storm influenced shelf, as described in Zelin Crnoluški section.

Unimodal macrocrystalline dolomite structure suggests its late diagenetic origin from primary limestones (Fig. 6).

The sample taken from the basal part of this section (ZC-1, GeoZS 3644) produced a small, poorly preserved fauna, consisting of fragmented conodont elements (Tab. 1). It includes: *Hadrodontina* sp. and *Pachycladina obliqua* Staesche. The latter is represented by most elements of the apparatus. There occur also few slender and flattened elements, however of incomplete preservation, referred to ?*Parachirognathus* sp. The presence of *P. obliqua* and the absence of *Hindeodus parvus*, found in the basal parts of the Školski Brijeg section, indicate a slightly younger chronostratigraphic position of Zelin Crnoluški section.

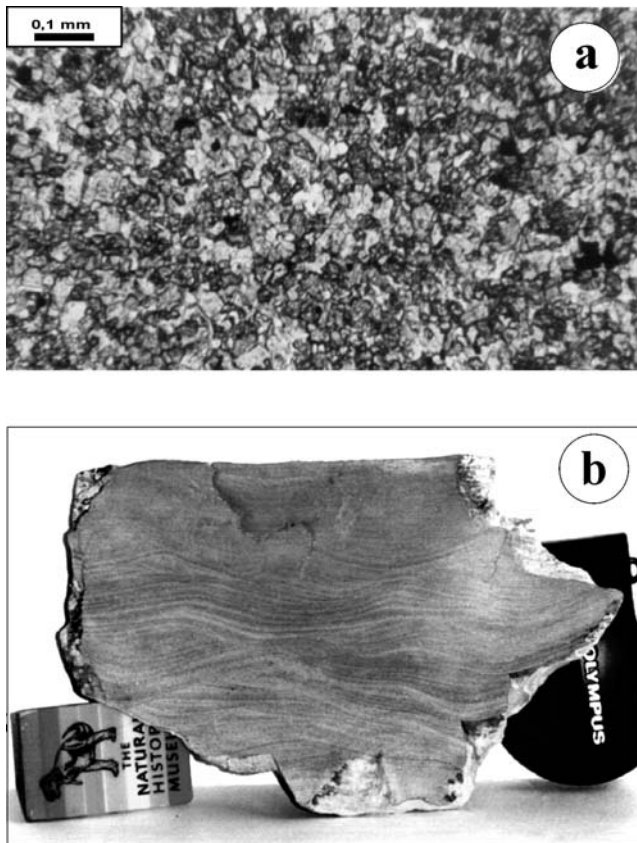


Fig. 6 - a) Unimodal anhedral structure of dolomite (Zelin Crno-luški section). Plane polarised light. b) Although the primary carbonate components are destroyed due to late diagenetic dolomitization, in the same rocks primary depositional structures (hummocky cross lamination) can be seen.

Kramarčin Potok and Dobra sections

In the northwestern and eastern parts of Gorski Kotar region (vicinity of Gerovo and Vrbovsko, Fig. 1), carbonate facies F-1, F-2 and F-3 were not found. Instead, meter scale reddish cross-bedded ooid grainstones or sandstones (**ooid-sandy shoal facies F-4**) alternate in vertical succession with red laminated, thin-bedded, carbonate-siliciclastic mudstones (**restricted bay facies F-5**) or **flat pebble conglomerates (F-6)**.

Kramarčin Potok section. Vertical facies succession at Kramarčin Potok locality is characterized by facies F-4 and F-5, which are usually organized in fining-upward sequences and where the deposition of each sequence commences with ooid grainstone or/and red sandstone (F-4) and terminates with the deposition of laminated carbonate-siliciclastic mudstones of restricted bays (F-5) (Fig. 7 and 8).

Ooid-sandy shoal facies consists of meter-scale thick, tabular or trough cross-bedded, ooid grainstones and sandstones. Fine to medium grained ooid detritus is diagenetically altered to late diagenetic macrocrystalline

dolomite or sandy dolomite. The amount of sand is variable and with its increase the sandy grainstones gradually pass into sandstones. Dolomitised ooid grainstones are composed of planar subhedral to euhedral crystals, where ooid detritus is visible mainly due to preserved ferroan films that coated primary ooid forms. Scarse skeletal fragments occur occasionally. Sandstones consist of quartz and lithic fragments with intergranular dolomitic cement.

The depositional environment was influenced by mixing of intrabasinal carbonate (mainly ooid) detritus and red terrigenous material. The presence of ooids and red ferroan oxides suggest well oxygenated marine environments. The erosive base of the deposition at the beginning of each sequence, as well as lack of particular signs of tidal origin, suggests that deposition occurred in wave or storm dominated shallow sea similarly as described in ancient and modern examples by Swift et al. (1979, 1987) and Levell (1980). Coarse-grained flat pebbles accumulated at the base of some cross-bedded intervals are interpreted as storm lags. Shale partings, present in some thick, cross-bedded ooid grainstone intervals, suggest amalgamation, i.e. the reduction of fine units during storms.

Facies F-5 is characterized by alternation of dolomitic, intraclastic and silty laminae (or very thin interlayers). The deposition of different grain size particles indicate the different energy currents or imply the existence of tidal currents capable of carrying intraclastic and silty particles, as well as dispersed mud, at the same time (Demico 1983). The tight association with the F-4 facies, interpreted as high-energy facies, suggests that the deposition of F-5 facies occurred in a shallow, but restricted, tide-dominated, marine area. Mottled structure is the result of reworking by organisms. Desiccation cracks found in muddy sediments, envisioned as fractured laminae, imply that at least parts of the restricted bays were periodically dried out. Sequence architecture suggests that the laterally existing facies (F-4 and F-5) appear in the vertical succession due to lateral migration of ooid or muddy shoals or due to sea level oscillation. Restricted muddy bays as well as ooid-sandy wave/storm dominated shallow sea can be interpreted as parts of an extensive, shallow, epicontinental sea, formed as a consequence of advanced transgression.

From the Kramarčin Potok section, nine samples were collected for conodont analyses from carbonate layers, mainly oolitic grainstones with variable amount of sandy detritus (Tab. 1). These are samples KP 1 - KP 8 (GeoZS 3645-3652, 3720, 3721, 3722). They produced small but diagnostic conodont fauna. It is characterized by *Pachycladina obliqua* Staesche, *Platyvillus costatus* (Staesche), *P. hamadai* Koike, ?*Parachirognathus* sp., *Hadrodontina* sp. (*biserialis* type present in

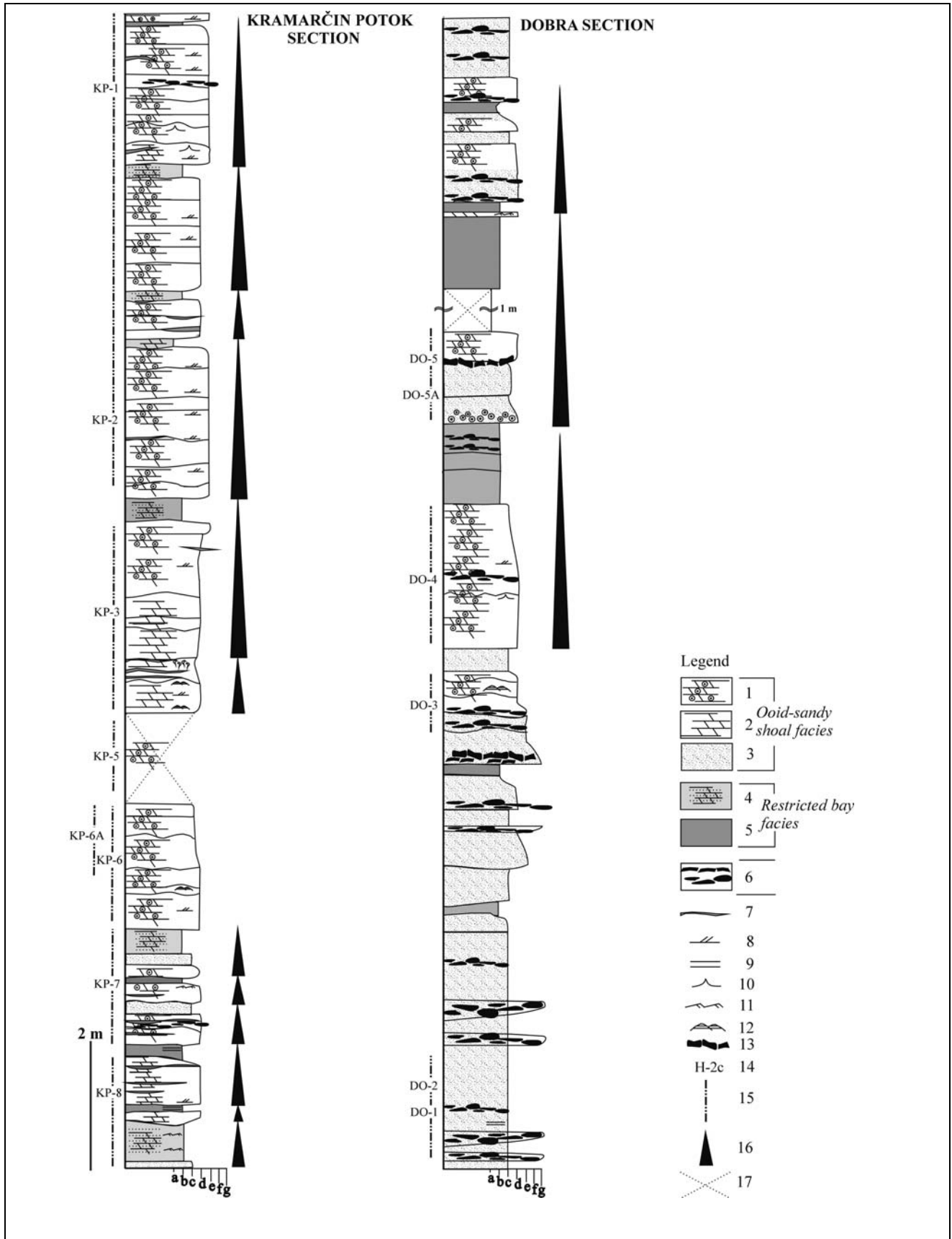


Fig. 7 - Kramarčin Potok and Dobra sections; legend: 1) dolomitised ooid grainstone, 2) dolomite, 3) sandstone, 4) dolomitic, intraclastic and silty laminae, 5) siltstone, 6) flat pebble conglomerate, 7) shale partings, 8) cross-bedding, 9) parallel lamination, 10) wave ripple cross-lamination, 11) current ripple cross-lamination, 12) hummocky cross-lamination, 13) mud cracks, 14) conodont sample, 15) sampled interval, 16) fining upward sequence, 17) partly covered section. Grain size: a) mud, b) silt, c) very fine sand, d) fine sand, e) medium sand, f) coarse sand, g) gravel.



Fig. 8 - Kramarčin Potok section. Pen for scale – 14 cm, encircled.

	<i>Ellisonia</i> sp.	<i>Hadrodontina</i> sp.	<i>Hindeodus parvus</i>	<i>Hindeodus</i> sp.	<i>Foliella gardenae</i>	? <i>Parachirognathus</i> sp.	<i>Pachycladina obliqua</i>	<i>Platyvillosus costatus</i>	<i>Platyvillosus hamadai</i>	Conodont fragments
H-1										+
H-2										+
H-2A										
H-2B										
H-3C										
ŠB-1			+							
ŠB-2				+						
ŠB-2E										
ŠB-3										
ZC-1		+				+	+			
KP-1	+	+								
KP-2										
KP-3										+
KP-4										
KP-5	+	+								+
KP-6		+						+	+	
KP-6A										
KP-7										
KP-8	+	+			+	+	+			+
DO-1										
DO-2										
DO-3							+			
DO-4		+								
DO-5	+	+								
DO-5A										+

Tab. 1 - Conodont distribution in the studied samples of Gorski Kotar (Croatia). H – Homer, ŠB – Školski Brijeg, ZC – Zelin Crnoluški, KP – Kramarčin Potok, DO – Dobra.

the sample KP-1), *Ellisonia* sp. and *Foliella gardenae* (Staesche).

Dobra section. Vertical facies association at Dobra locality exhibits the same characteristic as the Kramarčin Potok section but, except F-4 and F-5 facies, distinctive layers of flat pebble conglomerates (facies F-6) occurred (Fig. 7). The gradual transition from flat pebble conglomerates to horizontally laminated sandstones has been noticed. In vertical sections there are intervals consisting of fragmented mud cracks. Slight dislocation of the fragmented mud particles has also been noticed. The accumulation of angular particles resembles more a breccia (“pseudobreccia” sensu Babić 1968) than a conglomerate. Appearance of both desiccation cracks and angular particles suggest a rather shallow environment and in situ accumulation of fragmented mud particles. As this is in vertical succession noticed several times, it can be assumed that supratidal conditions were established periodically. Rounded fragments suggest that the primary angular fragmented muds were repeatedly reworked and rounded, possibly by wave action in a coastal zone. Mud clasts were also noticed at the base of ooid grainstones or sandstones, assuming that the coarse fragments were periodically reworked and deposited as basal lag, together with ooids and sandy particles.

The short sequence enabled collection of only a few samples for conodonts. These are samples DO-1 - DO-5, DO-5A (GeoZS 3654-3659), all collected in F-4 facies (Tab. 1). They yielded fragmented and rare robust elements of the genera *Hadrodontina* and ?*Ellisonia*. The fragmentation might stem from intense reworking due to waves in a rather shallow marine environment (epicontinental sea). The sample DO-3 yielded more abundant fossil material; the fragments of conodont elements are abraded, but some of them still retained characteristic features of the *P. obliqua* apparatus (Pa, Pb, Sc elements can be recognized).

Conodont fauna

Conodont dating

The conodont faunas from the five locations of Gorski Kotar, Croatia, are characterized by occurrence of *Hindeodus* in the oldest Triassic strata, but the younger part is marked mainly by *Pachycladina* and/or *Hadrodontina* associated occasionally by *Ellisonia*. Rare representatives of genera *Foliella* and *Platyvillosus* are present in two particular levels. All recovered conodont genera are considered to reflect shallow water environments, but *Hindeodus parvus* is an ubiquitous species.

The collected conodont faunas document the following main events/zones, from the earliest to the latest:

- *parvus-isarcica* zones. Two specimens determined as *Hindeodus parvus* (Kozur & Pjatakova) and *Hindeodus* sp. were found in the Školski Brijeg section (samples ŠB-1 and ŠB-2). *H. parvus* is proven to be very tolerant ecologically, but its abundance varies in on-shore-offshore relationship. It is diagnostic for the lowermost Triassic and globally recognized marker for the lower boundary of the Triassic. The stratigraphic range of *H. parvus* extends up to the *isarcica* Zone sensu Kozur (1996, 2003), defined by the first appearance of *Isarcicella isarcica* (Staesche);

- *obliqua* Zone. The fauna referred to the zone is characterized by predominating elements of *Pachycladina obliqua* Staesche whose first occurrence defines the biozone base. In sample DO-3 (Dobra section) it occurs as a monospecific fauna, but in samples ZC-1 (Zelin Crnoluški section) and KP-8 (Kramarčin Potok section) it is associated with *Hadrodontina* sp. and ?*Parachirognathus* sp., and in the KP-8 sample with *Ellisonia* sp. and *Foliella gardenae*. The entire investigated part of the Kramarčin Potok section is attributed to the *obliqua* Zone, including the KP-1 sample that contains *Ellisonia* sp. and *Hadrodontina* sp. The determined taxa are characteristic Lower Triassic shallow water elements.

A similar Early Triassic fauna was recorded also from Mt. Svilaja in Croatia (Jelaska et al. 2003). Equivalent faunas were documented in several locations of Slovenia, where elements of *Pachycladina obliqua* apparatus are frequently accompanied by abundant elements of *Foliella gardenae* and *Parachirognathus ethingtoni* Clark (Kolar-Jurkovšek 1990; Kolar-Jurkovšek & Jurkovšek 1995, 1996; Jurkovšek et al. 1999). *P. obliqua* is a widely geographically distributed species; it ranges from the Smithian to the Spathian (Perri & Andraghetti 1987). As reported by Solien (1979), in Thaynes Formation of Utah, *Pachycladina* and *Hadrodontina* characterize the Smithian. These faunas were compared to the Zone 7 (*Parachirognathus-Furnishius* Zone) of Sweet et al. (1971) and thus attributed to the Smithian. *P. obliqua* and *Parachirognathus* are significant biostratigraphic markers for the Lower Triassic sequences of Slovenia (Kolar-Jurkovšek & Jurkovšek 1996);

- *Platyvillosus* Subzone. The sample KP-6 (Kramarčin Potok section) is characterized by elements of the less represented Early Triassic genus, *Platyvillosus*; the collection yields Pa-elements of *P. costatus* (Staesche) and *P. hamadai* Koike. Sweet et al. (1971) defined the Zone 10 (*Platyvillosus* Zone) for the earliest Spathian. The zone was based on two species, *P. costatus* in its lower part and *P. asperatus* Clark, Sincavage & Stone in its upper part. *P. costatus* was first described from the Campil Beds (middle part) of South Tyrol, Italy (Staesche 1964), and later reported from some

other locations. In Spiti, this species is associated with diverse *Neospathodus* faunas of the Dienerian age (Goel 1977). *P. hamadai* was hitherto known from two locations of Asia (Japan and Malaysia) in Smithian strata (Koike 1982, 1988), but its occurrence at Sichuan, China, determined as *P. laevigatus* by Tian and Jiang (1983), seems to be of Dienerian age (Koike 1988).

Platyvillosus asperatus is known to be restricted to the Early Spathian of the Great Basin, USA (Clark et al. 1964; Sweet et al. 1971). The Dienerian occurrences of the genus *Platyvillosus* are so far confined to the Asian locations (Sichuan, China and Spiti, India) and the oldest appearances in regions outside the continent should be evidenced. It seems very likely that this genus is geographically and stratigraphically limited due to ecological factors.

The *Platyvillosus* fauna defines here the *Platyvillosus* Subzone within the *obliqua* Zone. In Southern Tyrol and in Serbia, both *Foliella gardenae* and *Platyvillosus costatus* appear in the Campil Beds, but do not co-occur; *Foliella* is reported to be confined to its upper part. It should be also noted here that based on the vertical distribution of the two species, the lower *costatus*, and the upper *gardenae* zones were discriminated by Budurov & Pantić (1974).

Biostratigraphic and chronostratigraphic discussion

Stratigraphically most important species across the Permian-Triassic boundary belong to the *Hindeodus-Isarcicella* group. The first appearance datum (FAD) of *Hindeodus parvus* has been favoured and approved to define the base of the Triassic system (Yin 1993; Yin et al. 1996, 2001). *Hindeodus parvus* is an easily recognizable species with wide geographic distribution and no facies restriction (very high facies tolerance). It can be found both in cold water and warm water deposits, and it is the first globally distributed species that appears just above the minimum faunal diversity indicated by the minimum in $\delta^{13}\text{C}$ (Kozur 1996; Kozur et al. 1996).

In the Lower Triassic, different conodont biofacies depending upon lithofacies were recognized in the Western North America (Solien 1979; Clark & Carr 1984; Paull 1982; Paull & Paull 1994). Early Triassic conodont zonation have been based on conodont species representing different biofacies. Orchard & Krystyn (1998) established a double conodont zones for the lowermost Triassic of Spiti, Himalayas: a zonation based on the pelagic *Neogondolella* was correlated with the zonation based on the shallow water *Hindeodus-Isarcicella* group.

Since the 1970 Sweet's first complete conodont-based zonation for the Lower Triassic series, there were several attempts to establish conodont zonation and to make comparison with the standard ammonoid zones.

SWEET 1970b	SWEET et al. 1971		KOZUR and MOSTLER		SOLIEN 1979 CARR & PAULL			MATSUDA	PERRI 1991 PERRI & FARABEGOLI
			1972	1973	1983			1985	2003
Timorensis	SPATHIAN STAGE	Timorensis	Timorensis	Timorensis		8		Timorensis	triangularis
Jubata		Jubata	Homeri	Homeri		7		Triangularis - Homeri	
		Neosp. n. sp. G.				6			
		Platyvillosus				5	B A		
Waageni	SMITHIAN STAGE	Milleri	Waageni	Elongata	4		D	Elongata	obliqua
		Conservativus	Milleri	G. aff. Milleri			C	Milleri	
		Parachirognathus Furnishius		Eotriassica			B A	Waageni	
Pakistanensis		Pakistanensis	N. gen. n. sp.	Gondolella n. sp. B.				Pakistanensis	anceps
Cristagalli	DIENERIAN STAGE	Cristagalli	Dieneri	(not discussed)	3	Dieneri		Cristagalli	aequabilis
Dieneri							Dieneri		
Kummeli							Kummeli		
Carinata	GRIES - BACHIAN	Carinata	Carinata	Carinata	1	Typicalis		Carinata	isarcica staeschei lobata parvus
			Typicalis	Parvus				Parvus	
--- Typicalis ---	PER - MIAN	--- Typicalis ---		Isarcica				Minutus	praeparvus
									U L

Tab. 2 - Schematic presentation of correlation of conodont biozones for the Lower Triassic (after Sweet & Bergström 1986, Matsuda 1985, and supplemented with data of Perri 1991, Perri & Farabegoli 2003).

In this scheme, the Lower Triassic was subdivided into 9 conodont biozones. During the Symposium on Conodont Biostratigraphy, a biozonation for the whole Triassic was proposed: 22 biozones were established for the whole system, but 13 biozones are for the Lower Triassic based on data from Pakistan and Western United States (Sweet et al. 1971). The upper limit of each biozone is marked by the first appearance of the index conodont species of the next successive biozone. Tab. 2 is schematic presentation of correlation of conodont biozones for the Lower Triassic (supplemented after Sweet & Bergström 1986; Matsuda 1981, 1985).

Comparison of conodont faunas of adjacent areas

The P-T sediments were extensively investigated in the Southern Alps of Italy and Austria. A subdivision into lithostratigraphic units is based on the recognition of transgressive and regressive events. In the Dolomites, the Werfen Formation can be divided in the W 1 - Tesero Horizon, W 2 - Mazzin Member, W 3 - Andraz Horizon, W 4 - Siusi Member, W 5 - Gastropod Oolite Member, W 6 - Campil Member, W 7 - Val Badia Member and W 8 - Cencenighe Member (Broglia Loriga 1983, 1986).

First Early Triassic conodonts of the Southern Alps were reported by Huckriede (1958); he erected a new conodont species *Isarcicella isarcica* that was recognized as an important marker in the P-T sequences.

Staesche (1964) distinguished 15 form species from the Werfen Formation. Then followed a period of intensive study of conodont biostratigraphy across the P-T boundary in a wide area of the Southern Alps (Farabegoli et al. 1986; Perri & Andraghetti 1987; Perri 1991; Farabegoli & Perri 1998; Nicora & Perri 1999).

In the faunas of Lower Triassic succession of the Southern Alps three biozones were discriminated, the *typicalis*, *isarcica* and *triangularis* zones, based on the presence of diagnostic species known from previous biostratigraphic schemes (Perri & Andraghetti 1987). However, by utilizing data on the occurrences of the representatives of some other Early Triassic genera (*Ellisonia*, *Hadrodontina* and *Pachycladina*), also three local zones, the *aequabilis*, *anceps* and *obliqua* zones, were established (Perri 1991). Recent biostratigraphic study in the area across the P-T boundary clarified morphological trends among *Hindeodus* and *Isarcicella*, and it allowed the recognition of *praeparvus* Zone (the youngest Permian conodont Zone on top of the Bellerophon Formation) and the following succeeding zones in the Werfen Formation: *parvus*, *lobata*, *staeschei* and *isarcica* zones (Perri & Farabegoli 2003). In the Bulla section, Southern Alps, in the P-T sequence with the medium-high sedimentation rate, *H. parvus* is present in the uppermost Tesero Member and lowermost Mazzin Member (samples BU 12B - BU 13B), in an interval of approximate thickness of 2 meters, but its

first appearance was recorded 1.30 m above the base of the Werfen Formation (Perri & Farabegoli 2003).

In the Carnic Alps, the Gartenkofel – 1 core, comprising mainly dolomitic carbonates of the Upper Permian Bellerophon Formation and the Lower Triassic Werfen Formation, was studied by a consortium of experts (Holser et al. 1991). The mainly dolomitic carbonates of the Upper Permian Bellerophon Formation were deposited in a shallow marine innershelf area and were conformably overlain by limestone-dolomite-marl alternations (containing varying amounts of terrigenous material) of the Lower Triassic Werfen Formation. The standard profile of the Werfen Formation in Gartenkofel area is similar as in the Dolomites, with only minor differences: the Tesero Horizon is only locally developed and the Gastropod Oolite Member is not developed here, but a “gastropod oolite” facies occurs from the Seis (= Siusi) Member up to the Val Badia Member (Boeckelmann 1991). Diverse *Hindeodus-Isaricella* faunas (Assemblages A - D), and the youngest assemblage (Assemblage E) characterized by *Ellisonia aequabilis* (Staesche) were obtained (Schönlaub 1991). The lowermost association of the Lower Triassic is characterized by the joint occurrences of *Hindeodus* cf. *latidentatus*, *Hindeodus minutus*, *Hindeodus* n. sp. and the first occurrence of *Hindeodus parvus* that was derived from the lowermost Tesero Horizon.

In Slovenia, the lowermost Triassic strata have so far not been documented by means of conodonts. However, a regionally widespread oolitic horizon that was for a long time thought to be unproductive, proved to yield conodont fauna. It has been evidenced in several locations in the Slovenian part of the External Dinarides. The term External Dinarides, precisely the macro-tectonic dismembering of the border region between the Southern Alps and the External Dinarides is used according to the explanation of Placer (1999). A summary report on the Lower Triassic conodont faunas was given by Kolar-Jurkovšek & Jurkovšek (2001). All recovered assemblages are characterized by *Pachycladina obliqua* apparatus and *Hadrodontina* sp. and/or *Furnishius triserratus* Clark, *Parachirognathus ethingtoni* Clark, and *Foliella gardenae* (Staesche), respectively. Occasionally, the elements of *Ellisonia* can be present. Conodont collections from Slovenian part of the External Dinarides have been well documented and can be compared well with other equivalent collections hitherto studied in other parts of Slovenia (Kolar-Jurkovšek 1990, 1996; Kolar-Jurkovšek & Jurkovšek 1995). Faunal lists of these Smithian localities are very similar. They were correlated to the Lower Smithian Zone 7 (*Parachirognathus-Furnishius* Zone) of Sweet and others (1971). Shallow water Early Triassic genera *Foliella*, *Hadrodontina*, *Pachycladina*, and *Parachirognathus* are significant

biostratigraphic markers that have proved useful in the conodont zonation of Slovenia.

This study resulted new paleontological data for Gorski Kotar and revealed similar composition of the equivalent conodont faunas in the area. Thus, it may be concluded that the element *P. obliqua* is an important biostratigraphic tool in the Western Tethys. Outside External Dinarides, its stratigraphic use has been previously demonstrated in the Southern Alps (Perri & Andraghetti 1987; Perri 1991), as well as in the Inner Dinarides: Jadar Zone in Serbia (Budurov & Pantić 1973, 1974; Sudar 1986).

Conclusions

Lithostratigraphic and biostratigraphic study of the five Lower Triassic sequences of Gorski Kotar region was undertaken. Lithofacies analysis of the Lower Triassic sedimentary succession at Homer and Školski Brijeg (central part of Gorski Kotar region) correspond to a dominantly carbonate shallow marine sedimentation, influenced by storms and post storm tidal reworking. Oolitic bars (facies F-1) were deposited some distance from shore as ooid barrier sands, restricting the landward laying muddy lagoon (F-2). Oolitic bar overlain by lagoonal facies (as described at both successions) was interpreted as a sudden transgression by the “in place drowning” mechanism. When a sudden transgression occurs, as is supposed in this case, bars are covered with a large wider lagoon as long as the coastline “jumps” landward. There a wave/storm dominated, unrimmed coast can form. The sequences characteristics for unrestricted shallow sea were obtained at Zelin Crnoluški section (facies F-3).

By the advanced transgression a wide epicontinental sea was established, displaying lithofacial characteristics, as investigated in the Kramarčin Potok and Dobra sections. These sections are lacking deposition of F-1, F-2 and F-3, instead, reddish ooid-sandy shoal facies (F-4) alternate vertically with restricted muddy bay facies (F-5) and/or flat pebble conglomerates (F-5).

Occurrences of facies F-4, F-5 and F-6 can be explained as being the result of the deposition in a wide epicontinental sea with simultaneous lateral existence of a highly agitated wave/storm influenced shoals and restricted muddy bays exposed to desiccation. The deposition in these areas begins when an initially bar-rimmed shallow shelf widens enough so that the sea covers all distal (marginal) areas. Wide depositional environments were strongly influenced by increasing siliclastic input and high amount of red ferroan pigment. The alternation of three lithofacies types - F-4, F-5 and F-6 is typical for Siusi beds and can be easily compared

to the Lower Triassic deposits in other part of External Dinarides.

Conodont fauna was recovered from samples in all five sections, but in one case (Homer section) its preservation was inadequate for determination. The occurrence of *Hindeodus parvus* in the Školski Brijeg section is documented and thus the first time reported from the Dinarides. The biostratigraphical data enable recognition of the *parvus-isarcicella* zones, *obliqua* Zone and *Platyvillosus* Subzone. The finds of *Hindeodus parvus*, *Platyvillosus costatus* and *Pl. hamadai* represent their first records in the External Dinarides and enable the correlation of the Early Triassic conodont faunas of Gorski Kotar area with those from some other parts of the Western Tethyan realm.

The conodont faunas of the three sections (Zelin Crnoluški, Kramarčin Potok, Dobra) is marked by presence of *Pachycladina obliqua* associated with some other characteristic Early Triassic genera (*Ellisonia*, *Haddodontina*, *?Parachirognathus*). *P. obliqua* is well represented and it seems to be an important biostratigraphic element for the local conodont zonation. Similar observations have been made from the areas NW and NE from here. Considering very similar composition of the equivalent faunas recorded in other locations of the External Dinarides in Croatia and Slovenia, it can be concluded that the element *P. obliqua* is a significant biostratigraphic tool in the Western Tethys. The biostratigraphic use of this species has been demonstrated both in the Southern Alps (Perri & Andraghetti 1987; Perri 1991), and in the Internal Dinarides (Budurov & Pantić 1973, 1974; Sudar 1986).

Systematic paleontology

Genus *Foliella* Budurov & Pantić, 1973

Type species: *Polygnathus gardenae* Staesche, 1964

Foliella gardenae (Staesche, 1964)

Pl. 1, fig. 7a-b

1964 *Platyvillosus gardenae* Staesche, p. 286-288, fig. 4, 59, pl. 30, fig. 3-6.

1973 *Foliella gardenae* - Budurov & Pantić, p. 52-53, pl. 1, fig. 19, 20.

1995 *Foliella gardenae* - Kolar-Jurkovšek & Jurkovšek, p. 793-794, pl. 2, fig. 2-4

1996 *Foliella gardenae* - Kolar-Jurkovšek & Jurkovšek, pl. 1, fig. 1-4, pl. 2, fig. 1-3, pl. 3, fig. 3.

Remarks. The species reveals great variety in shape and ornamentation as pointed out already by Staesche (1964). Two morphotypes were differentiated by Kolar-Jurkovšek & Jurkovšek (1996). The morphotype A is characterized by numerous lateral nodes of moderate size that are connected with the cusp by ra-

dially arranged structures. The latter are visible under higher magnifications as well as polygonal microsculpture at lateralmost edges that may represent cell imprints as observed on the upper surface of many conodont elements (Von Bitter & Norby 1994). The morphotype B has smooth oral surface but a narrow belt with microsculpture polygons on the lateralmost edges might be present. In some specimens, weakly developed origins of lateral nodes can be observed on the lateralmost edges of the oral surface. Both morphotypes are connected through several transitional forms, and it is clear that morphotype B constitutes only minor part of the *Foliella* population.

Although the collected specimen is not fully preserved, it bears all characteristic features of the taxon. The oral surface is marked by well developed lateral nodes, diagnostic for the morphotype A sensu Kolar-Jurkovšek & Jurkovšek (1996).

Occurrence. Kramarčin Potok (KP - 8).

Range. Campil Beds (upper part), Southern Alps (Staesche 1964); Campil Beds (upper part): *gardenae* Zone, Western Serbia, Yugoslavia (Budurov & Pantić 1974); Smithian, Slovenia (Kolar-Jurkovšek & Jurkovšek 1995, 1996).

Genus *Hindeodus* Rexroad & Furnish, 1964

Type species: *Hindeodus cristulus* (Youngquist & Miller, 1949)

Hindeodus parvus (Kozur & Pjatakova, 1976)

Pl. 1, fig. 6a-b

1976 *Anchignathodus parvus* Kozur & Pjatakova, p. 123-125, fig. 1a-b, e, h.

1981 *Hindeodus parvus* - Matsuda, p. 91-93, pl. 5, fig. 1-3.

1985 *Hindeodus parvus* - Matsuda, pl. 1, fig. 2.

1994 *Isarcicella? parva* - Orchard et al., p. 833, pl. 1, fig. 21, pl. 2, fig. 5-7.

1996 *Hindeodus parvus* - Kozur, p. 94-96, pl. 2, figs. 5-8, pl. 3, fig. 1-11, pl. 4, fig. 5-7.

1998 *Hindeodus parvus* - Orchard & Krystyn, p. 351-352, pl. 6, fig. 9, 16, 17, 20.

1998 *Hindeodus parvus* - Farabegoli & Perri, pl. 4. 3.1., fig. 10, 11.

2000 *Hindeodus parvus* - Jiang Wu et al., pl. 1, fig. 4a-b.

2002 *Hindeodus parvus* - Nicoll et al., p. 628, fig. 15, 16.

2003 *Hindeodus parvus* - Krystyn et al., pl. 3, fig. 2-3.

2003 *Hindeodus parvus* - Perri & Farabegoli, pl. 2, fig. 4-12.

2004 *Hindeodus parvus* - Kozur, p. 51-52, fig. 3, 5-9.

Diagnosis: The Pa element is marked by small unit with high cusp, approximately double height of the subequal posterior denticles.

Remarks. Kozur (1996) distinguished three subspecies: *H. parvus parvus* (Kozur & Pjatakova), *H. parvus anterodentatus* (Dai, Tian & Zhang) - the taxon was earlier discriminated at a specific level by the authors, and *H. parvus erectus* Kozur. Nicoll et al. (2002) recom-

mended that the morphotypes should be considered as a single species due to no consistent morphologic stability or stratigraphic utility. In the specimen under study (the only conodont element was produced from the rock sample with weight of 6 kg) the tips of denticles are missing, especially mostly those of the posterior that are diagnostic for the subspecies determination. The overall unit size, number of the denticles, markedly high and stronger cusp, fit well with the species description.

A rapid evolution of the *Hindeodus-Isarcicella* lineage was demonstrated, but there are different views of the phylomorphogenetic development. The proposed schemes are based on a common origin. The rootstock of this lineage is *H. typicalis* (Sweet) that first appeared already in the uppermost Permian and gave rise to all other species of the group.

Occurrence. Školski Brijeg (ŠB-1).

Range. World-wide guide from of the lowermost Triassic (*H. parvus* to *I. isarcica* zones) (Kozur 1996).

In Orchard's (1996) opinion *H. parvus erectus* is diagnostic form of the species. His conclusion can be supported by an observation of Kozur (1996) this subspecies is facies more tolerant than *H. parvus parvus*; *H. parvus erectus* is present in variety of habitats: from anoxic to dysaerobic environments of greater depth in Sicily, Italy, shallow-water sediments of Alps, pelagic beds (ammonoid and/or gondolellid bearing horizons of several locations in Asia and Greenland (Kozur 1996)).

Genus *Pachycladina* Staesche, 1964

Type species: *Pachycladina obliqua* Staesche, 1964

***Pachycladina obliqua* Staesche, 1964**

Pl. 1, fig. 1-3

1964 *Pachycladina obliqua* Staesche, p. 279, fig. 14, 21, 31, 46, 47; pl. 29, fig. 2-4.

1987 *Pachycladina obliqua* - Perri & Andraghetti, p. 312-314, pl. 34, fig. 1-7 (cum syn.).

1995 *Pachycladina obliqua* - Kolar-Jurkovšek & Jurkovšek, p. 794-795, pl. 1, fig. 1, 3, 5.

1996 *Pachycladina obliqua* - Kolar-Jurkovšek & Jurkovšek, pl. 4, fig. 1-8.

2000 *Pachycladina longispinosa* - Jiang Wu et al., pl. 2, fig. 2 a-d.

2000 *Pachycladina obliqua* - Jiang Wu et al., pl. 2, fig. 2 e-f.

2000 *Pachycladina symmetrica* - Jiang Wu et al., pl. 2, fig. 2 g-j.

Remarks. Apparatus is seximembrate composed of Pa (carminate to planate), Pb (digyrate), M (digyrate), Sa (alate), Sb (digyrate) and Sc (bipennate) elements (Sweet 1981). Most elements occupying different position at every growth stage have been found. The elements of *Pachycladina obliqua* Staesche can be easily distinguished from other ramiform elements by the pre-

sence of the midlateral rib and fine longitudinal striations of the denticles. An extensive discussion on the skeletal apparatus of *P. obliqua* was given by Perri & Andraghetti (1987).

Occurrence. Zelin Crnoluški (ZC-1), Kramarčin Potok (KP-8), Dobra (DO-3).

Range. Campil Beds: from *obliqua* Zone to *triangularis* Zone (Smithian - Spathian), Southern Alps (Staesche 1964; Perri & Andraghetti 1987; Perri 1991); Campil Beds, Serbia, Yugoslavia (Budurov & Pantić 1973, 1974); *obliqua* Zone, Croatia (Jelaska et al. 2003); Smithian, Slovenia (Kolar-Jurkovšek & Jurkovšek 1995, 1996); Upper Scythian, Israel (Hirsch & Gerry 1974).

Genus *Parachirognathus* Clark, 1959

Type species: *Parachirognathus ethingtoni* Clark, 1959

? *Parachirognathus* sp.

1959 *Parachirognathus ethingtoni* Clark, p. 311-312, pl. 45, fig. 3, 5, 7.

1959 *Parachirognathus geiseri* Clark, p. 312, pl. 45, fig. 4, 8, 10, 11.

1971 *Parachirognathus ethingtoni* - Sweet et al., pl. 1, fig. 39.

1973 *Parachirognathus ethingtoni* - Budurov & Pantić, p. 57, Pl. 1, fig. 30-31; Pl. 2, fig. 1-2, 5-6.

1976 *Parachirognathus ethingtoni* - Clark & Rosser, fig. 5: 1-10.

1979 *Parachirognathus ethingtoni* - Solien, p. 304-305, pl. 1, fig. 10, 14, 15, 19.

1995 *Parachirognathus ethingtoni* - Kolar-Jurkovšek & Jurkovšek, p. 795, pl. 1, fig. 9.

1996 *Parachirognathus ethingtoni* - Kolar-Jurkovšek & Jurkovšek, pl. 3, fig. 4.

2000 *Parachirognathus ethingtoni* - Jiang Wu et al., pl. 2, fig. 1c, d.

Remarks. Within the paragraph on the Zone 7 (*Parachirognathus-Furnishius* Zone), the lowest Smithian fauna in the western United States after Sweet et al. (1971), the authors made a remark on the record from Italy. In their view, the *Parachirognathus* specimens (collected below *Platyvillosus*) reported from northern Italy, apparently do not belong to *Parachirognathus*, due to their larger size as well as different shape of denticles. Therefore they are of opinion the specimens are more similar to the *Lonchodina* illustrated by Müller (1956). In comparing the illustrations we could not observe similarities of the Staesche's (1964) *Parachirognathus* and *Lonchodina* of Müller (1956). In the first description of the *Lonchodina* genus there stands a remark on difficult study of this fauna due to inadequate material.

Several Lower Triassic faunas of External Dinarides dominated by shallow water conodont apparatus *Pachycladina obliqua* (Staesche) yield also some speci-

mens that stand very close to *Parachirognathus* (Kolar-Jurkovšek 1995, 1996; Jelaska et al. 2003). The preservation of elements is mainly incomplete and they usually occur rare in the faunas. Nevertheless, they were discriminated from other genera due to lateral compression resulting also the flat shape of denticles, flattened or with oval section, as well as due to marked different white matter distribution. It has to be mentioned that these specimens show great resemblance to *Parachirognathus* of Staesche (1964 - pl. 30, fig. 1). The specimens from Gorski Kotar are for any reason attributed to *Parachirognathus* with question.

Occurrence. Zelin Crnoluški (ZC-1), Kramarčin potok (KP-8).

Range. Smithian (Zone 7; Zones 7B and 8) Western United States (Clark 1959; Sweet et al. 1971; Clark & Rosser 1976; Solien 1979); Lower Triassic: *Parachirognathus-Pachycladina* Zone, Sichuan, China (Jiang Wu et al. 2000); Campil Beds, Serbia, Yugoslavia (Budurov & Pantić 1973, 1974); *obliqua* Zone, Croatia (Jelaska et al. 2003).

Genus *Platyvillosus* Clark, Sincavage & Stone, 1964

Type species: *Platyvillosus asperatus* Clark, Sincavage & Stone, 1964

Remarks. *Platyvillosus* is not a well documented Lower Triassic genus. Among very few described species, only *P. costatus* (Staesche) has been known to have wider geographic occurrence. Based on rich *Platyvillosus* content in the Taho Limestone of Japan, Koike (1988) made the morphological study of the obtained specimens and presented a review of hitherto know species. In his opinion, the genus *Platyvillosus* comprises the following four species: *P. asperatus* (Clark, Sincavage & Stone), *P. costatus* (Staesche), *P. hamadai* Koike, and *P. magnidentatus* Dai & Tian. *Platyvillosus* species can be distinguished by the ornamentation on the upper surface. On the other hand, they all reveal the same aboral side that is marked by centrally located cavity as a starting-point of a prominent groove. *P. asperatus*, the type species of the genus, is characterized by large nodes on its upper side. It was reported from Nevada, and also from Sichuan Province, China (Clark 1959; Sweet et al. 1971; Tian et al. 1983). *P. costatus* was named after its ridgelike denticles. It was first described from the Campil beds of South Tyrol, Italy (Staesche 1964). For the specimens without ornamentation on the upper side, Koike (1982) proposed *P. hamadai*. This species has been documented from the locations in Malaysia and Japan (Koike 1982, 1988) as well from Sichuan Province, China (according to this author *P. laevigatus* Tian & Jiang is a junior synonym of *P. hamadai*).

Platyvillosus costatus (Staesche, 1964)

Pl. 1. fig. 4a-b

1964 *Eurygnathodus costatus* Staesche, p. 270-271, fig. 5, 36-39, pl. 28, fig. 1-6, pl. 32, fig. 3, 4.

1971 *Platyvillosus costatus* - Sweet et al., pl. 1, fig. 32.

1973 *Eurygnathodus costatus* - Budurov & Pantić, p. 51-52, pl. 1, fig. 1-15.

1977 *Platyvillosus costatus* - Goel, p. 1098, pl. 2, fig. 15-21.

1982 *Platyvillosus costatus* - Koike, p. 44-45, pl. 5, fig. 1-9.

1987 *Platyvillosus costatus* - Zakharov & Rybalka, p. 44, pl. 5, fig. 11.

1988 *Platyvillosus costatus* - Koike, pl. 1, fig. 1-57, pl. 2, fig. 1-37.

1991 *Platyvillosus costatus* - Beyers & Orchard, pl. 5, fig. 10.

1994 *Platyvillosus costatus* - Wang Zhi-hao & Zhong Duan, p. 404, pl. 1, fig. 15, 23.

2000 *Platyvillosus costatus* - Jiang Wu et al., pl. 1, fig. 12a,b.

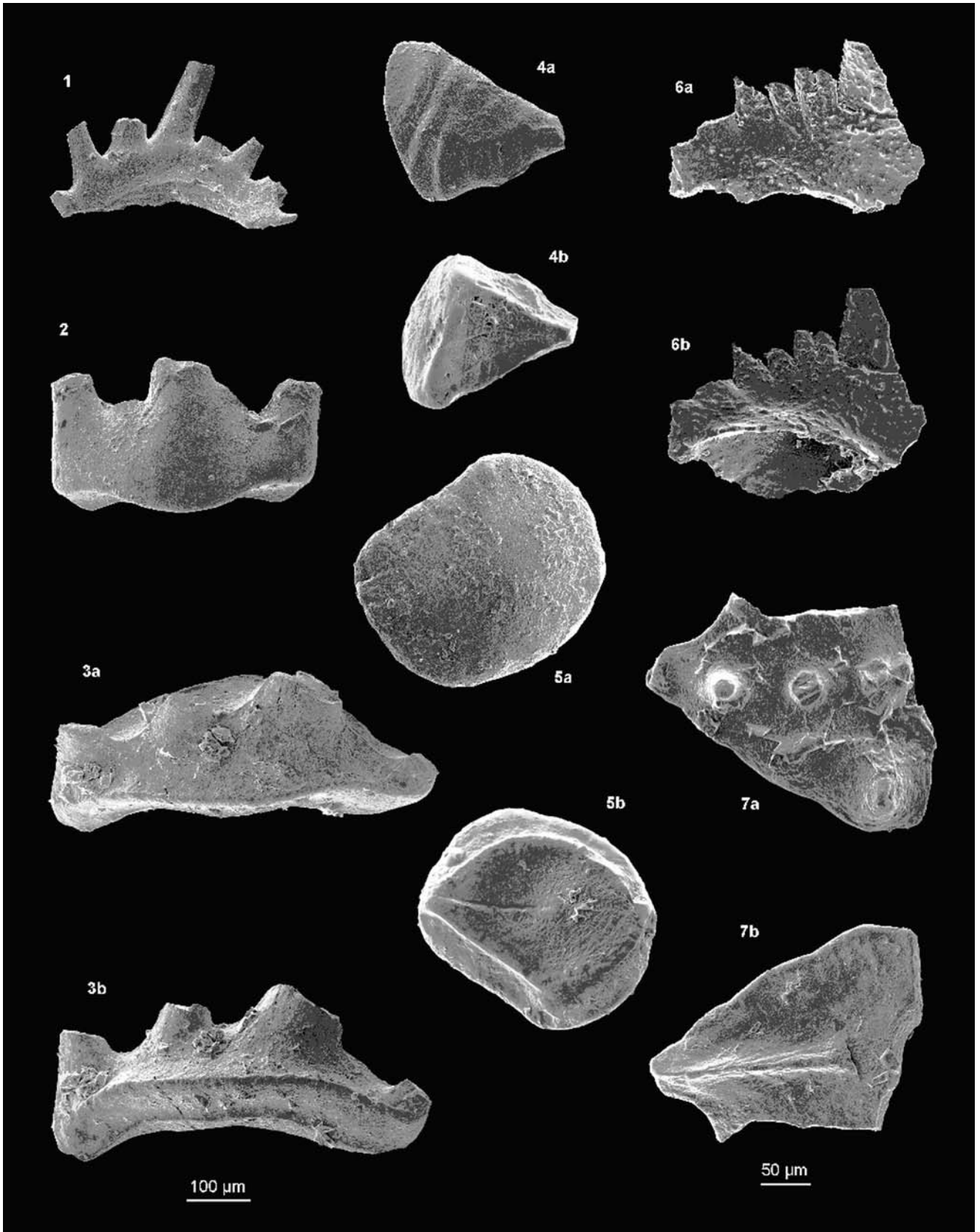
Remarks. The obtained specimens are not completely preserved but they reveal typical ornamentation of the species. The illustrated specimen (Pl. 1, fig. 4a,b) represents the anterior portion of the unit revealing lateral ridges in the upper side. The lower side of the unit is nearly flat and marked by a narrow groove. A great variation of the species, both in shape and ornamentation, was first pointed out by Goel (1977) and he could distinguish at least three types. Koike (1988) presented four morphotypes (α , β , γ , δ) of *P. costatus* and documented the transitional forms between *P. costatus* and *P. hamadai*. The specimens presented herein fit well with the first description of Staesche (1964); the illustrated specimen from Gorski Kotar shows great similarity to the specimen from South Tyrol (Staesche 1964, fig. 36).

Occurrence. Kramarčin Potok (KP-6).

Range. Dienerian, Spiti, India (Goel 1977); Campil Beds (middle part), South Tyrol, Italy (Staesche 1964); Campil Beds (lower and middle part: *costatus*

PLATE 1

- Fig. 1, 2, 3 - *Pachycladina obliqua* Staesche, 1964; *obliqua* Zone, 1,3 - Kramarčin Potok, KP-8 (GeoZS 3652), 2 - Zelin Crnoluški, ZC-1 (GeoZS 3644).
- Fig. 4a, b - *Platyvillosus costatus* (Staesche, 1964); *obliqua* Zone, *Platyvillosus* Subzone, Kramarčin Potok, KP-6 (GeoZS 3650).
- Fig. 5a, b - *Platyvillosus hamadai* Koike, 1982; *obliqua* Zone, *Platyvillosus* Subzone, Kramarčin Potok, KP-6 (GeoZS 3650).
- Fig. 6a, b - *Hindeodus parvus* (Kozur & Pjatakova, 1976); *parvus-isarcica* zones, Školski Brijeg, ŠB-1 (GeoZS 3636).
- Fig. 7a, b - *Foliella gardenae* (Staesche, 1964); *obliqua* Zone, Kramarčin Potok, KP-8 (GeoZS 3652).
- Scale bar equals 100 μ m, except 50 μ m for figs. 6-7.



Zone), Serbia, Yugoslavia (Budurov & Pantić 1974); Zone 10 (*Platyvillosus* Zone), Nevada (Sweet et al. 1971); Smithian, Kedah, Malaysia and Japan (Koike 1981, 1988); Lower Triassic of China: Yunnan and Guangxi (Wang Zhi-hao & Zhong Duan 1994), *Platyvillosus costatus* Zone, Sichuan (Jiang Wu et al. 2000); Smithian, Fauna 6, British Columbia, Canada (Beyers & Orchard 1991).

Platyvillosus hamadai Koike, 1982

Pl. 1, fig. 5a,b

1982 *Platyvillosus hamadai* Koike, p. 45, pl. 5, fig. 10-36.

1988 *Platyvillosus hamadai* - Koike, pl. 2, fig. 38-45.

Remarks. Large form is marked by subrounded thick unit. Aboral side reveals typical features of the genus: subcentrally located pit from which extends anterior groove. Oral side is convex and practically smooth without ornamentation (lacking nodes or ridges), except some delicate short furrows can be observed along posterior and anterior ridges.

Based on abundant material obtained in the Tahoe Limestone, Japan a detailed morphological study of the *P. costatus* and *P. hamadai* was done by Koike (1988). Several transitional forms between *P. costatus* (with several distinguished morphotypes) and *P. hamadai* were demonstrated. A variation nature of *P. costatus* was pointed out already by Goel (1977). Koike (1988) noted the smooth *Platyvillosus* occur very common, for exam-

ple in Dienerian of Spiti, India among *P. costatus* (reported by Goel 1977) and in Spathian of Nevada among *P. asperatus* (reported by Clark et al. 1964). Koike (1988, p. 72) noted that there is "a possibility that *P. hamadai* is an extreme variant of *P. costatus* of which ornamentation is entirely covered with phosphatic material or dissolved due to some physiological condition". We share Koike's (1988) opinion in use independent species name *P. hamadai* for the units with smooth ornamentation on upper side as a diagnostic feature, until more data are available, especially from the inner structure. The specimen from Gorski Kotar (here illustrated on Pl. 1, fig. 5) represents an adult form with practically no ornamentation.

Occurrence. Kramarčin Potok (KP-6).

Range. Smithian of Kedah, Malaysia and Tahoe Limestone, Japan (Koike 1981, 1988); Dienerian of Sichuan, China (after Koike 1988 but reported by Tian & Jiang 1983).

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