CONODONT DATING OF THE LOWER TRIASSIC SEDIMENTARY ROCKS IN THE EXTERNAL DINARIDES (CROATIA AND BOSNIA AND HERZEGOVINA)

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Abstract. Two Lower Triassic sedimentary successions have been dated by means of conodonts in the External Dinarides: Plavno section near Knin, Croatia and Bosansko Grahovo section in Bosnia and Herzegovina. Deposition in both sections shows similar characteristics, differentiated in three continuously deposited facies. The Siliciclastic facies was previously considered Seis beds and assigned to the lower Lower Triassic, the Mudstone facies, and the Siltstone-mudstone facies (occurring in the upper part of the succession) were formerly considered as Campil beds of the upper Lower Triassic. Vertical succession of Siliciclastic, Mudstone, and Siltstone-mudstone facies of both investigated sequences was interpreted as deepening of the environment envisaged as a transgressive trend in a shallow shelf environment.

Facies successions at Plavno (690 m thick) and Bosansko Grahovo (229 m thick) differentiate for the presence of Dolostone facies in the lowest part of the Plavno succession.

Conodont fauna of Dolostone facies at Plavno section is represented by isarcicellids, *Isarcicella staeschei* and *I. isarcica* that marks the Griesbachian *isarcica* Zone. The Siliciclastic facies of Plavno and Bosansko Grahovo sections is characterized by shallow-water euryhaline taxa attributed to the Smithian, part of the late Dinerian-Smithian *obliqua* Zone. This fauna is prevailed by *Hadrodontina anceps* and *Pachycladina obliqua* with co-occurrence of *Parachirognathus ethingtoni* and very rare presence of *Foliella* sp. or *?Furnishius* sp.

Discerned conodont taxa enable us to establish conodont zonation which gives new insight to the range of the so-called Seis and Campil beds.

Riassunto. Sono state datate per mezzo dei conodonti due sezioni stratigrafiche del Triassico Inferiore nelle Dinaridi Esterne: la sezione di Plavno presso Knin in Croazia e quella di Bosansko Grahovo in Bosnia/Herzegovina. La sedimentazione mostra caratteri simili in entrambe le sezioni, che può venir suddivisa in tre facies sovrapposte. La facies Siliciclastica veniva in precedenza assimilata agli Strati di Siusi ed assegnata come età al Triassico basale, la facies a Mudstone e quella a Siltstone-mudstone (costituenti la parte alta della successione) venivano in precedenza correlate con gli Strati di Campil della parte alta del Triassico Inferiore. La sovrapposizione verticale della tre facies in entrambe le successioni studiate è stata interpretata come evidenza dell'approfondimento nell'ambito di una tendenza trasgressiva, entro un contesto ambientale di piattaforma poco profonda.

Le due successioni di Plavno (potente 690 m) e di Bosansko Grahovo (potente 229 m) differiscono per la presenza di una facies Dolomitica nel porzione inferiore della sezione di Plavno.

La fauna a conodonti della facies Dolomitica a Plavno è rappresentata da isarcicellidi, *Isarcicella staeschei* and *I. isarcica*, che caratterizza la Zona a *isarcica* del Griesbachiano. La facies Siliciclastica a Plavno e Bosansko Grahovo è caratterizzata da taxa euryhalini di acque basse, attribuite allo Smithiano, facenti parte della Zona a *obliqua* del tardo Dineriano-Smithiano. Questa fauna è in prevalenza costituita da *Hadrodontina anceps* e *Pachycladina obliqua*, con la presenza concomitante della forma *Parachirognathus ethingtoni* e la presenza molto rara di *Foliella* sp. o *?Furnishius* sp.

I taxa di conodonti identificati consentono di stabilire una zonazione a conodonti che fornisce nuovi elementi per determinare le età dei cosiddetti strati di Siusi e Campil nella regione esaminata.

Introduction

Lower Triassic rocks frequently crop out all along the Karst Zone in Slovenia, Croatia, and Bosnia and Herzegovina. The Karst Zone, nowdays called Karst Dinarides, represents a geotectonic unit of the External Dinarides (Lewandowski et al. 2009). The Lower Triassic sequence represents a shallow marine setting that is

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characterized by mixed siliciclastic and carbonate deposition with varied thickness, from 40 to 800 m. The purpose of our study was to investigate the Lower Triassic beds in the southern part of the External Dinarides in two sections – Bosansko Grahovo and Plavno, especially by dating of conodont microfossils.

In the last few years, an intensive study of conodonts of the P-T interval and Lower Triassic started in many sections of the External and Internal Dinarides in order to biostratigraphically define the systemic boundary. As a result, representatives of *Hindeodus* were obtained in several sections of the External Dinarides. Conodonts of the *Hindeodus typicalis* group belonging to the Lower *praeparvus* Zone (Changhsingian) were documented in the Jadar Block of Vardar Zone in the Inner Dinarides of Serbia (Sudar et al. 2007). In addition, the element *Hindeodus parvus* was recorded in the External Dinarides of Croatia (Aljinović et al. 2006a, b), but more recent study in Slovenia revealed presence of diversified *Hindeodus-Isarcicella* population in the lowermost Triassic strata (Kolar-Jurkovšek & Jurkovšek 2007). The first appearance datum (FAD) of *Hindeodus parvus* defines the base of the Triassic system (Yin et al. 2001).

The Lower Triassic sedimentary rocks in the Dinarides have usually been divided into two lithostratigraphic units: red mixed siliciclastic-carbonate deposits (shales, sandstones, siltstones, oolitic and/or bioclastic grainstones) were defined as Seis (Siusi) beds, while grey dominantly carbonate deposits (micritic limestones, marls and calcareous siltstones) as Campil beds. Campil beds conformably overlay Seis deposits. Nevertheless, to this lithostratigraphic division was given also a chronostratigraphic meaning, thus Seis beds have been assigned to the early Lower Triassic – Induan (T_1^1) and the Campil beds to the late Lower Triassic – Olenekian (T_1^2). This twofold lithostratigraphic/chronostratigraphic division has been applied for the basic geologic mapping in nearly the entire Dinaridic area. The exception is the Gorski Kotar Region, where this separation has never been applied. The purpose of such division was to make possible the comparison with the Lower Triassic succession (i.e. Werfen Formation) of the Southern Alps.

Biostratigraphic constrains for the Lower Triassic beds in the External Dinarides have commonly been obtained by macrofossils (mollusks and ammonoids) and rarely by microfossils such as conodonts (Herak et al. 1983; Jelaska et al. 2003; Aljinović et al. 2006a, b). Representatives of the characteristic bivalve genus *Claraia* have been reported from the Seis beds in the Gorski Kotar region (e.g. Babić 1968) while Krystyn (1974) defined the two ammonoid zones (the *Tirolites carniolicus* and the *Tirolites cassianus* zones) in the upper Lower Triassic beds near Sinj (Mt. Svilaja) in Croatia.

The exact age of Lower Triassic succession in the External Dinarides was for the first time set by means of conodonts in the vicinity of Sinj – Mt. Svilaja in the 55 m thick succession at Muć by Jelaska et al. (2003) and Kolar-Jurkovšek et al. (2006). A conodont fauna yielding *Pachycladina obliqua* apparatus was recorded at Mt. Svilaja pointing out to the *obliqua* Zone of the late Early Triassic. In addition, investigations in the Gorski Kotar region (north-western part of the External Dinarides in Croatia) enabled the recognition of the *Hindeodus parvus* in the lowermost Lower Triassic strata followed by *parvus-isarcicella* zones, *obliqua* Zone and *Platyvillosus* Subzone in younger strata (Aljinović et al. 2006a, b). Sedimentary facies show characteristics of a shallow marine, storm-influenced shelf.

The Olenekian conodont faunas of the External Dinarides compare well with the faunas from the Internal Dinarides. In the Jadar Zone of the Inner Dinarides, the recorded "Campilian" conodonts were assigned to the Smithian *Parachirognathus-Furnishius*-Z. and Spathian *triangularis-homeri*-C.R.Z. (Budurov & Pantić 1973, 1974; Sudar 1986).

Our investigation concerning conodont dating extends to the central part of the External Dinarides in Croatia (vicinity of Knin) and neighboring Bosnian External Dinaridic terrains (vicinity of Bosansko Grahovo) (Fig. 1). Discerned conodont taxa enable us to establish conodont zonation which gives new insight to the range of so-called Seis and Campil beds.

This paper is the first report on the Lower Triassic conodonts in Bosnia and Herzegovina.

Geological setting

The two study areas, Plavno and Bosansko Grahovo are located within the thrust belt of the External Dinarids in Croatia and Bosnia and Herzegovina, respectively. The thrusts were formed at the end of Cretaceous/beginning of Eocene and display the usual NW-SE vergent structures (Fig. 1) (Grimani et al. 1972, 1975; Hrvatović 2006). In this particular part of the External Dinarides, tectonic activity was also strongly influenced by a diapirism of Permian evaporites (Chorowicz 1977; Herak 1973; Hrvatović 2006).

The Late Permian and Early Triassic depositional environment can be envisaged as a shallow epeiric sea (Herak 1973). Deposition in large lagoons with evaporites (gypsum and anhydrite) were compared to the Bellerophon Formation and assigned to the Late Permian by Tišljar (1992). Permian-Triassic strata in the study area are usually in tectonic contact due to diapirism of the evaporites. The Lower Triassic succession is charac-
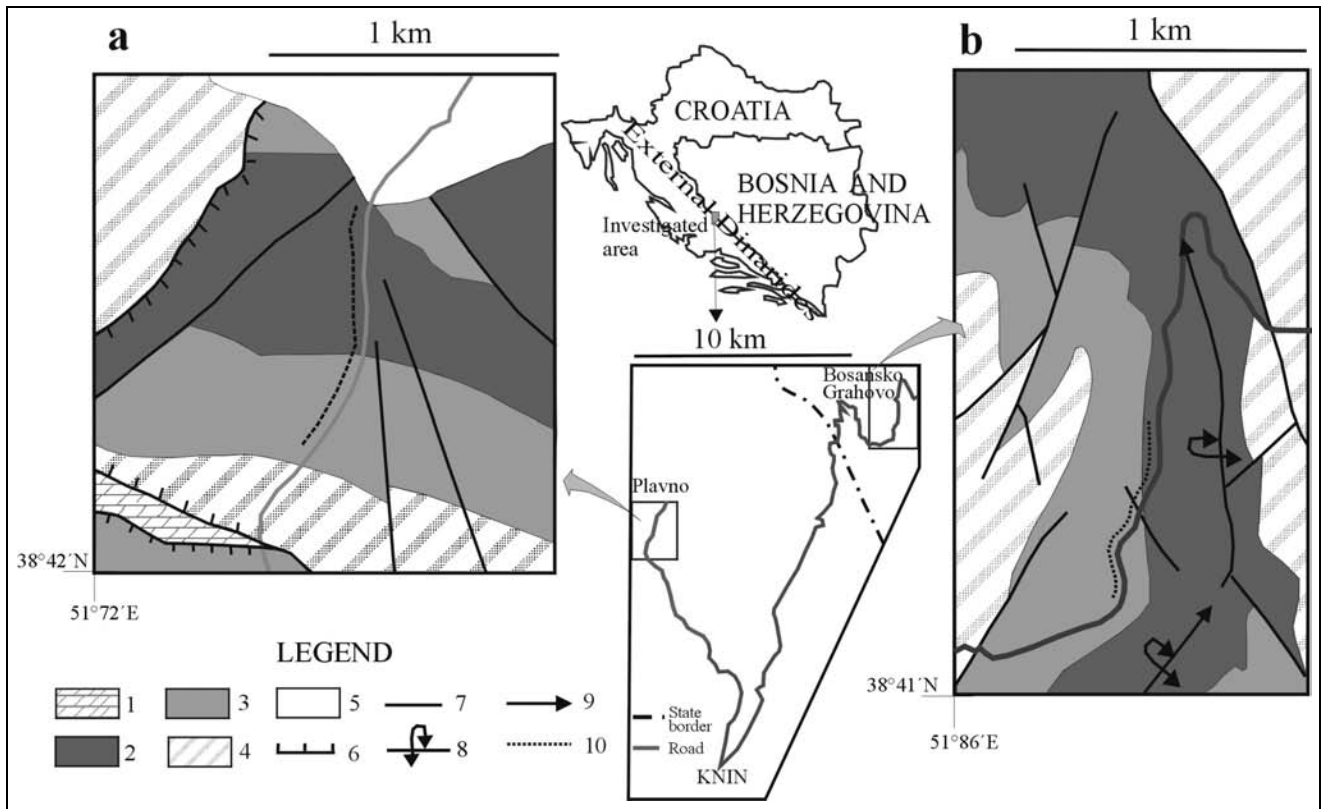
Fig. 1 - a) Location map; b) Schematic geologic map of Bosansko Grahovo; c) Schematic geologic map of Plavno; a & b modified after Grimani et al. (1972); Legend: 1 - Permian evaporites; 2 - Siliciclastic facies (former Seis beds of lower Lower Triassic), 3 - Mudstone and Siltstone-mudstone facies (former Campil beds of upper Lower Triassic), 4 - Middle Triassic carbonates; 5 - Quaternary deposits; 6 - thrust fault, 7 - fault, 8 - overturned fold, 9 - axis of overturned fold, 10 - trace of measured section.

terized by storm-influenced inner and outer shelf deposition (Aljinović 1995). The main characteristic of the vertical sediment succession indicates a general transgressive trend.

The data presented in this work have been obtained from two road cuts near the villages of Plavno (Fig. 1a) and Bosansko Grahovo (Fig. 1b). At Plavno the Lower Triassic succession is ca 700 m thick (Figs 1a, 2). It represents one of the most complete Lower Triassic sequence in the External Dinarides. The contact with underlying Permian layers is covered by Quaternary sediments. The succession is conformably overlain by Anisian limestones (Fig. 1a, Grimani et al. 1975). The Bosansko Grahovo succession represents a 229 m thick sequence in the southwestern limb of an overturned fold (Figs 1b, 2). The contact of the Lower Triassic and overlying Anisian limestones is tectonically influenced. The succession is slightly disturbed by a strike-slip fault near the boundary between the Seis and Campil beds (Fig. 1b, Grimani et al. 1975). Nevertheless, the succession can be easily traced and the preservation of sedimentary structures is remarkable. Facies characteristics were studied primarily at the Bosansko Grahovo succession due to its better exposure and preservation (Fig. 3). A correlation of the Plavno and the Bosansko Grahovo successions is illustrated in Fig. 2.

Conodont data were collected from both sections and compared (Fig. 2; Tabs 1, 2). The oldest rocks are located in the Plavno section and dated from this region only (Fig. 2). In the Bosansko Grahovo succession the oldest strata are not exposed.

Facies characteristics of the sedimentary successions

Sedimentary succession studied at Plavno most likely represents the whole Lower Triassic sequence, whereas succession at Bosansko Grahovo is considerably shorter. Nevertheless, in both sequences the similar vertical facies arrangement can be observed and therefore compared (Fig. 2). In the lower portion of both successions red coloured mixed siliciclastic-carbonate deposits occurred (consisting of shales, siltstones, sandstones, oolitic and/or bioclastic grainstones). They have been previously defined as Seis beds (T_1^1) (e.g. Grimani et al. 1975). Grey micritic limestones, marls and calcareous siltstones that occur in the upper portion of successions were subsequently correlated with Campil beds (T_1^2). The only difference between the two successions is the occurence of ca 40 m thick "Dolostone facies" that was observed only at the beginning of Plavno section, thus possibly representing
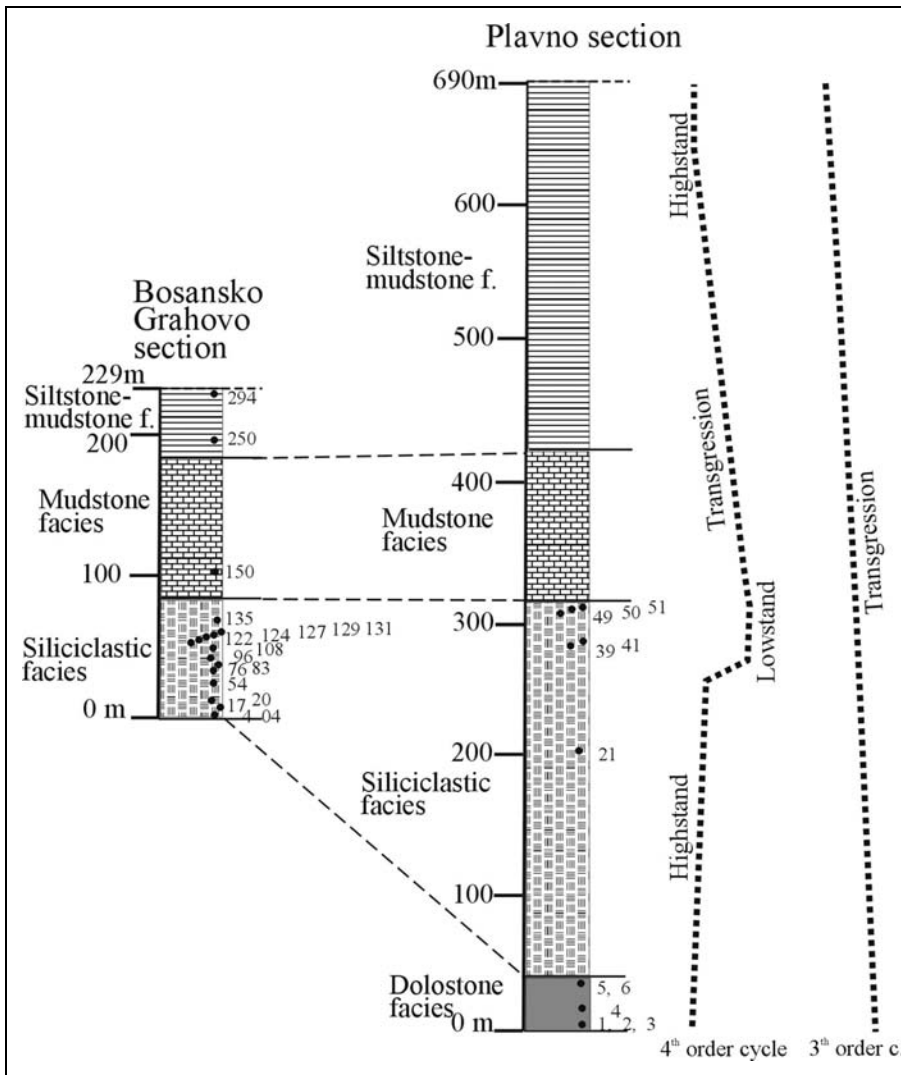
Fig. 2 - Schematic comparison of the investigated sections.

the oldest strata (Fig. 2). The Dolostone facies was not discernible in the Bosansko Grahovo sequence. Sedimentary characteristics and facies association will be presented in detail on the base of Bosansko Grahovo section (Fig. 3).

At the beginning of the Early Triassic, after initial transgression that drowned underlying evaporite complexes, marine conditions were established. The oldest strata at Plavno section are represented by ca 40 m thick pale yellow macrocrystalline subhedral dolomites ("Dolostone facies").

The sedimentation at Plavno and Bosansko Grahovo continued with the deposition of three conformably superimposed facies: the "Siliciclastic facies" (previously considered Seis beds), "Mudstone facies" and "Siltstone-mudstone facies" (forming the upper part of the Lower Triassic succession – i.e. Campil beds). The Siliciclastic facies is characterized by cycles of metre scale coarsening and thickening upward deposition (Figs 3, 4). In each cycle the lower portion consists of thin-bedded alternation of shales, siltstones and sandstones where well-preserved trace fossils are common (Fig. 5). The upper portion is represented by amalgamated, cross bedded oolitic grainstones (Fig. 4). A thin-bedded shale-siltstone-sandstone portion of the cycles were interpreted as deposits of a distal, mud-rich inner shelf while the thick-bedded sandstone-oolite portion was deposited in the proximal (shallower) part of inner shelf (Aljinović 1995). The sedimentation on the distal inner shelf was episodically punctuated by a shallowing of the environment that displaced the adjacent proximal shelf environment (thick-bedded sandstone/oolitic grainstones) in a basinal direction, thus forming the meter scale sedimentary cycles observed. Deposition of the Siliciclastic facies was strongly influenced by storms. The upward thickening and coarsening have also been noticed in the upper part of the Siliciclastic facies.

The Mudstone facies and Siltstone-mudstone facies occurring in the middle and upper part of both successions represent deposition in a slightly deeper, open marine environment (the outer shelf) where ammonoid bearing beds occur.
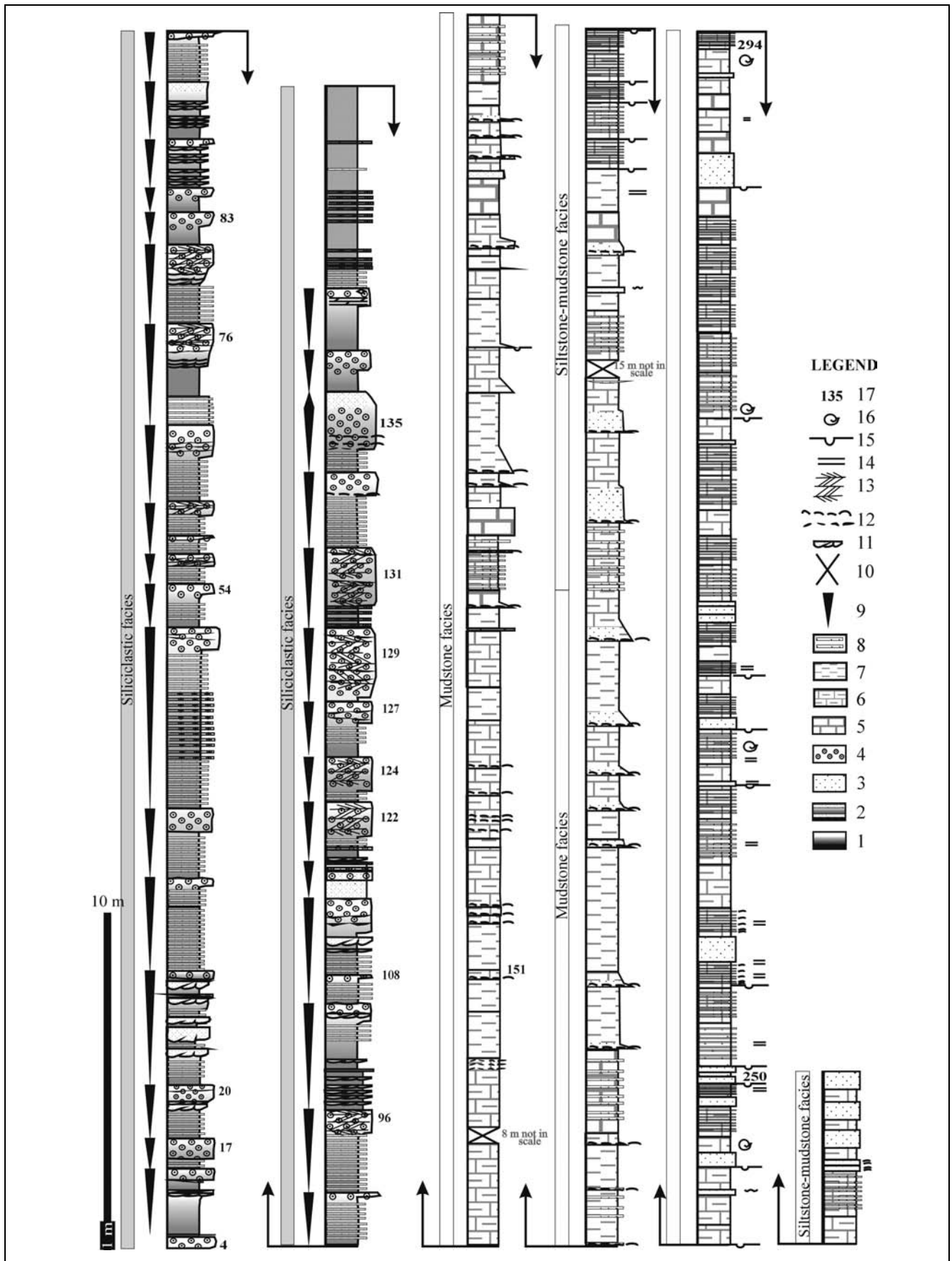
Fig. 3 - Sedimentological characteristics of Bosansko Grahovo section; Legend: 1 - fine grained clastics (prevalence of shale); 2 - shale, siltstone, sandstone intercalations; 3 - sandstone; 4 - oolitic grainstone; 5 - mudstone (micritic limestone); 6 - clayey mudstone; 7 - marl; 8 - calcareous siltstone intercalations; 9 - coarsening upward cycles; 10 - covered interval; 11 - load cast structure; 12 - skeletal lag; 13 - cross bedding; 14 - parallel plane lamination; 15 - gutter-cast structure; 16 - ammonoids; 17 - conodont samples.
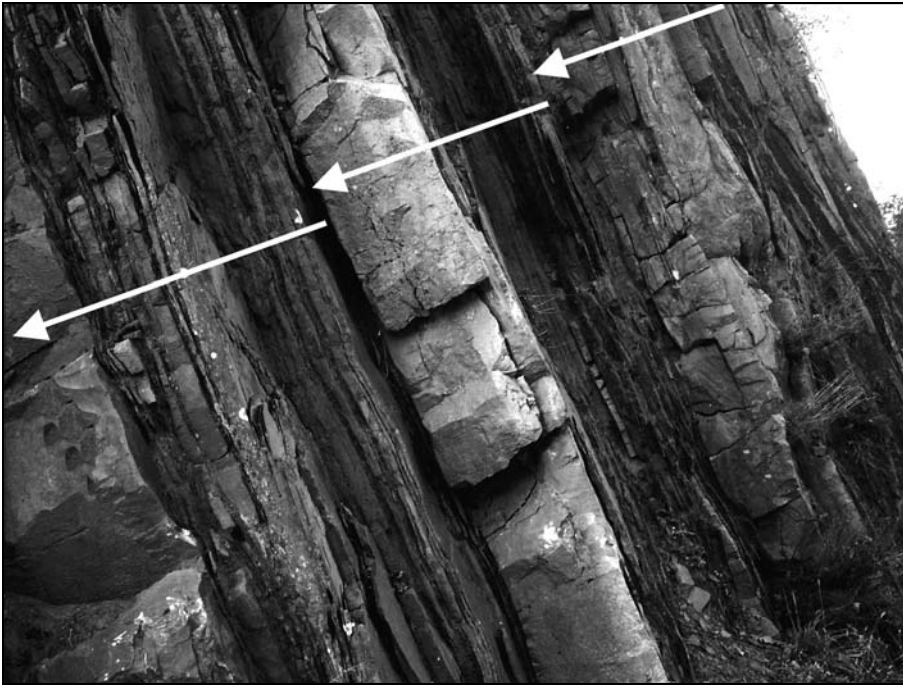
Fig. 4 - Meter scale coarsening up-ward sedimentary cycles (ar-rows) in Siliciclastic facies. Topmost part of the cycles is represented by oolitic grainstone beds. Overturned beds, stratigraphic top to the left; Bosansko Grahovo sec-tion.

The main lithology in the "Mudstone facies" is carbonate micritic mudstones, clayey mudstones and marls that contain lamina of siltsized carbonate detritus (intraclasts, peloids, and skeletal fragments). Storm layers are present in both facies emphasizing the im-portant role of storms also in the deeper, outer shelf environment. In the Mudstone facies storm layers are represented by exhumed skeletal material from the mudstone host sediments that accumulated as coarse skeletal lag at the base of storm beds. The mud rich units of this facies record slow sedimentation of micrite, and clayey mud in periods with no storms or bellow storm wave base.

"Siltstone-mudstone" facies consists predomi-nately of plane-parallel laminated micritic limestones. Subordinately, calcareous siltstone beds also occur. Silt-stones have a characteristic hummocky-cross lamina-tion and graded beds which suggest storm deposition in the outer shelf. Silt transport to the outer shelf by storm currents left remarkable gutter cast structures due to helicoidal flows parallel to bedding plane (Fig. 6) (Aljinović & Vrkljan 2002).

A vertical succession of the three facies (Siliclas-tic, Mudstone, and Siltstone-mudstone) was interpreted as a deepening of the environment indicative of a trans-gressive trend on the shallow continental shelf. The ver-tical facies arrangement could be inferred from a long-term transgression that corresponds to a third-order glo-bal transgressive trend in the Lower Triassic age (Haq et al. 1987). Moreover, the lowstand conditions observed at the end of Siliciclastic facies were followed by transgres-sive trend of Mudstone facies and then by highstand conditions in Siltstone-mudstone facies (Fig. 2).

Conodont stratigraphy: dating and comparison

Material and methods

The conodont fauna described and illustrated herein were ob-tained in the study areas during field campaigns in 2005, 2006 and 2009. A total of thirty-one conodont samples were processed using a standard technique for preparing conodont samples. Samples were leached with acetic acid and separated with heavy liquid. Preservation of conodont specimens is mostly fragmented and their abundance is relatively low. The recovered conodont taxa are listed in Tables 1-2, and illustrated in Fig. 7. Conodont Alteration Index CAI is 3-3,5, *sensu* Epstein et al. (1977).

The SEM examination of conodonts was done on a JEOL JSM-330A at the Ivan Rakovec Institute of Paleontology, Scientific Research Centre of the Slovenia Academy of Science and Arts, and on a JEOL JSM 6490LV at the Geological Survey of Slovenia. All studied conodont material is currently housed in a micropaleontological collection of the Geological Survey of Slovenia under the repository numbers 3853, 3871-3876, 4568-4571.

Plavno section

In the Plavno section, the Dolostone facies and Siliciclastic facies were sampled for conodont study. Distribution of conodont elements is given in Tab. 1. Conodont elements were obtained from the base of the Dolostone facies (samples 1-7), but only one sample from this facies yielded small but diagnostic conodont fauna represented by isarcicellids such as *Isarcicella staeschei* and *I. isarcica* (sample 3). The fauna marks the lowermost Triassic *isarcica* Zone. Samples 4 to 7 produced only conodont fragments.

The fauna recovered from samples of the Siliclas-tic facies (samples 21, 39, 41, 49, 50, 51) is marked by the fauna of the *obliqua* Zone based on presence of the elements of *Hadrodontina anceps, Pachycladina obli-qua, Parachirognathus ethingtoni* and very rare *? Fur-nishius* sp.
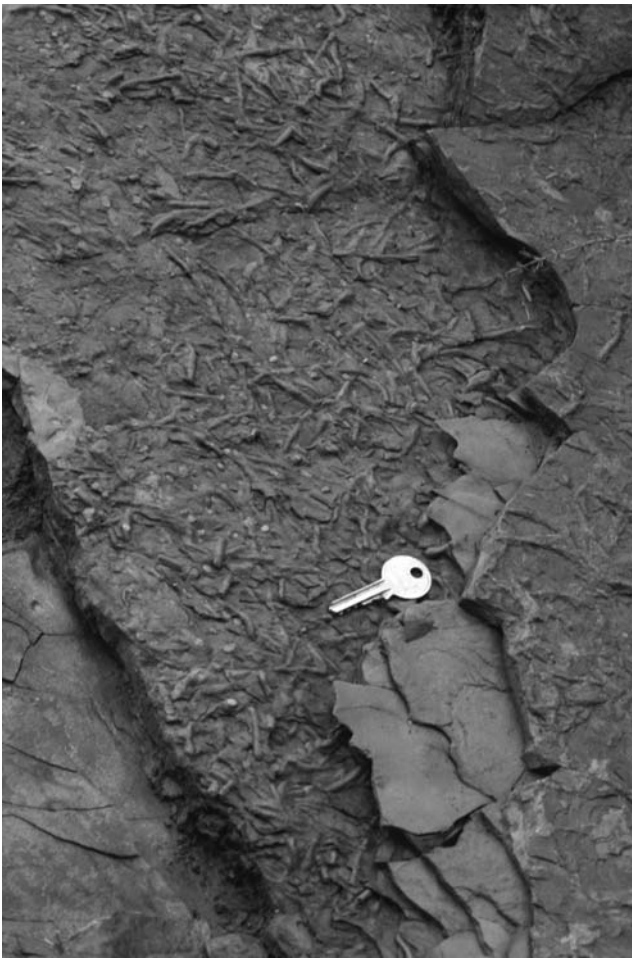
Fig. 5   - Trace fossils from the shale interbeds commonly occurring in the lower portion of cycles in Siliciclastic facies. Overturned beds in Bosansko Grahovo section.

	1	2	3	4	5	6	7	21	39	41	49	50	51
? Furnishius sp.													
Pa element									1				
Hadrodontina anceps													
Pa element									4	3			
Pb element									5				
Sa element									8	3			
M element									2				
indet. fragm.									5				
Pachycladina obliqua													
Pa element									12	2			
Pb element									9	2			
Sa element									7				
Sb element									11				
Sc element									5				
M element									3				
indet. fragm.									2				
Parachirognathus ethingtoni													
Sa element											2		
Sb element											3		
Sc element											1		
M element											1		
indet. fragm.													
Isarcicella staeschei													
Pa element			2										
Isarcicella isarcica													
Pa element		1											
Conodont fragments				11	6	3	5	2	5	2	1	4	5

Tab. 1   - Numeric distribution of conodonts from the Plavno section.

Bosansko Grahovo section

At the Bosansko Grahovo study area, eighteen conodont samples were collected from oolitic grain-stones from the Siliciclastic facies as well as from mud-stones and calcareous siltstones from the Mudstone and Siltstone-mudstone facies. The position of the conodont samples is shown in (Figs 2, 3).

The samples collected in the oolitic grainstones are characterised by the co-occurrence of *Hadrodontina anceps* and *Pachycladina obliqua* multielements (Tab. 2, Fig. 7). They are present throughout most of the section (samples 4 – 151), and joined by another multielement, here assigned to *Parachirognathus ethingtoni* (samples 4, 76, 83, 127, 131) and very rarely to *Foliella* sp. (sample 108). This fauna is attributed to the Smithian part of the *obliqua* Zone. Thus, the conodont biofacies is marked by shallow-water euryhaline taxa.

The upper part of the section is characterized by the occurrence of *Pachycladina obliqua* (samples 135, 151) that ranges in the *obliqua* Zone up to the Spathian *triangularis* Zone. The last two samples of the upper section (250, 294) contained only a few conodont fragments. The Spathian age of the upper part of the section is therefore not excluded, but it is debatable due to absence of *Neospathodus triangularis* that marks the youngest Lower Triassic (Spathian) zone.

Conodont taxa recovered in Bosansko Grahovo section point out that the assignment of Seis beds to the early Lower Triassic is not appropriate. According to conodont dating from the investigated section, the former Seis beds (Siliciclastic facies) do not differ in conodont taxa from so-called Campil beds (Mudstone and Siltstone-mudstone facies), thus their former chronostratigraphic assignment to early and late Early Triassic is not correct.

Comparison of conodont faunas of adjacent areas

The conodont fauna of the *isarcica* Zone is well correlated with the coeval faunas recovered in adjacent areas of Slovenia and northern Italy. Its lower limit is defined by the first appearance datum of nominate species. In Slovenia, *isarcica* Zone follows the *parvus* and *lobata* zones (Kolar-Jurkovšek et al. 2011). In the Dolomites, very fine biozonation was established based on the *Hindeodus-Isarcicella* population (namely the uppermost Permian Lower and Upper *praeparvus* zones), and four Lower Triassic zones (namely the *parvus, lobata, staeschei, isarcica*; Perri & Farabegoli 2003). In both areas the fauna of the *isarcica* Zone is marked by the co-occurrence of *I. staeschei* and *I. isarcica*.

Two recovered species, *Hadrodontina anceps* and *Pachycladina obliqua*, as well as *H. aequabilis* were first described from the Southern Alps by Staesche (1964). According to Perri & Andraghetti (1987), species *Hadrodontina anceps* ranges throughout the Werfen Formation, whereas *Pachycladina obliqua* is present in its upper part only. The range of *Hadrodontina anceps* was later confined to the *anceps, obliqua* and *triangularis*

|	4	17	20	54	76	83	96	108	112	122	124	127	129	131	135	151	250	294
Foliella sp.																		
Pa element								1										
Hadrodontina anceps																		
Pa element	1				1			1						1				
Pb element	1												2					
Sa element	1				1			1					2					
M element			1	1	1			1										
indet. fragm.	2	6			1	1		3	2			2	7					
Pachycladina obliqua																		
Pa element					2			1			2	1	2	3	5			
Pb element		1			3	1		2			1	5	2	2	2			
Sa element	1	1			2	1		1				1		1	3			
Sb element	1				1			2						3	2			
Sc element			1		1			2				5	4	2	3	2		
M element	1	1		1	3			3						2	1			
indet. fragm.	2	8	2	2	4	2	1	4			16	2	3	6	2	2		
Parachirognathus ethingtoni																		
Sa element					1													
Sb element													1					
Sc element					1													
M element																		
indet. fragm.	2				7	1							1		1			
Conodont fragments	4	4	2	2	4			7	2	2	10	21	5	6	12	1	7	5

Tab. 2   - Numeric distribution of conodonts from the Bosansko Grahovo section.

zones by Perri (1991) who also emphasized the importance of shallow-water and euryhaline species of *Ellisonia*, *Hadrodontina* and *Pachycladina* for stratigraphy of the Southern Alps, as greater part of the Werfen Formation is lacking index forms of the standard conodont biozonation. The Griesbachian basal part of the formation, i.e. Tesero and Mazzin members, is marked by index forms of the *Hindeodus –Isarcicella* population, but near the top of the *I. isarcica* range the appearance of the first *Hadrodontina* is evidenced. Based on successive entry of the three species in the late Griesbachian-Smithian interval (upper Mazzin Member, Andraz Horizon, Siusi, Gastropod and Campil members), the *Hadrodontina aequabilis*, *Hadrodontina anceps* and *Pachycladina obliqua* zones have been established. These biozones were determined in the Bulla section. *Hadrodontina aequabilis* makes its first occurrence in the upper Mazzin Member joining the *Isarcicella isarcica*. The disappearance of *I. isarcica* is marking the base of the *aequabilis* Zone. The dominantly occurring *Hadrodontina aequabilis* is associated with ellisonid taxa in its higher part (40.40 m thick interval from the upper Mazzin to Siusi members). Based on presence of the nominal taxon, the following part of the transitional facies (samples BU42-BU43), 23 m thick, was attributed to the *anceps* Zone. Appearance of *Pachycladina obliqua* in the BU45 sample (transitional facies) marks the lower limit of the *obliqua* Zone that is characterized also by the occurrence of *Hadrodontina* and *Ellisonia* (Perri 1991; Farabegoli & Perri 1998).

The conodont content in the Plavno and Bosansko Grahovo sections is marked by the presence of three multielement conodont taxa *H. anceps*, *P. obliqua* and *Pch. ethingtoni* that have been attributed to the Smithian part of the *obliqua* Zone. This age is confirmed also by presence of *Parachirognathus* representatives and very rare *Foliella* sp. or *?Furnishius* sp. *Parachirognathus* has been used in many biozonations schemes as a diagnostic element defining the lower Smithian *Parachirognathus-Furnishius* Zone (Sweet et al. 1971). The Spathian age of the upper part of the section is suggested, but it is debated due to absence of *Neospathodus triangularis* that marks one of the youngest Lower Triassic (Spathian) zones. Indeed, *Pachycladina obliqua* ranges to the Spathian, where it is usually joined by *Neospathodus triangularis* (Perri & Andraghetti 1987). However, there is no evidence of the latter species in the youngest levels of the investigated section.

Our conclusion is based on the comparison and stratigraphic occurrence of the shallow water taxa, *Hadrodontina anceps* and *Pachycladina obliqua* in the Southern Alps. The range of the two species has not yet been established in the External Dinarides. In the Bulla section of the Southern Alps, the two taxa occur together in the transitional facies (BU42 sample) and the first occurrence of the latter species identifies the lower limit of the *obliqua* Zone (Perri 1991; Farabegoli & Perri 1998). *Neospathodus triangularis* was recorded in the Spathian strata of the Val Badia and Cencenighe

Fig. 6 - Lower bedding plane of calcareous siltstone beds showing anastomosing gutter cast pattern as a distinct characteristic of the Siltstone-mudstone facies. The structure depicts silt transport by storm currents.
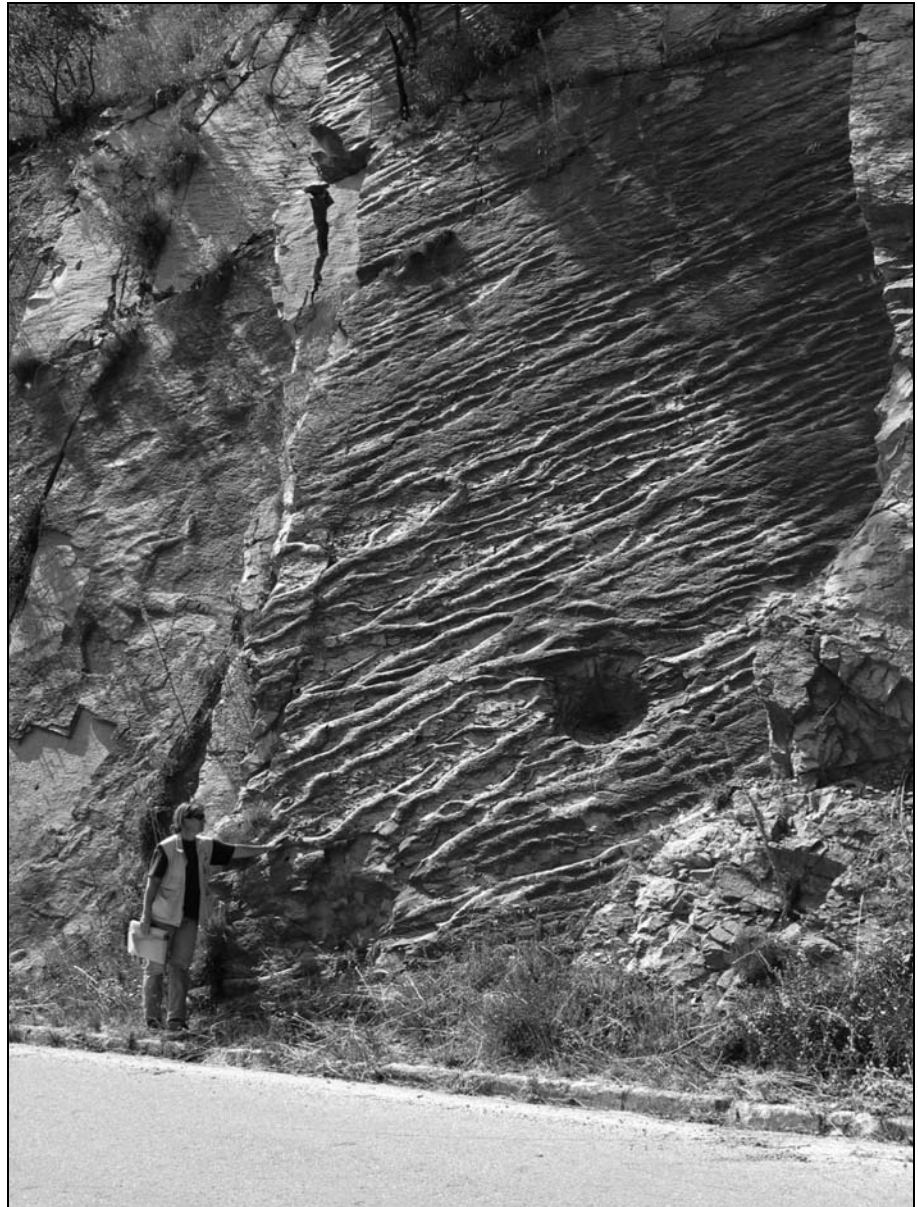
members, but it does not appear with *Pachycladina obliqua* (Perri & Andraghetti 1987 – tab. 2).

Thus we may conclude that the Siliciclastic facies of the Bosansko Grahovo and Plavno sections can be correlated based on conodont content. This part is attributed to the Smithian part of the *obliqua* Zone and, due to presence of *Pachirognathus,* it can be correlated to the *Parachirognathus-Furnishius* Zone (*sensu* Sweet et al. 1971). The uppermost part of the investigated section did not produce significant conodont fauna except rare Sc elements of *Pachycladina obliqua.*

Discussion

Because a division to Seis and Campil beds has been applied in the External Dinarides for a long time (e. g. Grimani et al. 1957; Šćavničar & Šušnjara 1983)

due to possible comparison with the succession in the Dolomites (Southern Alps), their characteristics will be briefly discussed here.

In the most famous regions of the Southern Alps, Tesero and Bulla sections in the Dolomites (Assereto et al. 1973; Brandner & Mostler 1982; Perri & Farabegoli 2003) as well as in the Gartnerkofel section in the Carnic Alps (Boeckelmann 1991; Schönlaub 1991), the Werfen Formation is divided into several units or members (6 to 9). The successions in the Dolomites as well as in the Carnic Alps are made up of transgressional-regressional cycles.

As can be seen from Tesero, Bulla and Gartnerkofel localities, the sedimentary facies are characteristically different from the sections investigated in the External Dinarides. If we strictly correlate on the basis of lithology, the Siusi Member from the Southern Alps has
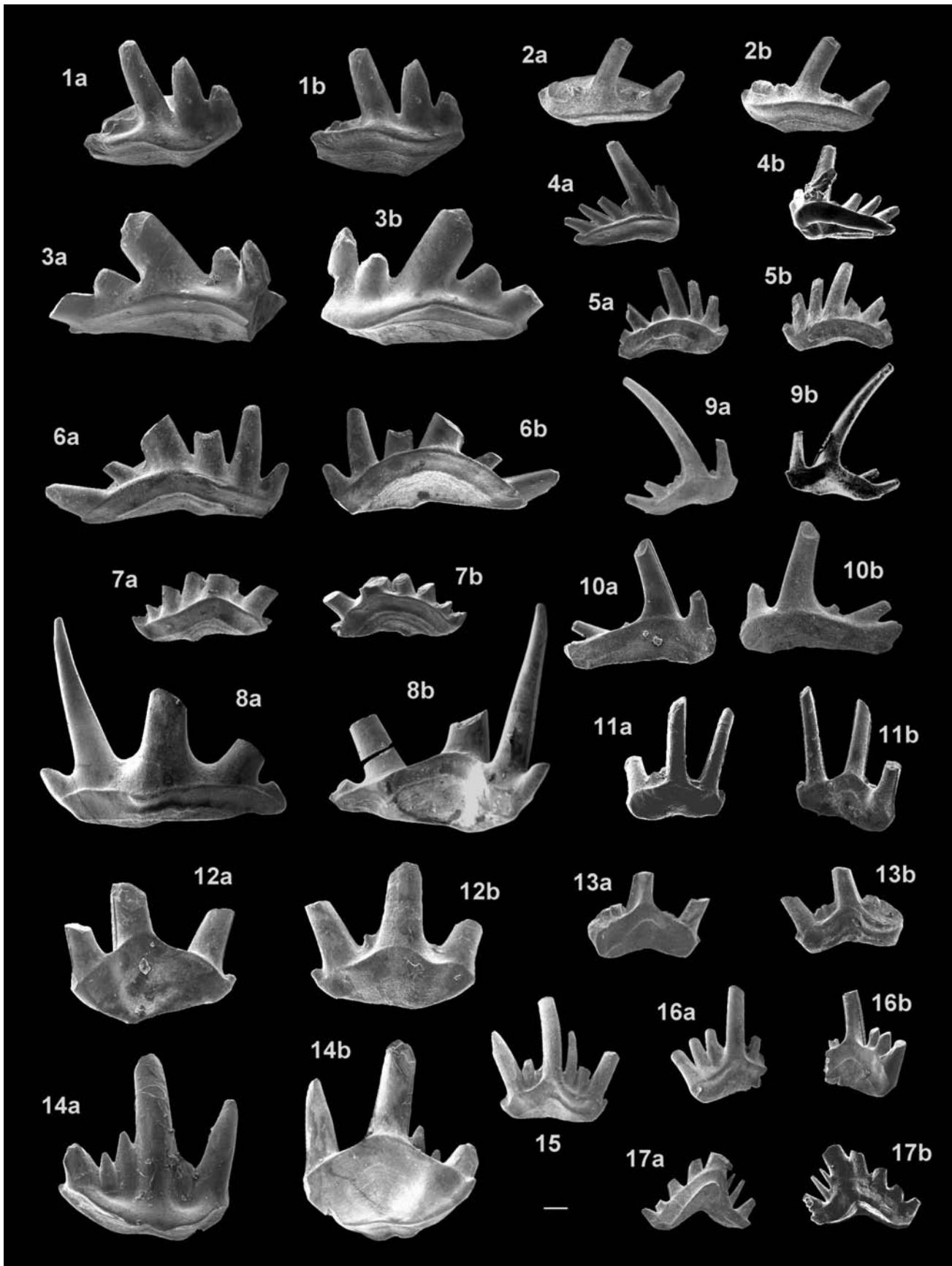
Fig. 7   - *Pachycladina obliqua* Staesche
        Bosansko Grahovo section, *obliqua* Zone, Smithian (samples BG 4, BG 129, BG 131) and Smithian -?Spathian (sample BG 135).
        1a-b, 2a-b, 3a-b, 4a-b - Pa elements, sample BG 135; 5a-b - Pb element, sample BG 135; 6a-b, 7a-b, 8a-b - Pb elements, samples BG 135,
        BG 129, BG 4; 9a-b, 10a-b - Sc elements, sample BG 135; 11a-b, 12a-b, 13a-b - Sb elements, samples BG 135, BG 131, BG 4; 14a-b, 15a-
        b, 16a-b - Sa elements, samples BG 135, BG 131, BG 127; 17a-b - M element, sample number BG 4. Scale bar equals 100 microns.

different characteristics than described in the Plavno and Bosansko Grahovo sections. The Siusi Member of the Bulla section is dominantly carbonate (mudstones alternated with packstones bearing bivalve faunas) and the Campil Member is predominantly reddish sandstone and siltstones (Farabegoli & Perri 1998; Perri & Farabegoli 2003). These facies characteristics are quite opposite to that described for the Seis beds in the External Dinarides. In the Carnic Alps, coquina tempestite and oolite beds characterize the Seis Member, while in Campil Member mixed dolomitic-siliciclastic material prevails. The increase in terrigenous material that occurs in the Campil Member has been interpreted as overall regression or shallowing of the environment (Boeckelman 1991). On the contrary, Campil beds in the Dinarides show transgressive trend. Thus, the lithology, as well as the transgression/regression trend of Southern and Carnic Alps, are different than in the Plavno and Bosansko Grahovo sections of the External Dinarides.

A section at Muć locality of the External Dinarides (located not far from the Plavno section) that was proposed for the "Upper Scythian" standard section (Herak at al. 1983), consists of 4 informal units ("members") :1) Permo(?)-Triassic dolomitic limestones, 2) brown reddish sandstone-siltstone beds, 3) grey limestone-marl beds and 4) Anisian dolomite. Herak et al. (1983) considered that the lithology, facies and vertical sequence correspond remarkably well with those of the Werfen beds of the Dolomites and suggested to establish these lithostratigraphic members for the Lower Triassic in the entire Alpine-Mediterranean realm (Alps, Dinarides). We argue against this suggestion because in the investigated profiles of Plavno and Bosansko Grahovo we can find significant differences with the type localities in the Southern Alps, regarding lithology, transgressive/regressive trends and especially the age range of the so-called Seis and Campil beds. Herak et al (1983) also implied that the "Campil Member" of Werfen facies in the Southern Alps was older than investigated Campil beds (unit B) of the Muć.

The Lower Triassic beds of the External Dinarides in Slovenia show similar microfacies characteristic as so called Seis beds described in the other parts of Dinarides, but with some differences. Alternation of clastic and carbonate rocks (particularly oolitic limestone with admixtures of siliciclastics) is the most characteristic lithotypes. The beds are often dolomitized. Oolitic beds are characterized by conodont association of the Smithian *obliqua* Zone represented by shallow water genera *Pachycladina, Hadrodontina, Furnishius* and *Parachirognathus* (Kolar-Jurkovšek & Jurkovšek 1996). Upwards, the Lower Triassic succession shows a reduction in the amount of detritic component: dark biomicritic and marly limestone is prevailing over do-

lostone. Among fossils, ostracods and rare stromatolitic laminae appear.

As seen in the examples from the Southern, Carnic Alps, and Slovenia, lithology varies from one section to another, and this age difference is well demonstrated from the conodont data. In the External Dinarides of Slovenia, for a long time a regionally widespread oolitic horizon has been thought to be devoid of conodonts. However, there is evidence for Olenekian (Smithian) fauna at several localities (Kolar-Jurkovšek 1990; Kolar-Jurkovšek & Jurkovšek 1996). All recovered assemblages are characterized by *Pachycladina obliqua* apparatus and *Hadrodontina* sp. and/or *Furnishius triserratus* Clark, *Parachirognathus ethingtoni* Clark, and *Foliella gardenae* (Staesche), respectivelly (Kolar-Jurkovšek & Jurkovšek 2001). Occasionally, the elements of *Ellisonia* can be present. Conodont collections from the External Dinarides in Slovenia have been well documented and can be compared with other equivalent collections hitherto studied in other parts of Slovenia, i.e., fauna obtained from the sequence near Tržič in Karavanke (Southern Alps) with dominant *Foliella gardenae* associated with typical shallow water elements (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 et al. (1971). Lower Triassic shallow water genera such as *Foliella, Hadrodontina, Pachycladina*, and *Parachirognathus* are significant biostratigraphic markers that have proved useful in the conodont zonation of Slovenia.

Recent geologic study in the External Dinarides of Croatia provided new paleontological data for Dalmatia and Gorski Kotar (Jelaska et al. 2003; Aljinović et al. 2006a, b) and revealed similar composition of the equivalent conodont faunas in the area.

As seen in the examples from the Southern Alps, Slovenia and Croatia lithology varies from one section to another. This is particularly true for the shallow shelf environment where slight changes in palaeomorphology influence important differences. Thus, there is no need to compare Lower Triassic developments of the External Dinarides with the type localities in the Alps, considering only lithology. Correlations should be drawn on the base of very precise conodont zonation, considering the whole cyclic deposition characterizing the Early Triassic in the area. Thus, it may be concluded that the multielement *P. obliqua* is an important biostratigraphic tool in the Western Tethys. Outside the External Dinarides, its stratigraphic use has been previously demonstrated in the Southern Alps (Perri & and Andraghetti 1987; Perri 1991).

Conclusion

Identified conodont taxa enable us to establish a conodont zonation which gives new insight to the age range of so-called Seis and Campil beds of the External Dinarides, as they were also given chronostratigraphic meaning (Seis beds = early Lower Triassic and Campil beds = late Lower Triassic). This partly lithostratigraphic and partly chronostratigraphic division is not applicable anymore in light of results presented here.

Dolostone facies that occurs at the base of Lower Triassic sequence (Plavno section) yields conodont fauna represented by isarcicellids, *Isarcicella staeschei* and *I. isarcica*. The fauna marks the lowermost Triassic *isarcica* Zone.

The investigated samples of the Siliciclastic facies (documented in the Plavno and Bosansko Grahovo sections), formerly defined as Seis beds, are characterized by co-occurrence of *Hadrodontina anceps*, *Pachycladina obliqua* and *Parachirognathus ethingtoni* multielements and very rare *Foliella* sp. or *?Furnishius* sp. This fauna is attributed to the Smithian part of the *obliqua* Zone. Conodont biofacies is marked by shallow-water euryhaline taxa.

The upper part of the Lower Triassic sequence, the former Campil beds, is characterized by occurrence of *Pachycladina obliqua* (sample 151 of the Mudstone facies) that ranges in the *obliqua* and *triangularis* zones, whereas the last two samples (250, 294 of the Siltstone-mudstone facies) contained only few conodont fragments. The absence of *Neospathodus triangularis* prevent us to conclude about the Spathian age of the uppermost part of the investigated sequences.

As seen in the examples from the Southern Alps and Slovenia lithology varies from one section to the other. It is particularly true for the shallow shelf environment where slight changes in palaeomorphology influence important differences. Thus, there is no need to compare Lower Triassic developments of the External Dinarides with the type localities, considering only lithology. The important comparison can be made based on established zoning especially using very precise conodont zonation.

On the basis of the conodont analyses, we therefore strongly argue the previous reference of the Seis beds to the early and Campil beds to the late Lower Triassic.

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