

FIRST REPORT ON THE UPPERMOST PERMIAN OSTRACODS FROM THE MASORE SECTION (EXTERNAL DINARIDES), SLOVENIA

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Abstract. The ostracod assemblages from the Upper Permian and Permian-Triassic transitional beds of the Masore section in the External Dinarides (Slovenia) were studied. Thirteen genera and 20 species of the orders Palaeocopida, Platycopida and Podocopida have been identified and illustrated. All recovered ostracods belong to shallow marine taxa. Two associations have been distinguished: a lower one from the uppermost Permian and an upper association from the Permian-Triassic boundary strata. This study presents the first report of ostracod faunas from the uppermost Permian and Permian-Triassic boundary interval of Slovenia. The recovered ostracod faunas record a distinct faunal change and yield important paleobiogeographic implications as it reveals similarity with stratigraphically equivalent faunas from some other neighboring localities in the western Paleotethys, such as Bulla in Italy, Komirić in Serbia, and the Bükk Mountains in Hungary.

INTRODUCTION

The Permian was a critical period in the Earth history, as the greatest mass extinction occurred at its end when up to 96% of all existing species of marine organisms vanished (Hallam & Wignall 1997; Dal Corso et al. 2022). The causes of the mass extinction across the Permian-Triassic boundary are

still a subject of discussion (Foster et al. 2022). The Masore section was part of intensive investigations to define the Permian-Triassic boundary (PTB) in the External Dinarides. Therefore, several geological studies have been carried out along sections, where the Upper Permian Bellerophon Formation and the Lower Triassic Werfen Formation in Slovenia are exposed (Kolar-Jurkovšek & Jurkovšek 2019 and references therein). The Lukač section located in the Žiri region has a record of *Hindeodus-Isarcicella* populations through the PTB interval. The species *Hindeodus parvus* (Kozur & Pjatakova,

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1976) was detected in sample L1 in the “transitional beds” (Kolar-Jurkovšek & Jurkovšek 2007; Kolar-Jurkovšek et al. 2011), thereby enabling an accurate placement of the PTB. Due to the precise position of the lower boundary of the Triassic and the succession of conodont zones across the boundary, the Lukač section is considered a key section to define the PTB according to international criteria (Yin et al. 2001). A recent study by Kolar-Jurkovšek et al. (2021) provides a comparison between the uppermost Permian and Lower Triassic strata of the Dinarides section and the adjacent areas. The Masore section is well known from numerous papers and the last biostratigraphic study was focused on the definition of the Triassic basal boundary according to international criteria (Kolar-Jurkovšek et al. 2018 and references therein). Another goal was also to correlate the succession of the western Paleotethys with the stratotype of Meishan in China that was located in the eastern Paleotethys (Kolar-Jurkovšek et al. 2018). The study of foraminifers and conodonts of the Masore section enabled identification of four conodont faunas. The present work is concerned with ostracods which were recovered from conodont samples processed during previous biostratigraphic studies. The subject of this paper is thus a documentation of the ostracods from the Masore section. This is also the first report on ostracod assemblages of the uppermost Permian and PTB interval beds of the region and thus an important contribution to the paleobiogeography of Upper Permian ostracods in the western Paleotethys. Abundant ostracods were found also in the PTB transitional interval of the Lukač section – the key section to define the PTB in the Dinarides, but these taxa were not determined (Kolar-Jurkovšek et al. 2011). Previous studies of ostracods of the Upper Permian and Lower Triassic of the Dinarides area were published by Pantić-Prodanović (1979), Krstić (1980) and Crasquin et al. (2010b). The report on the Upper Permian (Changhsingian) ostracods from the Komirić section was the first one from Serbia and the entire Dinarides area and three species were introduced: *Basslerella jadarensis* Crasquin et al., 2010, *Acratia sebianella* Crasquin et al., 2010 and *Knoxiella vardarensis* Crasquin et al., 2010 (Crasquin et al. 2010b). From the same area in Serbia, also Olenekian ostracod assemblages were reported (Pantić-Prodanović 1979; Krstić 1980; Sudar et al. 2014).

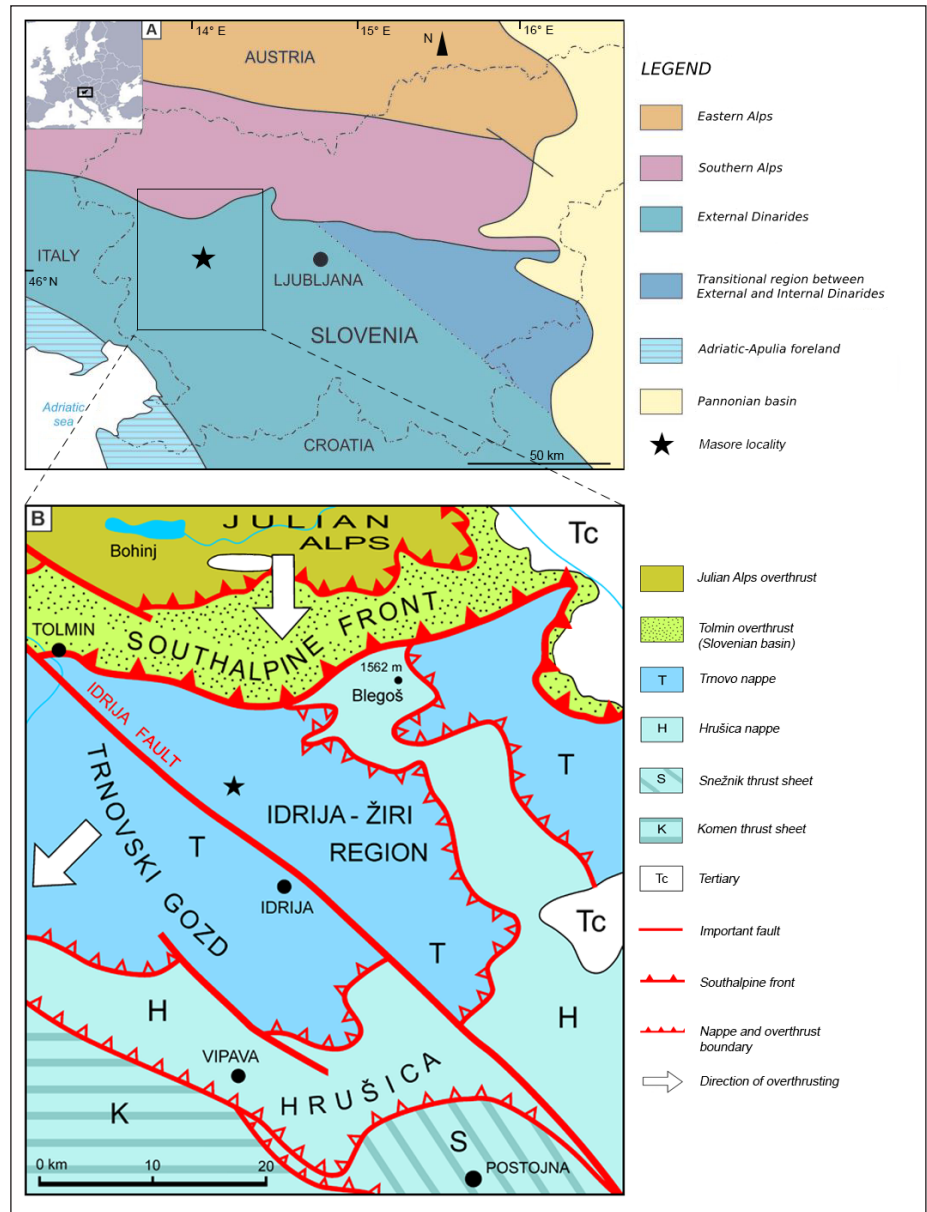
GEOLOGICAL SETTING

The Masore section is in the northwesternmost part of the External Dinarides (Fig. 1). The section exposes the Upper Permian Bellerophon Formation dominated by bioclastic packstone, and subordinated bioclastic siltite. It is conformably overlain by microbially laminated bindstone/stromatolite of the Permian-Triassic boundary beds that are designated as PTB transitional interval, but represent an informal unit (Kolar-Jurkovšek et al. 2018). The distribution of recovered conodonts in the section enabled the identification of four faunas, listed here in ascending order: the unnamed and *Hindeodus praeparvus* Zones (uppermost Changhsingian, uppermost Permian), the gondolellid level of the PTB transitional interval, and the *Isarcicella isarcica* Zone (Induan, Lower Triassic). The Bellerophon Formation yields abundant and diverse foraminiferal species which are characteristic for most of the Changhsingian, Upper Permian and known from many parts of the Paleotethys. The PTB transitional interval beds are marked by the rare occurrence of the agglutinated foraminiferal species *Ammodiscus kalbhor* (Brönnimann, Zaninetti & Bozorgnia, 1972) and *Hyperammia deformis* (Bérczi-Makk, 1987) in association with some Upper Permian representatives of *Geinitzina*, *Tristix*, *Globivalvulina* and “*Nodosaria*”, which were probably holdover taxa able to survive in a stressful environment after the mass extinction (Kolar-Jurkovšek et al. 2018).

The studied strata were deposited near the paleoequator, in the western Paleotethyan carbonate ramp. The mixed biota of the Bellerophon Formation indicates a relatively shallow environment of the distal part of the ramp with a diverse fauna. The laminated microbialites-stromatolites of the PTB transitional interval are interpreted to reflect a deeper ramp environment. The distribution and faunal composition of Induan microbialites investigated in several Tethyan sections, including at Masore in Slovenia, infers that suppressed competition was one of the crucial factors that allowed microbialite-forming microbial mats to flourish in different, even deeper marine environments on the ramp following the end-Permian mass extinction (Foster et al. 2020).

The Permian and Triassic strata of the Masore area were previously object of several geological studies (Buser et al. 1989; Dolenc et al. 2003,

Fig. 1 - A) Simplified map of geotectonic units in Slovenia; B) Tectonic map with geographic position of the Masore sections (star) (modified after Placer 1999, 2008; Kolar-Jurkovšek et al. 2018).



2004); for more detailed data, the reader is referred to Kolar-Jurkovšek et al. (2018). The results of the present study confirm the biostratigraphic interpretation which is adopted herein (Figs. 2, 3). Due to a fault in the middle part of the exposed section, the Masore section has been divided in two parts, and the obtained results are presented separately for the lower part Masore II (Mlakar) and the upper part Masore I (Bende) (Figs. 2, 3). The Masore II (Mlakar) section exposes exclusively strata of the Bellerophon Formation. Most of the Masore I (Bende) section is formed of the Permian Bellerophon Formation that continuously passes into the microbial strata of the PTB transitional interval.

MATERIALS AND METHODS

The field work in the Masore area was carried out in the 2006-2015 interval. The Masore II (Mlakar) section begins at coordinates $46^{\circ} 4' 12.40''$ N; $13^{\circ} 59' 18.94''$ E and the Masore I (Bende) section begins at coordinates $46^{\circ} 4' 3.59''$ N; $13^{\circ} 59' 9.57''$ E. Rock samples with a weight of minimum 4 kg were processed using standard laboratory techniques as outlined in Stone (1987) and Jeppsson et al. (1999). This work is based on the ostracod collections obtained from the residues for conodont extraction and altogether seventeen collections were examined. Laboratory processing and fossil picking was done at the Geological Survey of Slovenia / Geološki zavod Slovenije in Ljubljana. All studied ostracod material is currently stored under the acronym GeoZS at the micropaleontological collection of the Geological Survey of Slovenia. The illustrated ostracods were photographed using a Philips XL 20 scanning electron microscope at the Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland.

Microfacies and the depositional environment of the Masore sections

Both the investigated sections are composed of Upper Permian bioclastic carbonates of the Bellerophon Formation followed by the PTB transitional beds with microbial microfacies exposed in the upper 22 m of the Masore I (Bende) section. The thickness of the Masore I (Bende) and the Masore II (Mlakar) sections corresponds to about 180 m and 150 m, respectively, and they were studied biostratigraphically and petrographically. Microfacies types were defined in the first phase of the study in the Masore area. In this section, a summary of the microfacies types and interpretation is provided, and for a more detailed description the reader is referred to Kolar-Jurkovšek et al. (2018).

The Bellerophon Formation of the Masore area consists of four lithofacies: 1) the *Coarse Grained Biomicrite/Packstone* microfacies contains a rich biota of calcareous green algae, foraminifers, echinoderms (crinoids and echinoids), bivalves, gastropods, sponges and ostracods. Dolomitization is observed in some beds. The abundance of dasycladaceans and other green algae suggests a high photosynthetic activity that is indicative of a warm, shallow euphotic depositional environment; 2) the *Fine-grained Biopelmicrite/Packstone* is characterized by well sorted bioclasts and peloids. The main constituents in this microfacies type are skeletal fragments of echinoderms, bivalves, green algae, foraminifers, gastropods, brachiopods and ostracods. Peloids were the result of micritization processes; 3) the *Coarse Grained Intrabiomicrite/Packstone* microfacies consists of large well rounded intraclasts that dominate the texture. Bioclasts are mainly dominated by fragments of algae, echinoids, bivalves, gastropods, brachiopods, foraminifers and coated intraclasts or coated bioclasts. In the composition of intraclasts, a biomicritic fabric can be observed. The presence of intraclasts is a significant feature of this microfacies type; they were formed due to the reworking of primary biomicrites; 4) the *Bioclastic Siltite* beds are present in the lower part of the Bellerophon Formation. Parallel and small-scale cross lamination have been observed. The main constituents of this microfacies type are the skeletal fragments and echinoderms that are easily recognized due to their syntaxial rim cement. A significant amount of siliciclastic mineral grains (quartz, feldspar and mica) has been observed in this microfacies and suggests

intensive continental weathering and transport to a marine area. Mixing and reworking of the siliciclastic and bioclastic detritus is evidenced in parallel and ripple cross-lamination.

The *PTB Transitional Beds* are characterized by the *Microbial Laminated Bindstone – Stromatolite* microfacies. Its most characteristic textural feature is the alternation of dark (microbial) and light (microsparitic) lamina couplets. The thickness of laminae varies. Laminae, from submillimeter scale to 1-2 mm in thickness, are flat, uneven, or even cracked and fragmented. Dark, microbial laminae are micrite rich and frequently they contain significant amount of pyrite cubes and framboids. Several distinctive microfabrics was differentiated: microbial threads, sphere clusters, peloids and sparitic microspheres (terminology after Kershaw et al. 1999, 2002). The latter are rounded or ovoidal spores with sharp dark edges and macrocrystalline interior; that resemble ooids. The most characteristic textural feature in the stromatolite is an alternation of dark (microbial) and light grey (microsparitic) lamina couplets. Some laminae are enriched in bioclasts as very fine-grained fragments of bivalves, ostracods, echinoderms and foraminifers. Local dolomitization within the stromatolite is also observed. The presence of laminae that consist entirely of homogenous microsparite can be related to direct precipitation from seawater due to a significant change in marine geochemistry during Late Permian-Early Triassic interval (Hips & Haas 2006). For microbial threads, a filamentous microbial (cyanobacterial?) origin is inferred, whereas sphere clusters characterized by micrite-walled hollow spheres are considered coccoidal microbes preserved due to early mineralization.

Interpretation of depositional environment of the Masore sections

The investigated beds of the Upper Permian–Lower Triassic Masore sections were located in the western margin of the Paleotethys, close to the paleoequator, where a shallow ramp was established during the Late Permian (Scotese 2001; Sremac et al. 2016). The presence of bioclastic siltites indicates deposition in the deeper part of the ramp. A connection with the land and a deposition on a ramp can be indicated also by a presence of terrigenous debris (quartz and feldspar) noticed in the matrix of the coarse-grained intrabiomicrite/packstone microfacies. Mixed biota present in other recognized

microfacies indicate a well inhabited shallow sea. The abundance of dasycladaceans and other green algae in coarse-grained biomicrite/packstone and in fine-grained biopelmicrite/packstone indicates a high degree of algal photosynthetic activity that is indicative of a warm, very shallow euphotic depositional environment. The high amount of micrite in intergranular pores suggests deposition in overall stable and quiet shallow water conditions. Presence of worn foraminifers suggests at least some transportation. Fine-grained detrital quartz and feldspar in the matrix represents terrigenous debris that was deposited together with micrite and bioclasts in a low to moderate energy setting, possibly in the inner part of carbonate ramp. Microbial coatings of skeletal fragments imply slightly agitated water and rolling of nuclei. The occurrence of coarse-grained bioclasts suggests redeposition of bioclastic and intraclastic grains around the fair-weather wave base in a mid-ramp setting. The Permian-Triassic boundary interval is marked by laminated microbialites – stromatolites as characteristic disaster or anachronistic biota indicating the presence of global stressful conditions around the Permian-Triassic boundary (Kershaw et al. 1999, 2002). Alternation of laminae represents changing conditions that favor microbial growth (sphere clusters and threads) and accumulations of detrital calcitic component (microsparitic calcite, fine-grained bioclasts and peloids and microspheres). The presence of *Hyperrammmina* suggests stressful depositional conditions. Some laminae enriched in fine-grained bioclastic fragments were probably deposited by weak currents. In this facies, the occurrence of gondollelids apparently implies unrestricted conditions related to the distal and deeper depositional environment. Therefore, we suggest that the microbial facies was deposited on a ramp. The presence of a weak current implies deposition around a fair-weather wave base in the investigated time interval.

Ostracod fauna

This work is based on selected samples for conodont analysis that contained diverse ostracod associations. The ostracod abundance varies greatly. The overall preservation of most recovered ostracods is poor also due to the applied chemical processing. It is expected that hot acetolysis would favour more adequate preservation allowing a complete study of this group (Lethiers & Crasquin-Sole-

Order Palaeocopida Henningsmoen, 1953		
Family Paraparchitidae Scott, 1959		
<i>Shisharella</i> cf. <i>cyclopea</i> (Girty, 1910)		Pl. 1, figs. 1-3
Family Serenididae Rozhdstvenskaya, 1972		
<i>Sargentina longinodosa</i> (Kozur, 1985)		Pl. 1, figs. 4-8
<i>Sargentina postacuta</i> (Zalányi, 1974)		Pl. 1, fig. 9
Family Indivisiidae Egorov, 1954		
<i>Indivisia</i> cf. <i>buekkensis</i> Kozur, 1985		Pl. 1, fig. 10
Order Platycopida Sars, 1866		
Family Cavellinidae Egorov, 1950		
<i>Cavellina</i> cf. <i>bellerophonella</i> Crasquin, 2008		Pl. 1, fig. 11
<i>Cavellina</i> ? sp.		Pl. 2, fig. 20
<i>Sulcella suprapermiana</i> Kozur, 1985		Pl. 1, fig. 12
<i>Sulcella</i> sp.		Pl. 1, fig. 13
Order Podocopida Müller, 1894		
Family Microcheilinellidae Gramm, 1975		
<i>Microcheilinella</i> cf. <i>hungatica</i> Kozur 1985		Pl. 1, figs. 14-15
Family Bairdiocyprididae Shaver, 1961		
<i>Praecipilina minuta</i> Kozur, 1985		Pl. 1, figs. 16-17
Family Bairdiidae Sars, 1887		
<i>Bairdia deducta</i> Zalányi, 1974		Pl. 2, figs. 1-3
<i>Bairdia</i> sp. 1		Pl. 2, fig. 4
<i>Bairdia</i> sp. 2		Pl. 2, fig. 5
<i>Bairdiacypris</i> sp.		Pl. 2, figs. 6-9
<i>Bairdiacypris</i> ? sp.		Pl. 2, figs. 10-12
<i>Bairdiacypris</i> ? indet.		Pl. 2, fig. 19
<i>Paramacrocypris schallreuteri</i> Kozur, 1985		Pl. 2, figs. 13-16
<i>Praezabythocypris</i> sp.		Pl. 2, fig. 17
Family Acratidae Gründel, 1963		
<i>Acratia</i> sp.		Pl. 2, fig. 18
<i>Triassocypris</i> ? sp.		Pl. 2, fig. 21

Tab. 1 - List of determined and illustrated ostracod taxa.

au 1988). A forthcoming repeated sampling and use of more appropriate processing techniques would therefore enable a more accurate ostracod analysis. As ostracods have not been previously reported from the Permian-Triassic boundary strata of Slovenia, the recovered assemblages are documented here as a first report. Two associations from the Masore area are distinguished, the older from the Permian Bellerophon Formation and the younger from the PTB transitional beds (Figs. 2, 3). The two associations show a completely different composition and variable abundance which are in a correspondence with the lithological change (indicating a stressful environment) that caused extinction of most taxa in the PTB interval of the studied section.

Ostracods from the Masore section belong to 8 families of the orders Palaeocopida, Platycopida and Podocopida, and they are represented by 13 genera and 20 species of which 10 species are left in open nomenclature (Table 1, Pls. 1, 2). The ostracod association from the Bellerophon Formation show relatively high abundance and diversity. The lower part of this formation contains mainly fragments of ramiform conodont elements and few *Hindeodus* specimens and is thus assigned to the unnamed conodont zone (samples M2 through M12 in the Masore II section; samples B27 through B21 in the Masore I section). The upper part of the Bel-

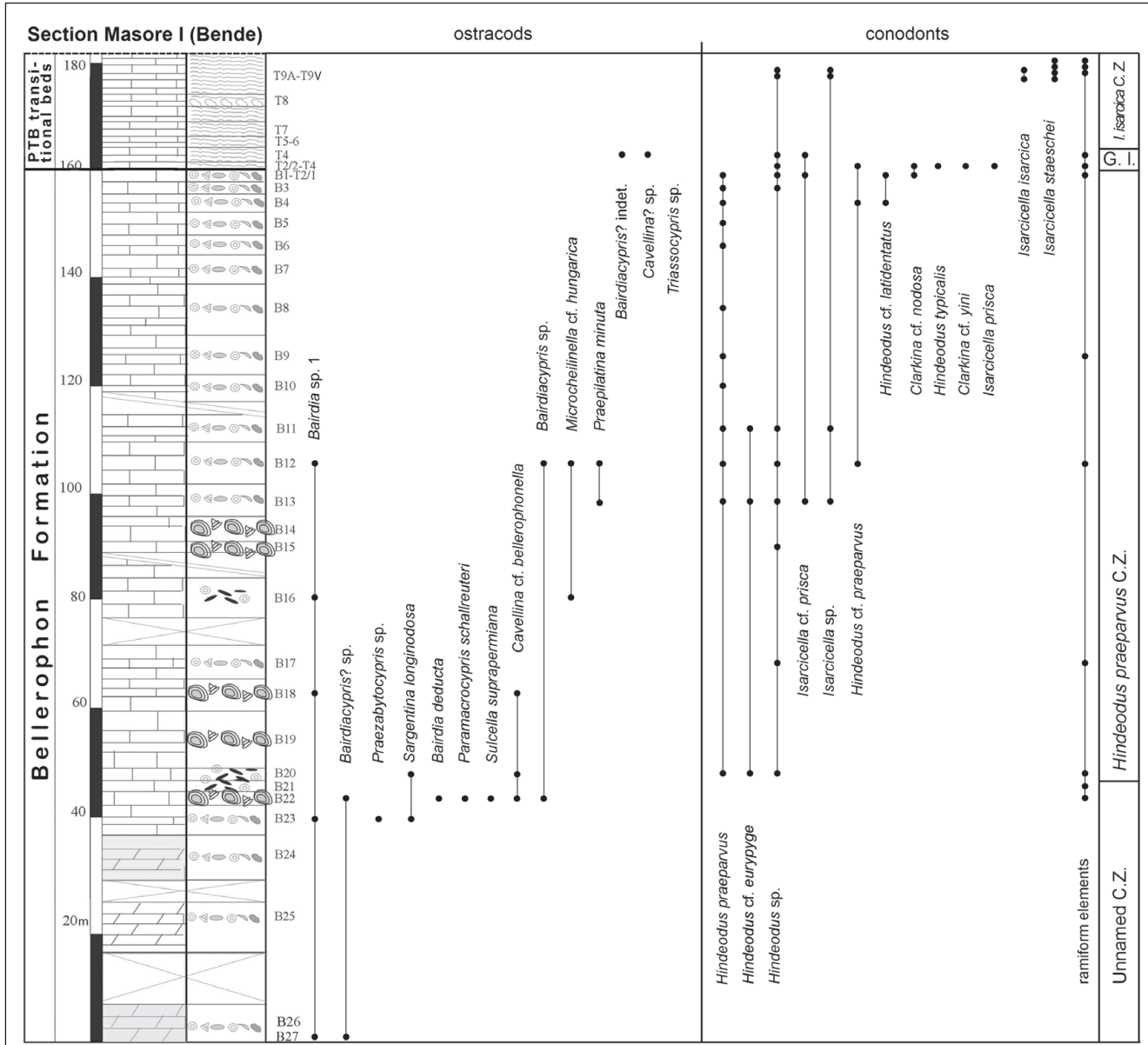


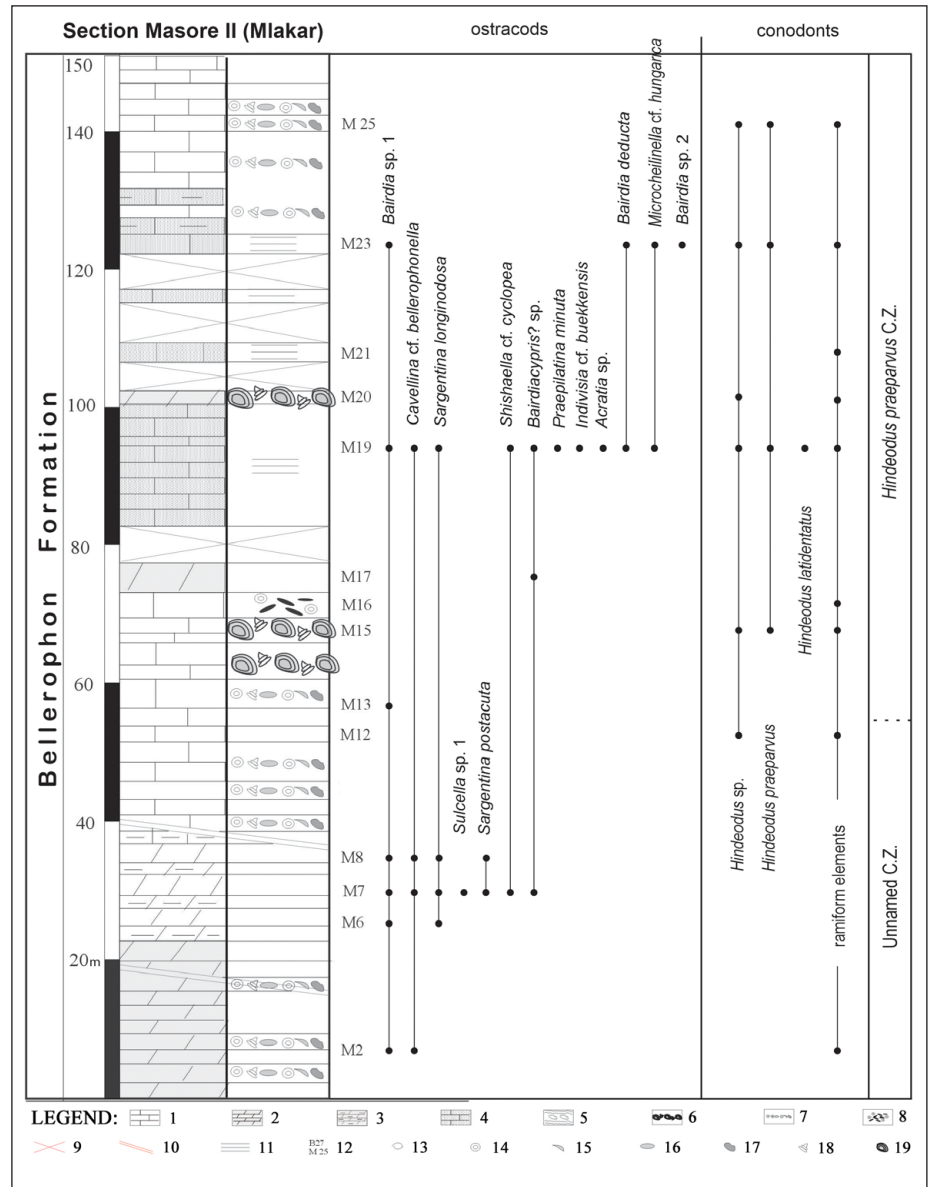
Fig. 2 - Distribution of ostracod and conodont taxa in the Masore I (Bende) section. Abbreviations: C.Z. – Conodont Zone, G. I. - Gondolellid level, I. – *Isarcicella*. Legend in Figure 3.

lerophon Formation is characterized by prevailing *Hindeodus praeparvus* Kozur, 1996 in association with some other species of *Isarcicella* and *Hindeodus* that corresponds to the *Hindeodus praeparvus* Zone and is latest Permian (late Changhsingian) in age. From the unnamed Zone of the Bellerophon Formation the following ostracod taxa are identified: *Bairdia deducta* Zálányi, 1974, *Bairdia* sp. 1, *Bairdiacypris?* sp., *Cavellina* cf. *bellerophonella* Crasquin, 2008, *Paramacrocypris schallreuteri* Kozur, 1985, *Praezabythocypris* sp., *Sargentina longinodosa* (Kozur, 1985), *Sargentina postacuta* (Zálányi, 1974), *Shishaella* cf. *cyclopea* (Girty, 1910), *Sulcella suprapermiana* Kozur, 1985, *Sulcella* sp. 1. These

strata are characterized by a relatively low diversity and the following ostracod taxa occur only in this zone: *Bairdia deducta* Zálányi, 1974, *Bairdiacypris?* sp., *Paramacrocypris schallreuteri* Kozur, 1985, *Praezabythocypris* sp., *Sargentina postacuta* (Zálányi, 1974), *Sulcella suprapermiana* Kozur, 1985, *Sulcella* sp. 1.

The overlying *Hindeodus praeparvus* Zone is marked by a higher ostracod species richness [*Acratia* sp., *Bairdia deducta* Zálányi, 1974, *Bairdia* sp. 1, *Bairdia* sp. 2, *Bairdiacypris* sp., *Bairdiacypris?* sp., *Cavellina* cf. *bellerophonella* Crasquin, 2008, *Indivisia* cf. *buekensis* Kozur, 1985, *Microcheilina* cf. *hungarica* Kozur, 1985, *Praepilatina minuta* Kozur, 1985, *Praezabythocypris* sp.,

Fig. 3 - Distribution of ostracod and conodont taxa in the Masore II (Mlakar) section. Abbreviation: C.Z. – Conodont Zone. Legend: 1: Limestone, 2: Dolostone, 3: Silty-clayey dolostone, 4: Bioclastic siltite, 5: Microbialite-stromatolite, 6: Coarse-grained intrabiomicrite/packstone, 7: Biomicrite/packstone, 8: Biopelmicrite/packstone, 9: Covered interval, 10: Tectonized, 11: Parallel lamination, 12: Samples, 13: Ostracods, 14: Algae, 15: Bivalves, 16: Foraminifers, 17: Echinoderms, 18: Gastropods, 19: Coated bioclasts/intraclasts.



Sargentina longinodosa (Kozur), *Shishaella* cf. *cyclopea* (Girty, 1910) of which only *Acratia* sp., *Bairdia* sp. 2, *Indivisia* cf. *buekkensis* Kozur, 1985, *Microcheilina* cf. *hungarica* Kozur, 1985, *Praepilatina minuta* Kozur, 1985 are confined to this zone, and six taxa [*Bairdia* sp. 1, *Bairdiacypris* sp., *Bairdiacypris?* sp., *Cavellina* cf. *bellerophonella* Crasquin, 2008, *Sargentina longinodosa* (Kozur, 1985), *Shishaella* cf. *cyclopea* (Girty, 1910)] are holdovers from the previous unnamed zone.

The Permian-Triassic boundary beds with microbial microfacies overlying the strata of the Bellerophon Formation (Kolar-Jurkovšek et al. 2018) are marked by the presence of gondolellids (Masore I – Bende section: samples T2/2 through T4/8). The fossil content of this level is very poor. The conodont fauna is marked by rare hindeodids and

isarcicellids and a few specimens of *Clarkina* cf. *nodosa* Kozur, 2004 and *C.* cf. *yini* (Mei, 1998), whereas the foraminifers are mostly represented by the species *Ammodiscus kalburi* (Brönnimann, Zaninetti & Bozorgnia, 1972) and *Hyperammia deformis* (Bérczi-Makk, 1987), and very rare nodosariids. The ostracod assemblage at this level is also very poor and of extremely low abundance and specific richness. Only three ostracod taxa are identified at this level, *Bairdiacypris?* indet., *Cavellina?* sp. and *Triassoeypris?* sp. Noteworthy they were found only in this level and thus document a distinct faunal change. The strata above the Gondolellid level contain only conodonts of the *Isarcicella isarcica* Zone (lower Induan, Lower Triassic) and no other microfauna was extracted from this level.

The recovered ostracod assemblage yields only limited information for a precise paleoecological interpretation. However, some general remarks can be outlined. Marine ostracods (Crustacea) are very common benthic organisms, and their distribution is associated with sea floor conditions. Being strongly affected by environmental conditions, they are valuable indicators of paleoenvironments, based on the occurrence of certain families/superfamilies with specific preferences (Lethiers 1981; Melnyk & Maddocks 1988). The ostracod associations reported herein are thus not only indicative of Upper Permian ostracod distribution patterns, but also confirm the previous interpretation of depositional environment in the studied section. The Bairdioidea are present in shallow to deep, open marine carbonate environments. The Cavellinidea and Parapatchitidae are adapted to euryhaline environments in shallow to very shallow waters. All recovered ostracods are indicating of tropical warm waters. Some specimens show a stacking of valves, known as ‘cup-in-cup’ preservation (e. g. Pl. 2, fig. 9), which can result from weak currents. Such a preservation is common and typical for non-marine ostracods deposited on the shore of lakes (e. g., Weakfield 1995).

The association of the Permian Bellerophon Formation corresponds to the “benthonic ostracod Eifelian Mega-assemblage” with ostracods occupying shelf settings (Crasquin & Horne 2018 and references therein). The data from the Masore section suggest a dramatic rate of ostracod extinction as all species of Permian ostracods disappeared in the upper part of the Bellerophon Formation (samples M23, B12 – see Figs. 2, 3).

The investigated uppermost Permian and lowermost Triassic beds of western Slovenia are interpreted as deposits of a shallow margin of the western Paleotethys possibly a carbonate ramp (Sremac et al. 2016; Aljinović et al. 2018). Bioclastic siltite and other recognized microfacies are suggested to be deposited in a deeper part of the ramp. Mixed biota in packstone indicate a well inhabited shallow sea, and the abundance of green algae suggests a warm, very shallow euphotic depositional environment. A shallow environment is also testified by the presence of the Bairdioidea, Cavellinidea and Parapatchitidae. Poorly represented specimens obtained from the PTB transitional beds yields *Bairdiocypris?* indet., *Triassocypris*

sp. and *Cavellina?* sp. The Cavellinidea were adapted to euryhaline conditions and could survive also in stressed environments with microbialite-stromatolite deposition (Forel et al. 2013). Ostracods have been reported from many PTB sections worldwide and their extinction rate varies between 68 and 100 % (Crasquin & Forel 2014). In the PTB transitional beds at Masore, three ostracod taxa (*Bairdiocypris?* indet., *Cavellina?* sp., *Triassocypris* sp.) occur which were able to tolerate the stressful conditions of microbial mats refugia following the end-Permian extinction (Forel et al. 2013).

Comparison of ostracod assemblages

The composition of the ostracod associations of the Masore section is compared with the associations of three neighboring sections, at Bulla in Italy and at Komirić in Serbia, as well as with data obtained from the Bükk Mountains in Hungary. The beds encompassing the PTB interval at Masore are characterized by the presence of two different ostracod associations marked by change in faunal composition. A very similar marked change in composition of the ostracod association around the PTB has been reported at the Bulla section (Lower Tesero Member, Lower Mazzin Member, Upper Tesero Member) (Crasquin et al. 2008). Four ostracod species are in common between the Masore and Bulla sections. *Cavellina* cf. *bellerophonella* Crasquin, 2008 occurs in the “Ostracod Unit”, whereas *Paramacrocypris schallreuteri* Kozur, 1985, *Sulcella supraPermiana* Kozur, 1985 and *Sargentina postacuta* (Zalányi, 1974) are present in the Bulla Member. The latter species appears also in the Permian part of the Werfen Formation (lower Tesero Member) (Crasquin et al. 2008). Although both sections show a distinct faunal turnover near the lithological change and a drastic decrease of diversity, only an approximate comparison of the PTB interval and lowermost Triassic beds is enabled by the presence of the genus *Cavellina*.

The Komirić section provided the first and hitherto the only record of the Upper Permian ostracods from the Dinarides area; the association was obtained from shallow-water marine carbonates of the “Bituminous Limestone” of Changhsingian age, and yielded 38 species, including three new ones (Crasquin et al. 2010b). Part of these beds belong to the Lower *praeparvus* conodont Zone, Upper Permian. The ostracod association is

typical of a platform environment with a depth of less than 50–100 m (Crasquin et al. 2010b). Two ostracod species, *Paramacrocypris schallreuteri* Kozur, 1985 and *Sulcella suprapermiana* Kozur, 1985 are in common in the Komirić and Masore sections.

There are also several species that are reported from the Upper Permian of the Bükk Mountains in Hungary and are common with the association of the Masore section. These are: *Sargentina longinodosa* (Kozur, 1985), *Sargentina postacuta* (Zalányi, 1974), *Indivisia* cf. *buekkensis* Kozur, 1985, *Sulcella suprapermiana* Kozur, 1985, *Microcheilinella* cf. *hungarica* Kozur, 1985, *Praepilatina minuta* Kozur, 1985, *Bairdia deducta* Zalányi, 1974 and *Paramacrocypris schallreuteri* Kozur, 1985 (Kozur 1985a, 1985b; Zalányi 1974). It is worthwhile to mention that two species, *Sulcella suprapermiana* Kozur, 1985 and *Paramacrocypris schallreuteri* Kozur, 1985, occur in the stratigraphically equivalent assemblages of all four sections, Bulla, Komirić, Masore and Bükk Mountains sections.

SYSTEMATIC PALEONTOLOGY

Class **OSTRACODA** Latreille, 1806

Subclass **PODOCOPA** Sars, 1866

Order **Palaeocopida** Henningsmoen, 1953

Suborder **Paraparchitoidea** Scott, 1959, emend.

Sohn, 1971

Superfamily Paraparchitidea Scott, 1959

Family Paraparchitidae Scott, 1959

Genus *Shishaella* Sohn, 1971

Shishaella cf. *cyclopea* (Girty, 1910)

Pl. 1, figs. 1-3

cf. 1910 *Paraparchites niclesi* var. *Cyclopean* Girty: p. 232

cf. 1971 *Shishaella cyclopean* (Girty); Sohn: p. 14, pl. 7: 1-35.

Material: 7 specimens.

Remarks. In its lateral outline, the specimens from Slovenia strongly resemble *Shishaella cyclopea* (Girty) from the Upper Mississippian of USA (Sohn 1971). The scarcity of material precludes any possibility of a more accurate comparison.

Occurrence. Slovenia (Masore II, samples: M6, M19).

Suborder **Kloedenellocopina** Scott, 1961
Superfamily Kloedenelloidea Ulrich & Bassler,
1908

Family Serenididae Rozhdestvenskaya, 1972

Genus *Sargentina* Coryell & Johnson, 1939, emend.
Sohn 1988

Sargentina longinodosa (Kozur, 1985)

Pl. 1, figs. 4-8

1985a *Hungarogeisina longinodosa* Kozur: pl. 3, figs. 5, 7.

Material: 11 specimens.

Occurrence. Bükk Mountains, Hungary, Wuchiapingian (basal Dzhulfian) Upper Permian (Kozur 1985a, b); Slovenia (Masore II, samples: M6, M7, M8, M19/4, M19; Masore I, samples: B20, B23).

Sargentina postacuta (Zalányi, 1974)

Pl. 1, fig. 9

1974 *Hollinella postacuta* Zalányi: p. 113-114, pl. 1, figs. 2a-d.

2008 *Sargentina postacuta* (Zalányi); Crasquin et al.: p. 240-241, pl. 1, figs. 12-14.

2012 *Sargentina postacuta* (Zalányi); Mette & Roozbahani: pl. 1, fig. 15.

Material: 5 specimens.

Remarks. Kozur (1985a) designated *Hollinella postacuta* Zalányi, 1974 as the type species of his new genus *Italogeisina* and referred *Sargentina dolomitica* Passini, 1981 as a junior synonym of *Italogeisina postacuta* (Zalányi). In the opinion of Sohn (1988), the genus *Italogeisina* remains 'a nomen dubium until the holotype of the type species is adequately described'. According to Crasquin-Soleau et al. (2004), the genera *Italogeisina* and *Hungarogeisina* from the Upper Permian strata of the Bükk Mountains, Hungary, erected by Kozur (1985a), are probably junior synonyms of *Sargentina*.

Occurrence. Bükk Mountains, Hungary: Upper Permian (Zalányi 1974); Bellerophon Formation, upper Changhsingian, Italy (Pasini 1981, Crasquin et al. 2008); Slovenia (Masore II, samples: M7, M8).

Family Indivisiidae Egorov, 1954

Genus *Indivisia* Zaspelova, 1954

***Indivisia* cf. *buekkensis* Kozur, 1985**

Pl. 1, fig. 10

cf. 1985a *Indivisia buekkensis* Kozur: p. 18, pl. 4, figs. 1-3.
 cf. 1985b *Indivisia buekkensis* Kozur: p. 232, pl. 12, fig. 3.

Material: 2 specimens.

Remarks. In its lateral outline, the specimens from Slovenia strongly resemble *Indivisia buekkensis* from the Upper Permian of Hungary (Kozur 1985a). The specimens from Slovenia differ in the outline of the anterior carapace end from *Indivisia* cf. *buekkensis* described from the Changhsingian Formation, Upper Permian, China (Crasquin et al. 2010a).

Occurrence. Bükk Mountains, Hungary, Changhsingian, Upper Permian (Kozur 1985a, b), Slovenia (Masore II, sample: M19/4).

Order **Platycopida** Sars, 1866
 Suborder **Platycopina** Sars, 1866
 Superfamily **Cavellinoidea** Egorov, 1950
 Family **Cavellinidae** Egorov, 1950
 Genus *Cavellina* Coryell, 1928

***Cavellina* cf. *bellerophonella* Crasquin, 2008**

Pl. 1, fig. 11

cf. 2008 *Cavellina bellerophonella* Crasquin: p. 254, pl. 6, figs. 3-7.
 cf. 2012 *Cavellina bellerophonella* Crasquin; Mette & Roozbahani: p. 78, 80, pl. 2, fig. 6-10.

Material: 7 specimens, mostly poorly preserved.

Remarks. The obtained specimens from Slovenia are most similar to *C. bellerophonella* Crasquin, 2008, from the Upper Permian of Southern Alps, Italy.

Occurrence. Bellerophon Formation, upper Changhsingian, Upper Permian, Southern Alps, northern Italy (Crasquin et al. 2008; Mette & Roozbahani 2012). Slovenia, Upper Permian (Masore II, samples: M2/3, M7, M8, M19/4; Masore I, samples: B22, B20, B18).

***Cavellina?* sp.**

Pl. 2, fig. 20

Material: 2 specimens.

Occurrence. Slovenia, Permian-Triassic transition interval (Masore I, sample: T4/2).

Genus *Sulcella* Coryell & Sample, 1932***Sulcella suprapermiana* Kozur, 1985**

Pl. 1, fig. 12

1985a *Sulcella suprapermiana* Kozur; p. 22, pl. 5, figs. 6, 8.
 1998 *Sulcella suprapermiana* Kozur; Crasquin-Soleau & Baud: p. 134, pl. 4, figs. 1-3
 1999 *Sulcella suprapermiana* Kozur; Crasquin-Soleau et al.: p. 169, 190, pl. 4, fig. 15.
 2008 *Sulcella suprapermiana* Kozur; Crasquin et al.: p. 255, pl. 6, figs. 1-2.
 2010 *Sulcella suprapermiana* Kozur; Crasquin et al.: pl. 2 figs. 26-29.
 2012 *Sulcella suprapermiana* Kozur; Mette & Roozbahani: pl. 2, fig. 12.
 2015 *Sulcella suprapermiana* Kozur; Zazzali et al.: p. 306, fig. 17.

Material: 2 valves.

Remarks. Similar specimen has been described as *Sulcella* sp. cf. *S. suprapermiana* Kozur 1985 from the Upper Permian Arqov Formation of Israel (Gerry et al. 1987).

Occurrence. Bükk Mountains, Hungary, Wuchiapingian, Upper Permian (Kozur 1985a); Hydra Island, Greece, upper part of the Middle Permian – lower part of the Upper Permian (Crasquin-

PLATE 1

Ostracods from the Bellerophon Formation of the Masore I (Bende) and Masore II (Mlakar) sections, Changhsingian, Upper Permian.

Figs. 1-3 - *Shisbaella* cf. *cyclopea* (Girty, 1910). 1: carapace in left lateral view; 2, carapace in left lateral view; 3, left valve in lateral view (M7-4206).

Figs. 4-8 - *Sargentina longinodosa* (Kozur, 1985). 4: carapace in left lateral view (M7-4206); 5: right valve in lateral view (M6-4205); 6: right valve in lateral view (B20-4192); 7: left valve in lateral view (B20-4192); 8: right valve in internal view (M19/4-4361).

Fig. 9 - *Sargentina postacuta* (Zalányi, 1974), carapace in left lateral view (M7-4206).

Fig. 10 - *Indivisia* cf. *buekkensis* Kozur, 1985, carapace in left lateral view (M19/4-4361)

Fig. 11 - *Cavellina* cf. *bellerophonella* Crasquin, 2008, left valve in internal view (B20-4192).

Fig. 12 - *Sulcella suprapermiana* Kozur, 1985, right valve in lateral view (B22-4194).

Fig. 13 - *Sulcella* sp., carapace in right lateral view (M7-4206).

Figs. 14-15 - *Microcheilinella* cf. *hungarica* Kozur 1985, 14: carapace in right lateral view (M23-4222), 15: right valve in internal view (B13-4185).

Figs. 16-17 - *Praepilatina minuta* Kozur, 1985, 16: carapace in right view; 17: left valve in internal view (M19/4-4361).

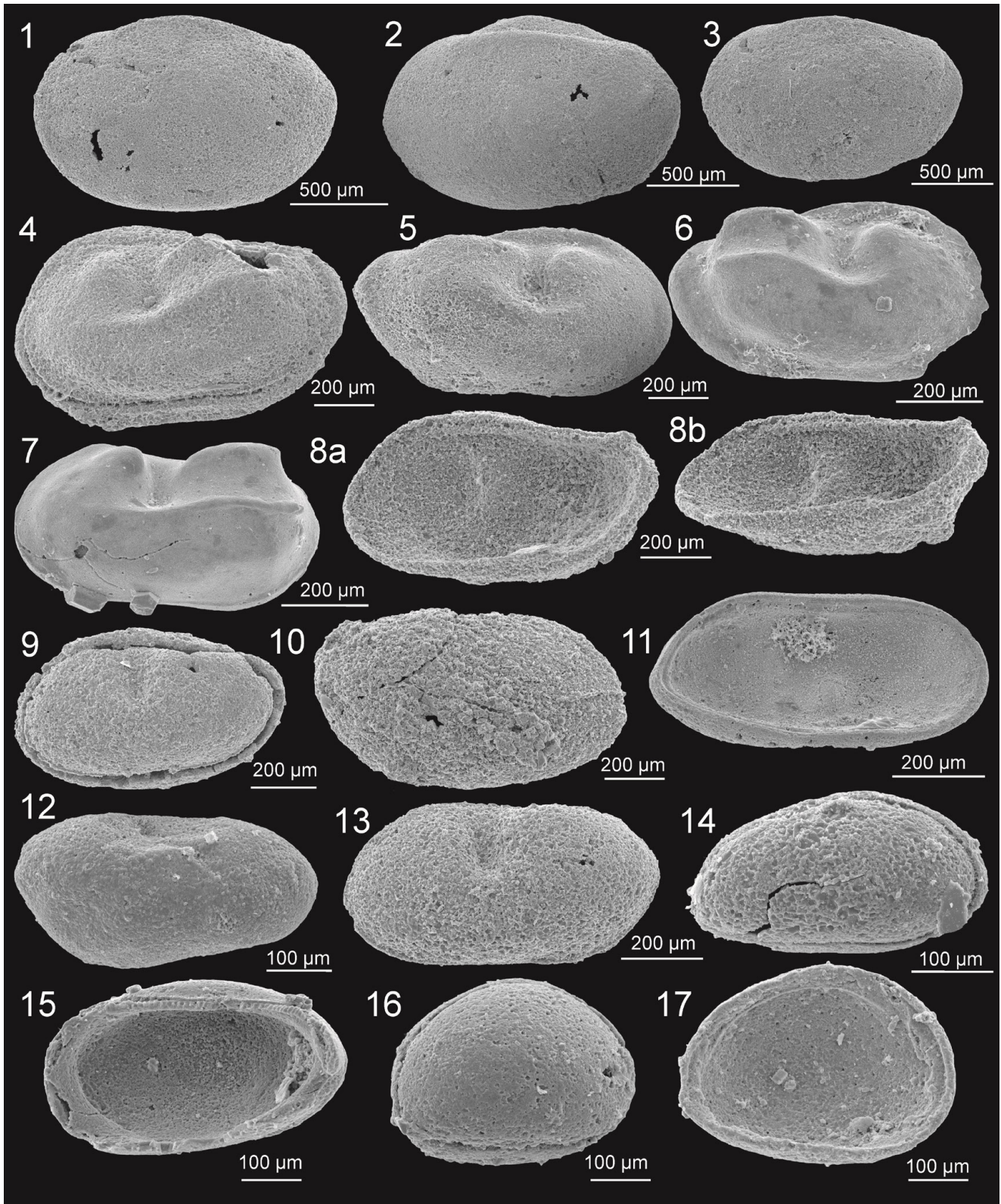


PLATE 1

Soleau & Baud 1998); Oman, Middle Permian (Crasquin-Soleau et al. 1999); Southern Alps, Italy, upper Changhsingian, Upper Permian (Crasquin et al. 2008; Mette & Roozbahani 2012); Sichuan Prov-

ince, China, Middle-Upper Permian (Zazzali et al. 2015); Jadar Block, Upper Permian, Changhsingian, Serbia (Crasquin et al. 2010b); Slovenia (Masore I, sample: B20).

***Sulcella* sp.**

Pl. 1, fig. 13

Material: 2 specimens.

Remarks. In lateral outline *Sulcella* sp. is most similar to *S. langdaiiformis* Kozur, 1985 from the Upper Permian of Hungary (Kozur 1985a).

Occurrence. Slovenia (Masore II, sample: M7).

Order **Podocopida** Müller, 1894Suborder **Sigilliocopina** Martens, 1992

Superfamily Sigillioidea Mandelstam, 1960

Family Microcheilinellidae Gramm, 1975

Genus *Microcheilinella* Geis, 1933***Microcheilinella* cf. *hungarica* Kozur, 1985**

Pl. 1, figs. 14-15

cf. 1985a *Microcheilinella hungarica* Kozur: p. 95, pl. 19, fig. 7.**Material:** 8 specimens.

Occurrence. Bükk Mountains, Hungary, Middle-Upper Permian (Kozur 1985a, b); Slovenia (Masore II, samples: M19/6, M23; Masore I, samples: B16, B12).

Suborder **Bairdiocopina** Gründel, 1967

Superfamily Bairdiocypridoidea Shaver, 1961

Family Bairdiocyprididae Shaver, 1961

Genus *Praepilatina* Polenova, 1970***Praepilatina minuta* Kozur, 1985**

Pl. 1, figs. 16-17

1985a *Praepilatina minuta* Kozur: p. 93, pl. 22, figs. 5-7.**Material:** 4 specimens.

Remarks. Kozur (1985a) distinguished two subspecies: *P. minuta minuta* and *P. minuta subtriangularis*. The specimens from Slovenia are more similar to *P. minuta minuta* which is more symmetrical in outline than *P. minuta subtriangularis*. The specimens from the Bellerophon Formation are very similar in lateral outline to several species from the Upper Permian assigned to *Basslerella* [e.g. *Basslerella jadarensis* Crasquin, 2010 from the Upper Permian of Jadar Block, NW

Serbia (Crasquin et al. 2010b); *Basslerella tota* Chen & Bao, 1986 illustrated from Upper Permian of Fujian Province, China (Yi 2004)]. However, species of *Basslerella* are characterised by a crenulated hinge structure and narrow inner lamella (Kellett 1935; Becker 2001, fig. 2:10), which is usually not visible in most of the species. *P. minuta minuta* from the Hungary has a simple hinge structure as in the genus *Praepilatina*. In specimens from Slovenia, hinge structure is poorly visible. It also resembles *Pseudobythocypris*? sp. from the Upper Permian of Israel with regard to carapace shape and size (Hoenigstein et al. 2006).

Occurrence. Bükk Mountains, Wuchiapingian, Upper Permian (Kozur 1985a, b); Slovenia (Masore II, samples: M19/4; Masore I, samples: B13, B12).

Superfamily Bairdioidea Sars, 1886

Family Bairdiidae Sars, 1887

Genus *Bairdia* McCoy, 1844***Bairdia deducta* Zálányi, 1974**

Pl. 2, figs. 1-3

1985b *Cryptobairdia deducta* (Zálányi); Kozur: p. 234, pl. 6 fig. 2.**Material:** 16 specimens.

PLATE 2

Figs. 1-18 - Ostracods from the Bellerophon Formation of the Masore I (Bende) and Masore II (Mlakar) sections, Changhsingian, Upper Permian;

Figs. 19-21 - Ostracods from the Permian-Triassic transitional beds, Masore I (Bende) section. 1-3) *Bairdia deducta* Zálányi, 1974, 1: carapace in right lateral view (B22-4194), 2: left valve in internal view (B22-4194), 3: right valve in internal view (B22-4194). 4) *Bairdia* sp. 1, carapace in right lateral view (M8-4207). 5) *Bairdia* sp. 2, left valve in internal view (M23-4222). 6-9) *Bairdiocypris* sp., 6: carapace in right lateral view; 7: left valve in internal view; 8: right valve in internal view; 9: left valve in internal view (B12-4184). 10-12) *Bairdiocypris*? sp., 10: left valve in lateral view; 11: left valve in internal view; 12: left valve in internal view (B22-4194). 13-16) *Paramacrocypris schallreuteri* Kozur, 1985, 13-14: carapace in right lateral view; 15: left valve in internal view; 16: left valve in lateral view (B22-4194). 17) *Praezabythocypris* sp., carapace in left lateral view (B22-4194). 18) *Acratia* sp., carapace in right lateral view (M19/4-4361). 19) *Bairdiocypris*? indet., mold in right lateral view (T4/2-4334). 20) *Cavellina*? sp., mold in right lateral view (T4/2-4334). 21) *Triassocypris*? sp., mold in left lateral view (T4/2-4334).

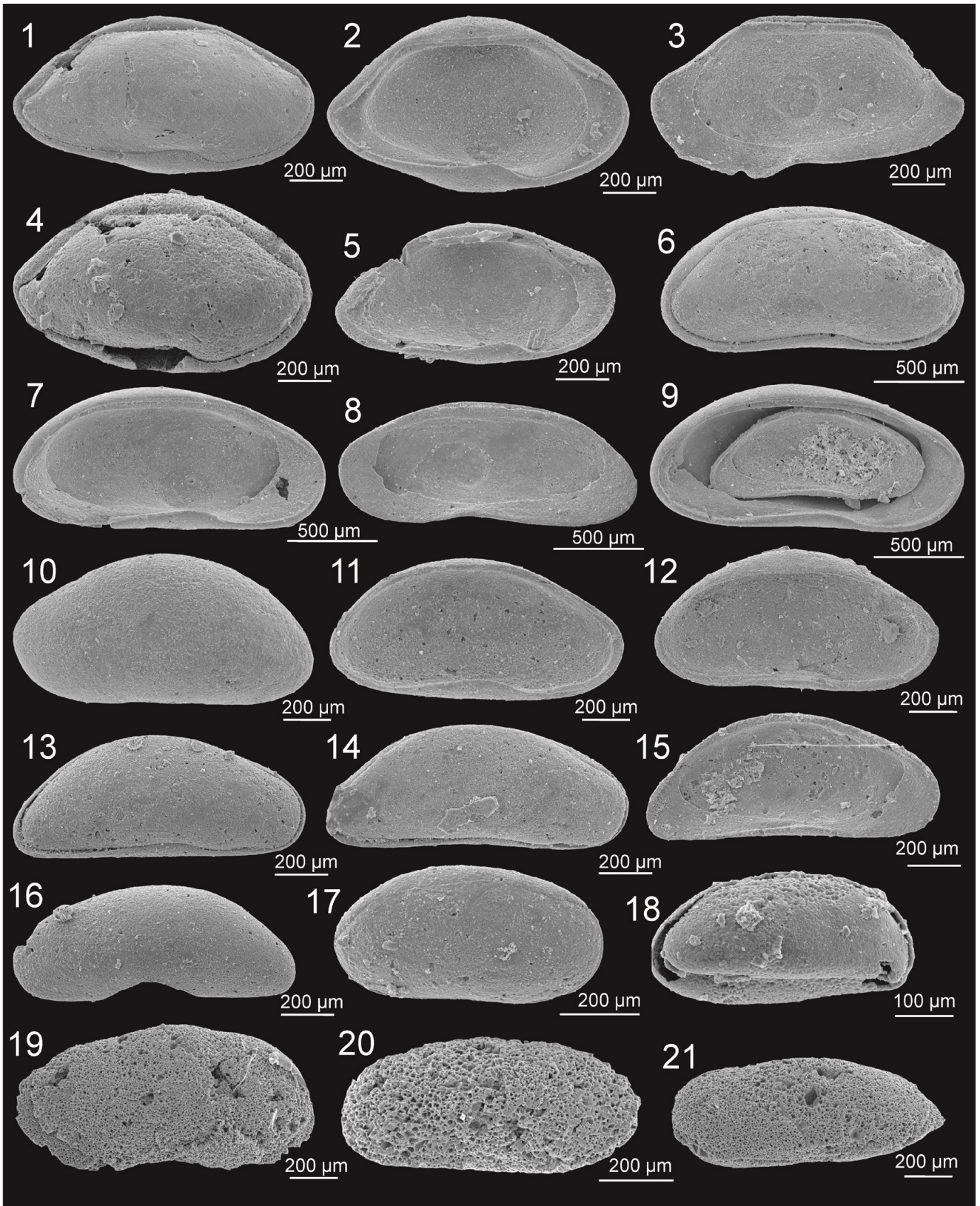


PLATE 2

Remarks. The recovered specimens are similar to *Bairdia cheni* Crasquin, 2008 from Italy (Crasquin et al.

2008) and also to *Bairdia subhassi* Belousova, 1965 from the Upper Permian of Azerbaijan (Belousova 1965).

Occurrence. Bükk Mountains, Hungary, Upper Permian (Kozur 1985b), Slovenia (Masore II, samples: M19/4, M19/6, M23; Masore I, sample: B22).

Genus *Bairdiacypris* Bradfield, 1935

***Bairdiacypris* sp.**

Pl. 2, figs. 6-9

Material: 3 specimens.

Description. Left valve overlaps all margins. The overreach is widest along dorsum. The ventral margin of LV is slightly concave in its median part, and the greatest length is located below the mid-height.

Remarks. These specimens are similar to *Bairdiacypris anisica* Kozur, 1971 from the Triassic of Hungary and to *B. ventralis* Chen, 1982 (Crasquin & Baud 1998).

Occurrence. Slovenia (Masore I, samples: B22, B12).

***Bairdiacypris?* sp.**

Pl. 2, figs. 10-12

Remarks. Although the inner lamella and adductor muscle scar are not preserved at the illustrated valves, the present material is questionably referred to *Bairdiacypris*, due to the shape of the specimens. *Bairdiacypris* was defined as having well developed duplicature.

Occurrence. Slovenia (Masore, samples M7, M17, M19/4, B22).

***Bairdiacypris?* indet.**

Pl. 2, fig. 19

Material: 2 specimens.

Occurrence. Slovenia, Permian-Triassic boundary strata (Masore I, sample: T4/2).

Genus *Paramacrocypris* Kozur, 1985

***Paramacrocypris schallreuteri* Kozur, 1985**

Pl. 2, figs. 13-16

1985 *Paramacrocypris schallreuteri* Kozur: p. 109, pl. 21, fig. 9.

2008 *Paramacrocypris schallreuteri* Kozur; Crasquin et al.: p. 249, pl. 4, figs. 13-14.

2010b *Paramacrocypris schallreuteri* Kozur; Crasquin et al.: pl. 1, fig. 31.

Material: 3 specimens.

Remarks. The present material is similar to *Paramacrocypris* sp. 1 sensu Mette (2010) from the Upper Permian of Iran (Mette 2010) but differs slightly in having larger overlap of the LV. The presence of wide duplicature similar to that in *Bairdiacypris* species suggests its assignment to Bairdiacypridae.

Occurrence. Bükk Mountains, Hungary, Wuchiapingian (Dzulfian), lower part of the Upper Permian (Kozur 1985a); Bellerophon Fm, upper Changhsingian, Upper Permian, Southern Alps, northern Italy (Crasquin et al. 2008); Upper Permian, Changhsingian, Jadar Block, NW Serbia (Crasquin et al. 2010b), Slovenia (Masore I, sample: B22).

Genus *Praezabythocypris* Kozur, 1985

***Praezabythocypris* sp.**

Pl. 2, fig. 17

Material: 2 specimens.

Remarks. This species is similar to *Praezabythocypris pulchra* Kozur, 1985 from the Upper Permian of Hungary, but differs in having a slightly more elongate carapace. It is also similar to *Praezabythocypris* sp. 2 described from lowermost Triassic of Iran (Mette 2010) but differs in the lack of pustulose ornamentation.

Occurrence. Slovenia (Masore I, sample: B22).

Family Acratidae Gründel, 1963

Genus *Acratia* Delo, 1930

***Acratia* sp.**

Pl. 2, fig. 18

Material: 3 specimens.

Remarks. The specimens are similar to *Acratia* sp. B sensu orel et al. (2013) from the Upper Permian of Hungary (Forel et al. 2013).

Occurrence. Slovenia (Masore II, sample: M19/4).

Genus *Triassocypris* Kozur, 1970

***Triassocypris?* sp.**

Pl. 2, fig. 21

Material: 2 specimens.

Remarks. The poorly preserved specimens from the Permian-Triassic boundary strata of Masore differ from the type species *Triassocypris pusilla* (Kozur, 1968) in posterior acumination at mid-height. It is most similar to *Triassocypris* sp. sensu Gerry et al. (1987) and Honigstein et al. (2006) from the Upper Permian of Israel.

Occurrence. Slovenia, Permian-Triassic boundary strata (Masore I, sample: T4/2).

CONCLUSIONS

The ostracods recovered from the uppermost Permian and Permian-Triassic boundary beds of the External Dinarides in Slovenia comprise 13 genera and 20 species of eight families: Paraparchitidae, Serenididae, Indivisiidae, Cavellinidae, Microcheillinellidae, Bairdiocyprididae, Baidiidae, Acratidae, of which 10 species are left in open nomenclature. The ostracod association of the Bellerophon Formation shows a relatively high diversity and abundance, and it corresponds to the “benthonic ostracod Eifelian-Mega assemblage” which is indicative of shallow marine settings. The ostracod association of the Permian-Triassic boundary beds, with *Bairdiocypris?* indet., *Cavellina?* sp., *Triassocypris* sp., records a marked decline in abundance and diversity with only three taxa identified. This paper is the first report of the ostracod associations obtained from the uppermost Permian and Permian-Triassic boundary beds of Slovenia, which are important for the paleoenvironmental reconstruction of the western Paleotethys.

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