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# Ostracods from the ‘Raibl Beds’ (Carnian, Late Triassic) of Belca section in Karavanke Mountains, northwestern Slovenia

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## ABSTRACT

The taxonomy of marine ostracod assemblages from Belca section in the Karavanke Mountains, northwestern Slovenia, is discussed, adding to the scientific understanding of marine ostracods during the Carnian stage, Late Triassic. In Belca, the ostracod assemblages include 39 species, among which two are newly described: *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris? karavankensis* Forel, n. sp. The recovery of abundant juvenile and adult specimens facilitated the illustration and discussion of the ontogenetic series of several typically Triassic species including *Renngartenella sanctaerucis* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973, *Leviella boggschi* Kozur, 1972 and *Leviella veghae* Kozur, 1972. The occurrence of sexual dimorphism is furthermore confirmed for *Renngartenella sanctaerucis*. Ostracods in Belca record a major shift from low diversity and high dominance assemblages at the base of the section to higher diversity and lower dominance with diversification of stable open-marine taxa in the upper part. This pattern might illustrate low salinity levels related to high land-derived input at the base of the section and a return to relatively normal marine salinity in the intermediate sublittoral zone in the upper portion of Belca section.

## KEY WORDS

Ostracods,  
Carnian,  
‘Raibl Beds’,  
Karavanke Mountains,  
Košuta Nappe,  
Slovenia.

## RÉSUMÉ

*Ostracodes des « Couches Raibl » (Carnien, Trias supérieur) de la coupe de Belca dans les Montagnes Karavanke, nord-ouest de la Slovénie.*

La taxinomie des assemblages d'ostracodes marins de la coupe de Belca dans les Montagnes Karavanke, nord-ouest de la Slovénie, est discutée et apporte à la compréhension scientifique des ostracodes marins du Carnien, Trias supérieur. À Belca, les assemblages d'ostracodes incluent 39 espèces, parmi lesquelles deux sont nouvelles : *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris? karavankensis* Forel, n. sp. La présence d'abondants spécimens juvéniles et adultes a facilité l'illustration et la discussion des séries ontogénétiques de plusieurs espèces typiquement triasiques, notamment *Renngartenella sanctaecrucis* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973, *Leviella boggschi* Kozur, 1972 and *Leviella vegiae* Kozur, 1972. L'existence de dimorphisme sexuel est par ailleurs confirmée pour *Renngartenella sanctaecrucis*. Les ostracodes à Belca enregistrent un changement majeur d'assemblages peu diversifiés à forte dominance à la base de la coupe, à des assemblages plus diversifiés, à plus faible dominance voyant la diversification des taxons de milieux marins stables et ouverts dans la partie supérieure. Cette tendance pourrait indiquer une salinité réduite reliée à un influx d'eau douce à la base de la coupe et un retour à une salinité marine normale dans la zone sublittoral intermédiaire dans la partie supérieure de la coupe de Belca.

## MOTS CLÉS

Ostracodes,  
Carnien,  
« Couches Raibl »,  
Montagnes Karavanke,  
Nappe de Košuta,  
Slovénie.

## INTRODUCTION

Following the end-Permian extinction that deeply affected marine organisms, the Carnian stage is one of the most scrutinized interval of the Triassic as it witnessed the most distinctive climate change within the Triassic about 230 Ma (Preto et al. 2010). In shallow marine areas of the western Tethys, this episode is characterized by the demise of early Carnian carbonate platforms and the sudden deposition of coarse siliciclastics (e.g., Simms & Ruffell 1989). It is recognized from deltaic to shallow marine successions of the Dolomites (e.g., Krystyn 1978; Breda et al. 2009) to deep-water settings of the Himalayas and Lagonegro Basin (Hornung et al. 2007a; Rigo et al. 2007). It has been termed ‘Carnian Wet Intermezzo’ in the Germanic Basin, ‘Carnian Pluvial Event’ in northern Europe, “Reingraben turnover” in the Northern Calcareous Alps, or ‘Raibl Event’ in the Italian Dolomites (e.g., Schlager & Schöelnberger 1974; Simms & Ruffell 1989, 1990; Hornung & Brandner 2005; Hornung et al. 2007a, b; Kozur & Bachmann 2010; Dal Corso et al. 2012; Ogg 2015). This event has been attributed to an increase in rainfall and is associated with extinction and biotic turnover (e.g., Simms & Ruffell 1989, 1990; Roghi et al. 2010).

Ostracods are crustaceans of millimeter size, which today inhabit oceans, seas, estuaries, lagoons, lakes, rivers, ponds and springs. They have been entirely marine during the Early Palaeozoic (e.g., Salas et al. 2007; Siveter 2008) and colonized non-marine water bodies during the Carboniferous (e.g., Williams et al. 2006; Bennett 2008; Bennett et al. 2012). The fossil record of ostracods’ carapaces provides information on their evolution, as well as on climatic changes throughout the Phanerozoic. Marine ostracods greatly suffered from the end-Permian crisis about 252 Ma and their recovery is considered complete during the Anisian, Middle Triassic (Crasquin & Forel 2014). However, increasing evidence of the residual presence of Palaeozoic taxa up to the Carnian challenges our current

knowledge on the survival and recovery mechanisms following this major event and revives discussion on the existence of refuge zones and oxygenation levels through this interval (e.g., Forel et al. 2019a).

Carnian marine ostracods have been reported worldwide since the end of the 19<sup>th</sup> century, from Alaska (Sohn 1964, 1987), Austria (Bunza & Kozur 1971; Kristan-Tollmann & Hamedani 1973), Hungary (Méhes 1911; Monostori 1994; Bunza & Kozur 1971; Kristan-Tollmann et al. 1991b; Kozur 1972; Széles 1965; Monostori & Tóth 2014), Iran (Crasquin-Soleau & Teherani 1995), Israel (Sohn 1968; Gerry et al. 1990), Italy (Reuss 1869; Gümbel 1869; Kollmann 1963; Urlich 1970; Kristan-Tollmann & Hamedani 1973); Kristan-Tollmann 1972, 1978; Liebermann 1979; Keim et al. 2001; Kustatscher et al. 2011; Haussmann & Nützel 2015; Crasquin et al. 2018), Jordan (Basha 1982), Slovenia (Kolar-Jurkovšek 1990, 1991), South China (Ye et al. 1977; Forel et al. 2019b) and Turkey (Forel et al. 2018, 2019a). Some of these recent works document the survival of Palaeozoic lineages (Palaeocopida, Beecherellidae, Rectonariidae) in deep-waters (Forel et al. 2019a). In parallel, Mesozoic features are also firstly recorded during the Carnian with the earliest occurrence of some typical Jurassic taxa (Schulerideidae) on the easternmost margin of the Tethys (Forel et al. 2019b) and the oldest evidence of drilling predation on ostracods (Forel et al. 2018). Although several ostracod assemblages witness the degradation of environmental conditions related to the Carnian Humid Episode (e.g., Keim et al. 2001), the influence of the Carnian Pluvial event on marine ostracods is still poorly studied. Furthermore, global- and sub-global-scale Carnian shallow-marine palaeobiogeography is relatively poorly understood, mainly because of the paucity of in-depth modern syntheses.

Ostracods have already been reported and illustrated from the Triassic succession of Slovenia but we provide here the first in-depth taxonomic analysis of Slovenian assemblages during the Carnian. Abundant ostracods are described from five pro-

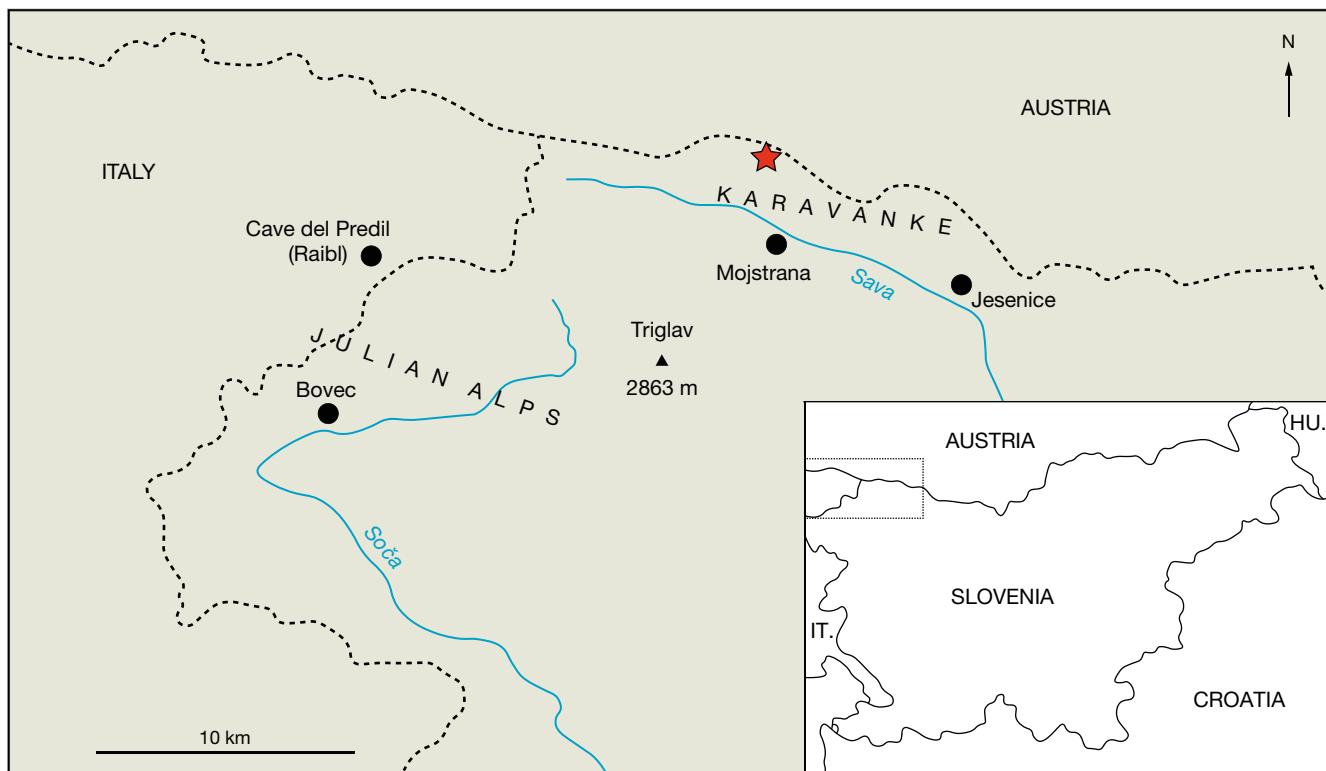


Fig. 1. — Geographical map of the studied area in the southern Karavanke Mountains, northwestern Slovenia. The star shows the position of the Belca section.

ductive samples spanning the Belca section in northwestern Slovenia, which exposes an 85-m thick succession of Carnian age (Kolar-Jurkovšek *et al.* 2005). These assemblages include 39 species (two of which are new: *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris? karavankensis* Forel, n. sp.) distributed into 21 genera. We describe the ontogenetic development of *Issacharella bisulcata*, *Leviella boggschi*, *L. vegiae*, *Rennergartenella sanctaecrucis*, for which sexual dimorphism hypothesized by Monostori (1994) is confirmed. In order to evaluate the representativeness of species richness in assemblages of different sizes and to discuss their palaeoenvironmental implications, we performed a rarefaction analysis as well as calculation of diversity indices (Shannon-Wiener and Simpson). These ostracod assemblages record a major diversity and environmental shift through the Belca section. The low diversity, high dominance (*Rennergartenella sanctaecrucis* and *Issacharella bisulcata*) as well as sedimentary features might indicate high land-derived inputs associated with low salinity levels in the lower part of the Belca section. The upper portion of the section sees the increase of diversity, reduction of dominance, associated with the increase of the abundance and diversity of stable open marine taxa.

#### GEOLOGICAL SETTING AND STUDIED SECTION

Thick Carnian successions are exposed on the southern flank of the Karavanke Mountains in northern Slovenia (Fig. 1). In this area, the ‘Raibl Beds’ are considered as part of the Košuta Nappe (Budkovič 1983, 1999; Buser 1980; Jurkovšek 1987;

Ogorelec *et al.* 1999) or of the Hahnkogel Unit (Krystyn *et al.* 1994; Lein *et al.* 1995), which should be a part of the Košuta Nappe (Fig. 2). The Carnian layers are exposed in the upper part of the Belca valley in the north of Mojstrana close to the Slovenian-Austrian state boundary (Fig. 1).

The Belca section is an 85 m-thick succession of Carnian age which was sampled by the last two authors of this work in 1994 for conodont investigation is positioned in the upper part of the ‘Raibl Beds’ (the coordinates of the section are  $46^{\circ}30'42''\text{N}$ ,  $13^{\circ}55'29''\text{E}$ ). In the Belca valley, the studied ‘Raibl Beds’ develop above the Schlern Dolomite, and are overlain by the dolomite and limestone of the Dachstein Formation in unclear tectonic contact. The ‘Raibl Beds’ principally consist of platy limestone with lenses and cherty nodules. Frequent layers and sheets of marly limestone and marl as well as breccia beds occur between the limestone beds. At the Belca section, an alternation of dark gray limestone and marly limestone with marlstone intercalations occur; thicker marl beds are rare. The limestone is platy to medium bedded and generally has an internally laminated biomicrite texture or is rarely calcarenous or brecciated. Breccia beds occur and are 30 to 40 cm in thickness (Fig. 3).

The most frequent macrofossils are thin valves of the bivalve *Posidonia*, which occur both in marlstone and limestone layers. The valves are generally articulated with the convex side oriented downward, indicative of a relatively quiet sedimentary environment. Plant fossils, dominated by *Voltzia* (Dobruskina *et al.* 2001), and fish remains only occur in the more marl beds of the lower part of the section. Conodont elements of

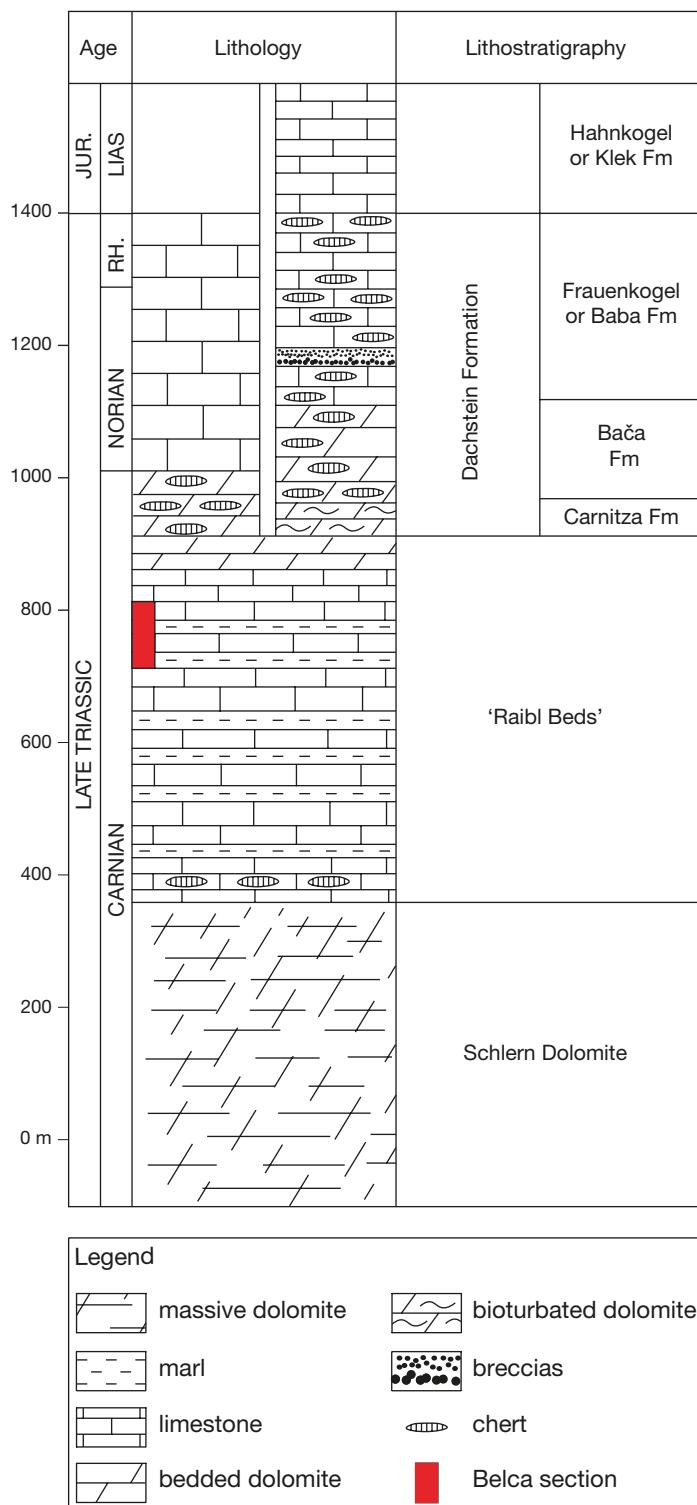


Fig. 2. — Schematic lithostratigraphic column of the Triassic formations in the Kočuta Nappe and in Hahnkogel Unit (modified from Kolar-Jurkovšek et al. 2005).

*Nicoraella?*, sponge spicules, holothurians were also found in the lower part of the section. A few samples from the upper part of the section yielded isolated whorls and segments of thalli of the alga *Clypeina besici* Pantić (Kolar-Jurkovšek & Jurkovšek 2003a, b). The ammonites *Trachyceras aonoides* and *Austrotrachyceras austriacum* have been recovered from

the base of the succession (Jurkovšek 1987). The 'Raibl Beds' carbonates that are well exposed in the Belca section contain involutinid, ammodiscid and endothyrid foraminifera.

The conodont *Nicoraella? budaensis* Kozur & Mock, 1989 confirms the Carnian age of the Belca succession (Kolar-Jurkovšek et al. 2005). In the Slovenian sections this species

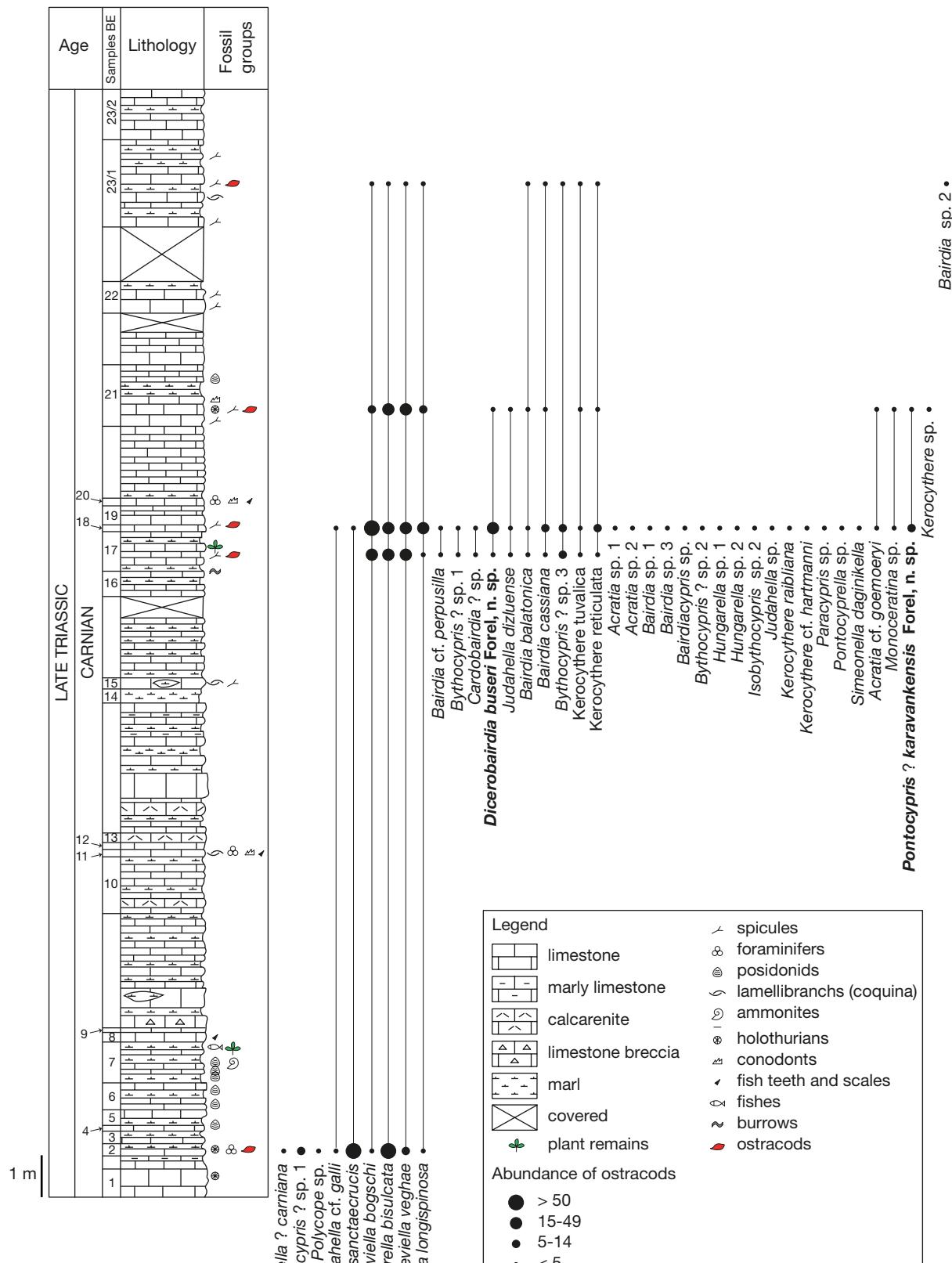


FIG. 3. — Distribution of ostracod species through the Belca section, Karavanke Mountains, northwestern Slovenia.

occurs as monofauna and indicates the stressful conditions of the Carnian Pluvial Event (Kolar-Jurkovšek & Jurkovšek 2010). The geographic distribution of *Nicoraella?* *budaensis* is limited to Central Europe where it is an important regional marker designating the late Julian-?earliest Tuvalian *Nicoraella?* *budaensis* conodont Range Zone (Rigo *et al.* 2018; Kolar-Jurkovšek & Jurkovšek 2019). This Carnian attribution is further confirmed by the dasyclad alga *Clypeina besici* Pantić (Kolar-Jurkovšek & Jurkovšek 2003a, b). The occurrence of the benthic foraminifera *Aulotortus sinuosus*, *A. tumidus*, *Pro-rakusia salaji*, *Pilamminella kuthani* and *Endothyra kuepperi* correspond to the Carnian *Pilamminella kuthani* foraminifer Interval-Zone (Salaj *et al.* 1988; Kolar-Jurkovšek *et al.* 2005).

## MATERIAL AND METHODS

Thirty-eight samples spanning the 85m succession exposed at Belca section were collected in 1994 for conodont investigation (Fig. 3). The samples have been processed by cold acetolysis and five yielded identifiable silicified ostracods: BE2, BE17, BE18, BE21 and BE23/1 (Fig. 3). Thirty-nine species belonging to 21 genera are identified and figured (Figs 4, 6-8, 11). Two species are newly described here: *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris?* *karavankensis* Forel, n. sp.

The growth of ostracods occurs by moulting and ontogenetic stages are labelled A (adult), A-1, A-2, A-3, etc., in order of decreasing size. The ontogeny of podocapid ostracods generally consists of eight juvenile stages and one adult stage (e.g., Horne *et al.* 2002). When plotted, the length and height of the instars gather into separate successive data-point clusters, with gaps separating each cluster from one another. To reconstruct the ontogeny of species in Belca, height/length diagrams have been drawn, where right and left valves of detached and complete carapaces are distinguished; right and left valves of carapaces serve as anchor points for the delimitation of ontogenetic stages (Figs 5, 9, 10, 12, 13). For each species, this method accounts for the difference of size between the valves and its possible variations through the ontogeny. It furthermore permits to constrain the large dispersal of the height/length scatter plots when specimens are plotted without distinction of their nature (left valve, right valve or carapace). When possible, the ontogenetic stages are distinguished and labelled. For several species, specimens are abundant in Belca and probably reflect different successive populations. For this reason, some portions of the ontogenetic development of *Renngartenella sanctaecrucis* and *Issacharella bisulcata* are only described and discussed but are not divided into stages.

## SYSTEMATIC PALAEONTOLOGY (by MBF)

In the present contribution, we follow the general classification of Moore (1961) and Horne *et al.* (2002). The taxonomy of the Cytheroidea is based on the amendments of Whatley & Boomer (2000). Species left in open nomenclature, except for peculiar ones, are omitted. All species are illustrated to allow future comparison and understanding of these unique assemblages (Figs 4, 6-8, 11). For morphological descriptions, we follow Maddocks (2015): the degree of slope of the anterodorsal and posterodorsal borders are measured on external lateral views of the carapaces or valves, with 0 being horizontal. The length convention is as follows: < 0.40 very small, 0.40-0.50 small, 0.50-0.70 medium, 0.70-1.00 large, > 1.00 very large.

All specimens are deposited in the micropalaeontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number.

Class OSTRACODA Latreille, 1802

Order PODOCOPIDA Sars, 1866

Suborder PODOCOPINA Sars, 1866

Superfamily BAIRDIOIDEA Sars, 1887

Family BAIRDIIDAE Sars, 1887

Genus *Bairdia* McCoy, 1844

TYPE SPECIES. — *Bairdia curta* McCoy, 1844 subsequently designated by Ulrich & Bassler (1923).

*Bairdia balatonica* Méhes, 1911

(Fig. 4E)

*Bairdia balatonica* Méhes, 1911: 13, 14, pl. 1, fig. 8-11. — non Széles 1965: 414, fig. 4. — Monostori 1995: 42, pl. 2, fig. 1 only. — ? Monostori 1995: 42, pl. 2, figs 2, 3. — Forel & Crasquin 2011: 252, fig. 5A. — Monostori & Tóth 2013: 309, pl. 2, figs 1-4 only. — ? Monostori & Tóth 2013: 309, pl. 2, fig. 5. — Crasquin *et al.* 2018: 134, 135, fig. 6P.

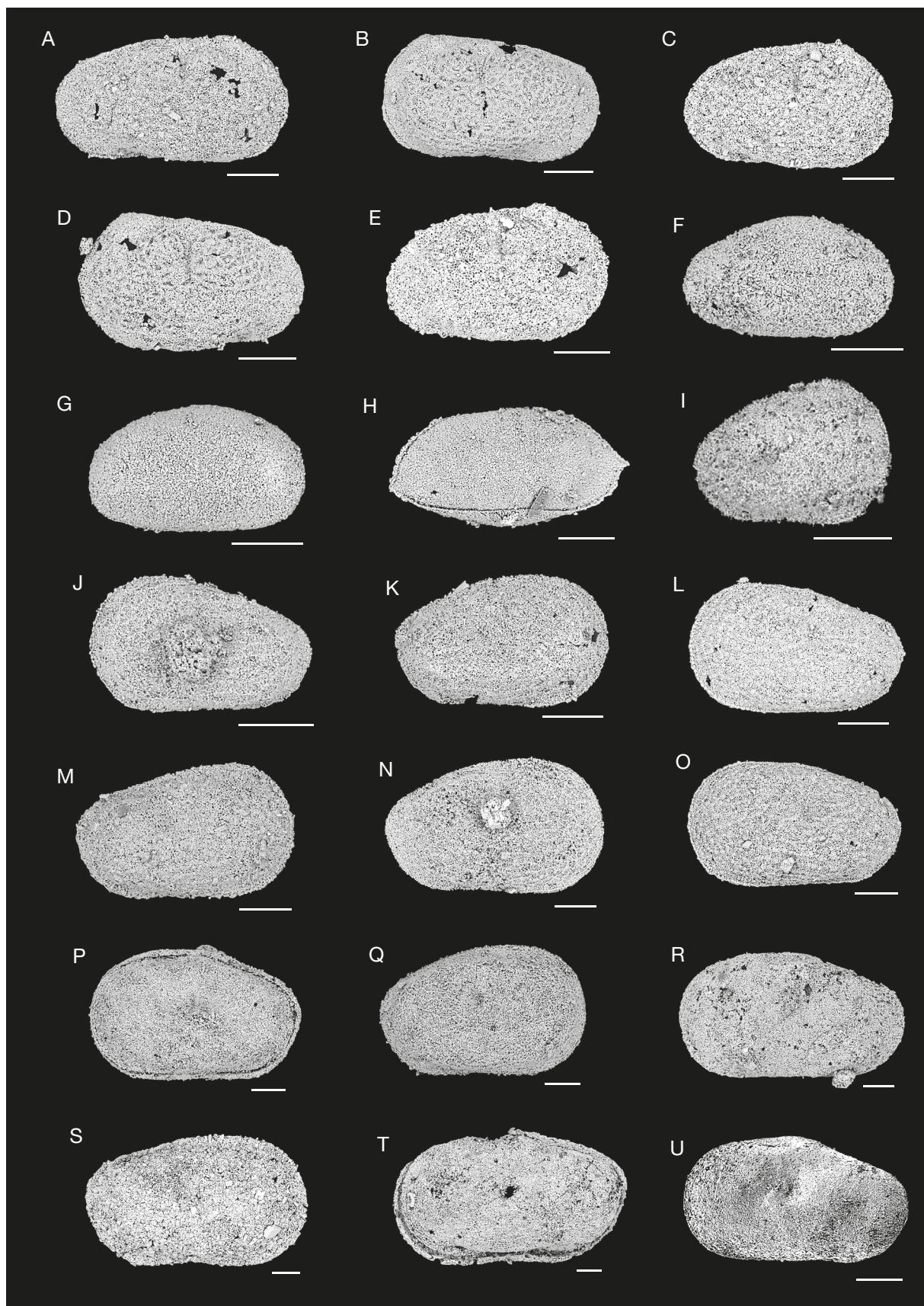
*Bairdia* cf. *balatonica* — Méhes in Kristan-Tollmann 1978: 81, pl. 1, figs 1-3.

*Bairdia dadayi* Méhes, 1911: 17, 18, pl. 1, figs 29, 30. — Széles 1965: 412, 413, fig. 1.

EXAMINED MATERIAL. — One left valve and several fragments.

OCCURRENCE. — Spathian-Anisian, Early-Middle Triassic, South Tibet (Forel & Crasquin 2011); Anisian (Monostori 1995), La-

Fig. 4. — Ostracods from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. All specimens are deposited in the micropalaeontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number: **A, B**, *Acratia* cf. *goemeryi* Kozur, 1970 emend. Forel *et al.* (2019a); **A**, lateral view of a right valve, BE21 (GeoZS6132); **B**, lateral view of a left valve, BE18 (GeoZS6133); **C**, *Acratia* sp. 1, lateral view of a broken left valve, BE18 (GeoZS6134); **D**, *Acratia* sp. 2, lateral view of a left valve, BE18 (GeoZS6135); **E**, *Bairdia balatonica* Méhes, 1911, lateral view of a left valve, BE17 (GeoZS6136); **F-H**, *Bairdia cassiana* (Reuss, 1869); **F**, lateral view of a right valve, BE18 (GeoZS6137); **G**, lateral view of a right valve, BE18 (GeoZS6138); **H**, right lateral view of a complete carapace, BE23/1 (GeoZS6139); **I**, *Bairdia* cf. *perpusilla* sensu Forel *et al.* (2019a), lateral view of a left valve, BE17 (GeoZS6140); **J**, *Bairdia* sp. 1, right lateral view of a complete carapace, BE18 (GeoZS6141); **K**, *Bairdia* sp. 2, lateral view of a right valve, BE23/1 (GeoZS6142); **L, M**, *Bairdia* sp. 3; **L**, lateral view of a left valve, BE18 (GeoZS6143); **M**, lateral view of a left valve, BE18 (GeoZS6144); **N**, *Bairdiacypris* sp. 1, lateral



view of a right valve, BE18 (GeoZS6145); **O–U**, *Dicerobairdia buseri* Forel, n. sp.; **O**, Holotype, lateral view of a left valve, BE18 (GeoZS6146); **P**, right lateral view of a complete carapace, BE21 (GeoZS6147); **Q**, lateral view of a left valve, BE17 (GeoZS6148); **R**, lateral view of a left valve, BE18 (GeoZS6149); **S**, Paratype, lateral view of a right valve, BE18 (GeoZS6150); **T**, lateral view of a right valve, BE18 (GeoZS6151); **U**, lateral view of a left valve, BE18 (GeoZS6152). Scale bars: 100 µm.

dinian (Monostori & Tóth 2013) and early Carnian (Méhes 1911; Széles 1965), Middle-Late Triassic, Balaton Highland, Hungary; early Carnian, Late Triassic, Southern Alps, Italy (Kristan-Tollmann 1978); *Tropites dilleri* zone, late Carnian, Late Triassic, Sicily, Italy (Crasquin et al. 2018); *Nicoraella? budaensis* conodont zone, late Julian-earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 5A.

#### DISCUSSION

This species occurs in samples BE17, 18, 21 and 23/1 of the Belca section but it is not abundant (Fig. 3). *Bairdia balatonica* Méhes, 1911 was described from the early Carnian, Late Triassic, of Hungary (Méhes 1911). Since then, it has been more largely documented and appears as typical of the Spathian-Carnian time interval, spreading from South Tibet (Forel & Crasquin 2011) to Hungary (e.g., Monostori 1995; Monostori & Tóth 2013). *Bairdia balatonica* identified from the early Carnian, Late Triassic, of Hungary by Széles (1965) is excluded because the drawn specimen is very asymmetric laterally and the right valve is uniformly rounded without the anterodorsal and posterodorsal angulations shown on the type material of Méhes (1911). Of the three specimens attributed to *B. balatonica* Méhes, 1911 in Monostori (1995) from the Anisian, Middle Triassic, of Hungary, two have a triangular dorsal overlap (Monostori 1995: pl. 2, figs 2, 3) : the attribution to *B. balatonica* is therefore questioned. One of the five specimens from the Ladinian, Middle Triassic, of Hungary (Monostori & Tóth 2013) is questioned as belonging to *B. balatonica* for the same reason (Monostori & Tóth 2013: pl. 2, fig. 5). These three specimens from the Middle Triassic of Hungary (Monostori 1995; Monostori & Tóth 2013) might represent an undescribed species characterized by its triangular dorsal overlap of left valve over right one. Lastly, Monostori & Tóth (2013) considered that *B. ventriosa* Bolz, 1971 from the late Norian-Rhaetian, Late Triassic, of the Northern Calcareous Alps (Bolz 1971) fit into the variations of the lateral outline of *B. balatonica*. However, the surface of *B. ventriosa* is evenly pitted so that we do not consider this synonymy as relevant.

The dimensions of all Carnian specimens available in the literature that are considered as truly belonging to *B. balatonica* have been plotted in Fig. 5A. The Carnian specimens gather into four scatter plots, which might correspond to the ontogenetic stages A-3 to Adult. However, each of the identified group correspond to one specimen from one locality: for this reason and until more material is made available, we choose not to attribute precise ontogenetic stages to these groups. For the Carnian stage, the largest specimens are reported from Italy (Kristan-Tollmann 1978). The development of *B. balatonica* is marked by the elongation of the valves, from plump and short posteriorly for the smaller specimen shown in Crasquin et al. (2018), to more elongate with dorsal angulations, slightly caudate posterior border and more pronounced posterodorsal concavity in the largest materiel illustrated by Kristan-Tollmann (1978).

#### *Bairdia cassiana* (Reuss, 1869) (Fig. 4F-H)

*Cythere cassiana* Reuss, 1869: 108.

*Bairdia cassiana* — Gümbel 1869: 180, pl. 5, figs 18, 19. — Styk 1958: 171, fig. 3/1. — Urlichs 1970: 705, 706, pl. 1, figs 1, 2. — Kristan-Tollmann 1978: 81, pl. 1, fig. 4; pl. 6, fig. 6. — Kristan-Tollmann et al. 1991b: 200, pl. 1, fig. 5. — Monostori & Tóth 2013: 310, pl. 2, figs 7, 8, 10; 2014: 26, pl. 1, fig. 14. — Mette et al. 2014: pl. 2, fig. 1. — Crasquin et al. 2018: 134, fig. 6M.

*Bairdia cassiana rotundidorsata* Monostori, 1995: 42, pl. 2, figs 4, 5.

*Bairdia (Rectobairdia) garciai* Crasquin-Soleau & Grădinaru, 1996: 77, 78, pl. 2, figs 5, 8.

EXAMINED MATERIAL. — Four right valves, four left valves and several fragments.

OCCURRENCE. — Early Carnian, Late Triassic, Southern Alps, Italy (Reuss 1869; Gümbel 1869; Urlichs 1970; Kristan-Tollmann 1978); Carnian, Late Triassic, Święty Krzyż Mountain, Poland (Styk 1958); Carnian, Late Triassic, Zsámbe-k-14 borehole, Transdanubian Range, Hungary (Kristan-Tollmann et al. 1991b); Late Anisian, Middle Triassic, Balaton Highland, Hungary (Monostori 1995); Early Anisian, Middle Triassic, North Dobrogea, Romania (Crasquin-Soleau & Grădinaru 1996); Ladinian, Middle Triassic, Balaton Highland, Hungary (Monostori & Tóth 2013, 2014); Middle Anisian, Middle Triassic, Northern Calcareous Alps, Austria (Mette et al. 2014); *Tropites dilleri* zone, late Carnian, Late Triassic, Sicily, Italy (Crasquin et al. 2018); *Nicoraella? budaensis* conodont zone, late Julian-earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 5B.

#### DISCUSSION

*Bairdia cassiana* (Reuss, 1869) has been found in all samples from BE17 to BE23/1 where it is not abundant, and it is moderately abundant in BE18 (Fig. 3). *Bairdia cassiana* is typical of the Middle and early Late Triassic of Europe, as shown by the synonym list. The height/length scatter plot of all Carnian specimens is shown in Fig. 5B (the dimensions of the specimens cited without mention of their nature, i.e. right valve, left valve or carapace, have been omitted). The largest specimens are from the Ladinian of Hungary (Monostori & Tóth 2013, 2014). The separate measurements of right and left valves of complete carapaces show that the degree of overlap is relatively constant during the ontogeny of this species. The left valve is slightly longer than the right valve in the first instars compared to later stages. The ontogenetic development of *B. cassiana* is also marked by the elongation of the posterior border.

#### Genus *Dicerobairdia* Kollmann, 1963

TYPE SPECIES. — *Dicerobairdia bicornuta* Kollmann, 1963 by original designation.

#### *Dicerobairdia buseri* Forel, n. sp. (Fig. 4O-U)

urn:lsid:zoobank.org:act:6B59784E-073E-4D76-8C70-B3706E500C8A

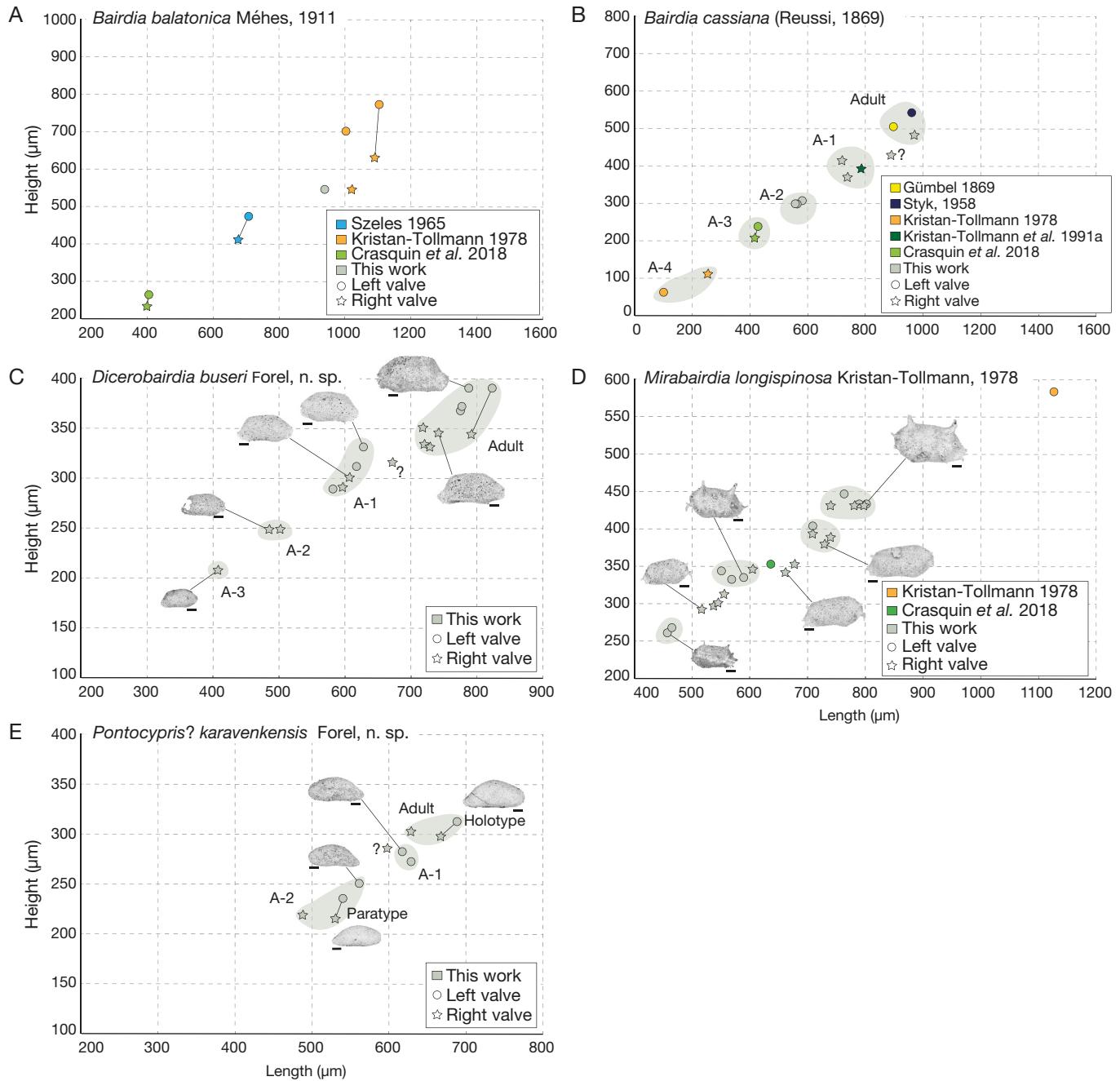


Fig. 5. — Height/Length scatter plots of species recovered from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. In all diagrams, the dimensions of right and left valves of complete carapaces are linked. **A**, *Bairdia balatonica* Méhes, 1911; **B**, *Bairdia cassiana* (Reuss, 1869); **C**, *Dicerobairdia buseri* Forel, n. sp., all specimens are from the Belca section (this work); **D**, *Mirabairdia longispinosa* Kristan-Tollmann, 1978; **E**, *Pontocypris?* *karavankensis* Forel, n. sp. all specimens are from the Belca section (this work). Scale bars: 100 µm.

TYPE MATERIAL. — Holotype: left valve (Fig. 4O), BE18 (GeoZS6146). — Paratype: right valve (Fig. 4S), BE18 (GeoZS6150).

EXAMINED MATERIAL. — One carapace, nine left valves, ten right valves and several fragments.

DERIVATION OF NAME. — In honour of Prof. Dr. Stanko Buser (University of Ljubljana, Slovenia) for his outstanding contribution to the knowledge of the Slovenian geology.

OCCURRENCE. — *Nicoraella?* *budaensis* conodont zone, late Julian? earliest Tuvanian, Carnian, Late Triassic, samples BE2, 17, 18, 21 (Fig. 3), Belca section, 'Raibl Beds', Karavanke Mountains, Slovenia (this work).

DIAGNOSIS. — A new species with reticulate lateral surface and poorly expressed dorso-lateral ornaments.

DIMENSIONS. — Fig. 5C.

#### DESCRIPTION

A large and relatively thick-shelled species with subrectangular outline in lateral view; greatest height located at the anterodorsal angulation at both valves, greatest length below mid-height; dorsal margin tripartite at both valves with anterodorsal angulation c. 30° and posterodorsal angulation

*c.* 55°; anterodorsal border straight and long (from *c.* 28% of maximum of length in adult forms, Fig. 4Q, to *c.* 32% in younger instars, Fig. 4T); dorsal border long and straight to gently convex (from *c.* 49% of maximum of length in adult forms, Fig. 4Q, to *c.* 53% in younger instars, Fig. 4T); postero-dorsal border steep and relatively short (*c.* 20% of maximum of length in adult and younger forms), close to straight in the youngest form, with a terminal concavity that accentuates through ontogeny; ventral border long (from *c.* 57% of maximum of length in adults, Fig. 4Q, to *c.* 48% in younger instars, Fig. 4T), with oral concavity located in anterior part; posteroventral border about  $\frac{1}{3}$ rd of maximum of height, very convex and bordered with marginal denticles visible at well preserved specimens (e.g., Fig. 4Q, R, U); anteroventral border longer than posteroventral border, gently convex and flanged by marginal denticles visible at well preserved specimens; anterior maximum of curvature large and located around to slightly below mid-height; posterior maximum of convexity narrower, located below  $\frac{1}{3}$ rd of maximum of height; anterodorsal, dorsal, posterodorsal and posteroventral borders and upper part of anteroventral border laterally compressed; anterior margin bordered by a large and low ridge in lower  $\frac{2}{3}$ rd, which then runs perpendicular to it and parallel to ventral margin, ending at the laterally compressed posteroventral area; two small elongate and reduced horns are built parallel to anterodorsal and posterodorsal borders at both valves; lateral surface evenly reticulate, with preferential longitudinal organisation of the reticulation visible at some specimens.

## DISCUSSION

*Dicerobairdia buseri* Forel, n. sp. occurs from samples BE17 to BE21 in the Belca section, and it is relatively abundant in BE18 (Fig. 3). *Dicerobairdia buseri* Forel, n. sp. differs from *D. torulosa* Kristan-Tollmann, 1970 from the late Ladinian, Middle Triassic, of Dolomites, Italy (Kristan-Tollmann 1970) by lacking the small ventrolateral ridges at both valves and by the stronger development of the sub-anterodorsal and sub-posterodorsal horns at adult stage. The new species also differs from *D. acornuta* Kristan-Tollmann, 1978 from the early Carnian, Late Triassic, of Dolomites, Italy (Kristan-Tollmann 1978) by its subdorsal ornamentation at the right valve, which consists of sub-anterodorsal and sub-posterodorsal reduced horns rather than a continuous subdorsal ridge. At the left valve, the dorsal ornamentation of *D. buseri* Forel, n. sp. differs in being sub-anterodorsal and sub-posterodorsal elongate horns rather than a continuous ridge as in *D. acornuta*. *Dicerobairdia buseri* Forel, n. sp. also shows secondary reticulation all over the lateral surface whereas *D. acornuta* is micromammillate.

The specimens of *Dicerobairdia buseri* Forel, n. sp. from Belca section are distributed into at least four ontogenetic stages, from A-3 to Adult in ascending order (Fig. 5C). Noteworthy, left valves only occur in A-1 and Adult stages, while A-3 and A-2 stages are only known by right valves. The ontogenetic development of *D. buseri* Forel, n. sp. is marked by an overall increase in the length of the ventral border. The development from A-3 to A-1 is dominated by the increase of the dimensions. The transition from A-1 to Adult records the enhancement of the ventral ridge and the terminal concavity at posterodorsal border.

## Genus *Mirabairdia* Kollmann, 1963

TYPE SPECIES. — *Mirabairdia pernodosa* Kollmann, 1963 by original designation.

### *Mirabairdia longispinosa* Kristan-Tollmann, 1978 (Fig. 6E-H)

*Mirabairdia longispinosa* Kristan-Tollmann, 1978: 94-96, pl. 3, figs 1-3; pl. 7, fig. 5. — Forel et al. 2018: 10, figs 4-20, 4-21.

EXAMINED MATERIAL. — Eleven left valves, 18 right valves and several fragments.

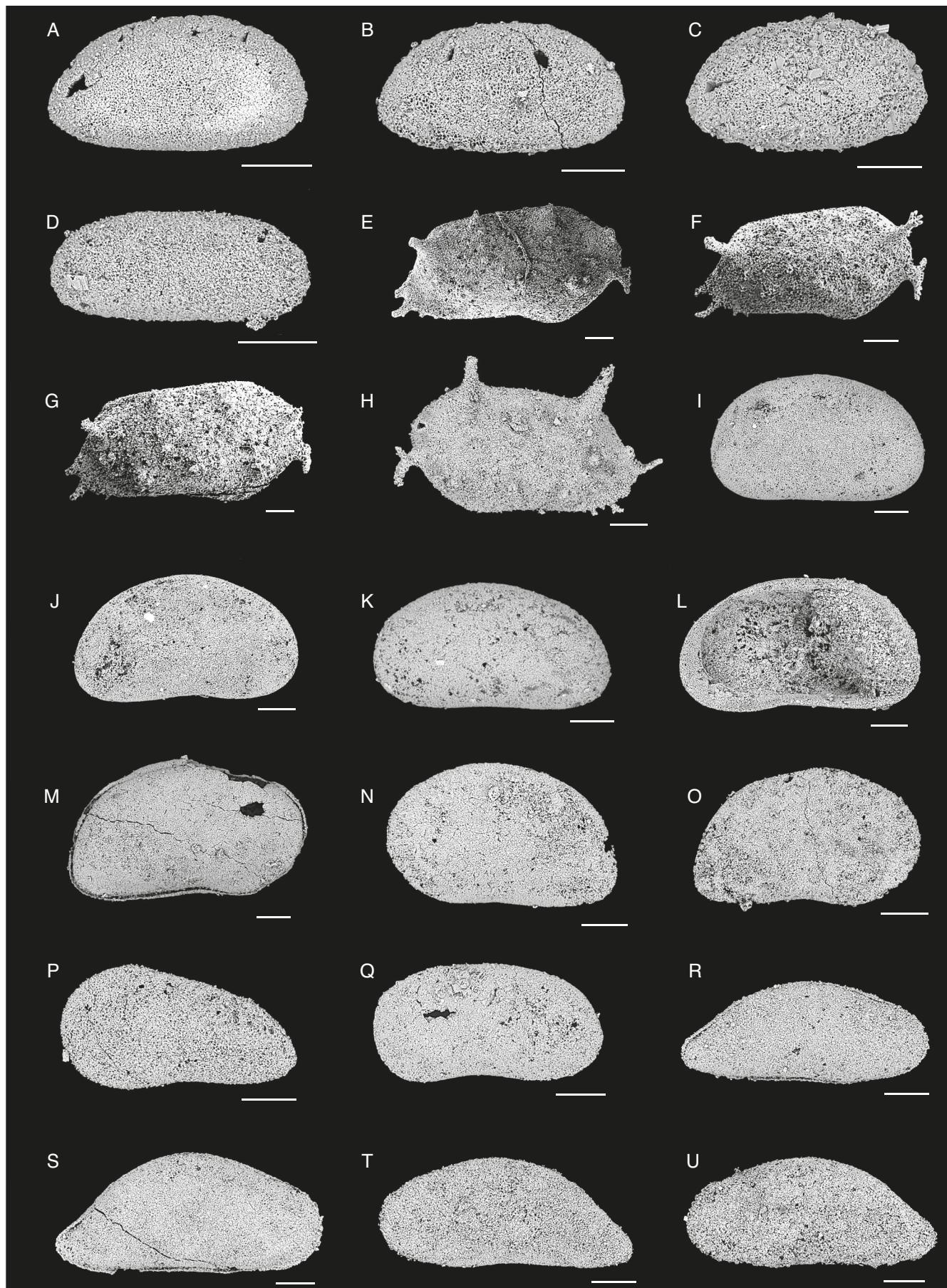
OCCURRENCE. — Cordovelian, early Carnian, Late Triassic, Ruones-Wiesen, Pralongia, Dolomites, Italy (Kristan-Tollmann 1978); *Spongotorilispinus moixi* radiolarian Zone, early Tuvalian, late Carnian, Late Triassic, Tavşayırı Block, Sorgun Ophiolitic Mélange, southern Turkey, Hügül Tuffite (Forel et al. 2018); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE2, 17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 5D.

## DISCUSSION

*Mirabairdia longispinosa* Kristan-Tollmann, 1978 has been found in all samples of the Belca section where is not abundant except in sample BE18 (Fig. 3). In the current state of our knowledge, this species is restricted to the Carnian of the western tethyan realm. The present record is the third known occurrence of *M. longispinosa* worldwide: it was described from the Cordovelian, early Carnian, Late Triassic, of Italy (Kristan-Tollmann 1978), and was more recently documented from the Tuvalian, late Carnian, Late Triassic, of Turkey (Forel et al. 2018). The present assemblage is unique in providing numerous specimens, making it possible to discuss the ontogenetic development of this species

Fig. 6. — Ostracods from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. All specimens are deposited in the micropalaeontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number: **A-C**, *Isobithocypris?* sp. 1; **A**, lateral view of a right valve, BE2 (GeoZS6153); **B**, lateral view of a right valve, BE2 (GeoZS6154); **C**, lateral view of a right valve, BE2 (GeoZS6155); **D**, *Isobithocypris* sp. 2, lateral view of a right valve, BE18 (GeoZS6156); **E-H**, *Mirabairdia longispinosa* Kristan-Tollmann, 1978; **E**, lateral view of a right valve, BE21 (GeoZS6157); **F**, lateral view of a right valve, BE18 (GeoZS6158); **G**, lateral view of a right valve, BE18 (GeoZS6159); **H**, lateral view of a left valve, BE17 (GeoZS6160); **I**, *Bythocypris?* sp. 1, lateral view of a right valve, BE18 (GeoZS6161); **J-L**, *Bythocypris?* sp. 2; **J**, lateral view of a right valve, BE18 (GeoZS6162); **K**, lateral view of a left valve, BE18 (GeoZS6163); **L**, internal view of a right valve, BE18 (GeoZS6164); **M-O**, *Bythocypris?* sp. 3; **M**, right lateral view of a complete carapace, BE17 (GeoZS6165); **N**, lateral view of a left valve, BE18 (GeoZS6166); **O**, lateral view of a right valve, BE18 (GeoZS6167); **P**, *Paracypris* sp., lateral view of a left valve, BE18 (GeoZS6168); **Q**, *Pontocyprilla* sp., lateral view of a left valve, BE18 (GeoZS6169); **R-U**, *Pontocypris?* karavankensis Forel, n. sp.; **R**, Paratype, right lateral view of a complete carapace, BE18 (GeoZS6170); **S**, Holotype, right lateral view of a complete carapace, BE18 (GeoZS6171); **T**, lateral view of a left valve, BE18 (GeoZS6172); **U**, lateral view of a left valve, BE18 (GeoZS6173). Scale bars: 100 µm.



(Fig. 5D). It first appears that the holotype of *M. longispinosa* (left valve; Kristan-Tollmann 1978) is larger than all other known specimens. Therefore, if the holotype is assumed adult, then all specimens recovered from the Carnian layers of Belca and Turkey should be juveniles. However, until inner structures are available for this species, this hypothesis is difficult to confirm. Because of the important size gap between the holotype and the largest specimens in Belca, which is 800 µm in length, we decide not to attribute the successive scatter-points observable in Fig. 5D to any given ontogenetic stage. We rather discuss the successive ontogenetic groups relatively to the surrounding ones, without assuming precisely the stage they might correspond to. The right and left valves obtained in Belca gather into four successive scatter plots (Fig. 5D). The ontogeny of *M. longispinosa* is marked by the strengthening of the lateral sculpture of the valves, with short and frail spines in the smallest left valve developing into robust and thick spines in the largest left valve (Fig. 5D). As a rule, the left valves are more rounded and plump than the more elongate right valves: this pattern is observed quite early in the development of the species, although the smallest specimens are here only represented by left valves.

Superfamily CYPRIDOIDEA Baird, 1845  
Family PONTOCYPRIDIDAE Müller, 1894

Genus *Pontocypris* Sars, 1866

TYPE SPECIES. — *Cythere (Bairdia) mytiloides* Norman, 1862 subsequently designated by Brady & Norman (1889).

*Pontocypris?* *karavankensis* Forel, n. sp.  
(Figs 6R-U; 7A)

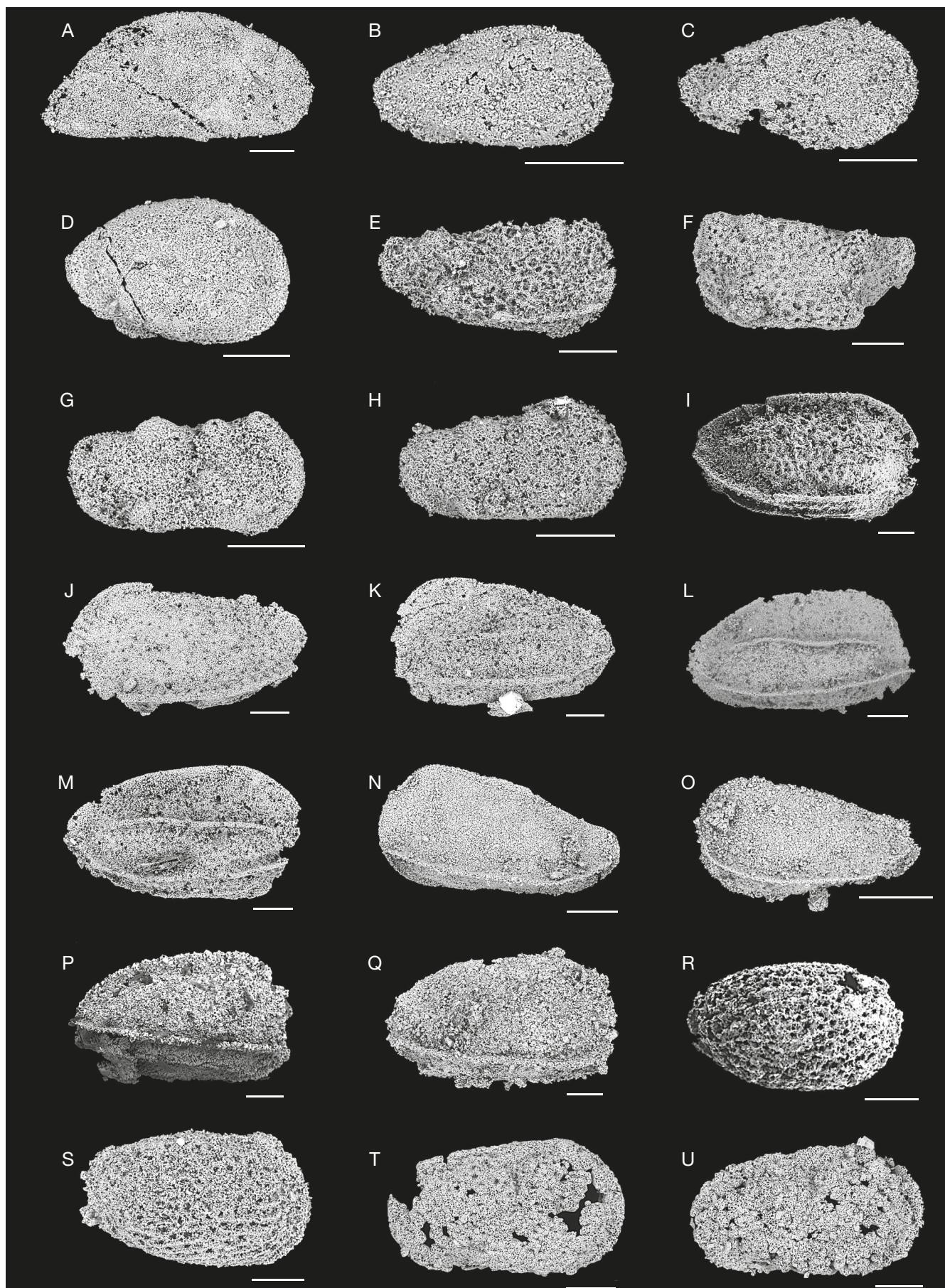
[urn:lsid:zoobank.org:act:A5970888-0E6E-439B-84A0-40555CF417F0](https://lsid.zoobank.org/act:A5970888-0E6E-439B-84A0-40555CF417F0)

TYPE MATERIAL. — Holotype: complete carapace (Fig. 6S), BE18 (GeoZS6171). — Paratype: complete carapace (Fig. 6R), BE18 (GeoZS6170).

EXAMINED MATERIAL. — Three right valves, three left valves and two complete carapaces.

DERIVATION OF NAME. — The specific epithet refers to the Karavanke Mountains in Slovenia, where is located the Belca section, type locality of the species.

Fig. 7. — Ostracods from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. All specimens are deposited in the micropalaeontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number: **A**, *Pontocypris?* *karavankensis* Forel, n. sp., lateral view of a right valve, BE18 (GeoZS6174); **B**, **C**, *Monoceratina* sp.; **B**, lateral view of a right valve, BE21 (GeoZS6175); **C**, lateral view of a right valve, BE18 (GeoZS6176); **D**, *Citrella?* *carniana* Forel in Forel et al. 2019, lateral view of a right valve, BE18 (GeoZS6174); **E**, **F**, *Judahella dizluense* Kristan-Tollmann, 1980; **E**, lateral view of a right valve, BE18 (GeoZS6178); **F**, lateral view of a left valve, BE21 (GeoZS6179); **G**, *Judahella cf. galli* Kozur & Bolz in Bunza & Kozur, 1971, lateral view of a right valve, BE18 (GeoZS6180); **H**, *Judahella* sp., lateral view of a right valve, BE18 (GeoZS6181); **I**, *Kerocythere* cf. *hartmanni* Bolz & Kozur in Bunza & Kozur, 1971, lateral view of a right valve, BE18 (GeoZS6182); **J**, *Kerocythere raiblana* (Gümbel, 1869), lateral view of a left valve, BE18 (GeoZS6183); **K-M**, *Kerocythere reticulata* Kristan-Tollmann, 1972; **K**, lateral view of a left valve, BE18 (GeoZS6184); **L**, lateral view of a right valve, BE18 (GeoZS6185); **M**, lateral view of a right valve, BE18 (GeoZS6186); **N**, **O**, *Kerocythere tuvalica* Kozur, 1971; **N**, lateral view of a left valve, BE17 (GeoZS6187); **O**, lateral view of a left valve, BE21 (GeoZS6188); **P**, **Q**, *Kerocythere* sp. 1; **P**, lateral view of a right valve, BE21 (GeoZS6189); **Q**, lateral view of a right valve, BE21 (GeoZS6190); **R**, **S**, *Simeonella daginikella* Forel in Forel et al. 2019; **R**, lateral view of a right valve, BE18 (GeoZS6191); **S**, lateral view of a right valve, BE18 (GeoZS6192); **T**, **U**, *Renngartnerella sanctaerucis* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973; **T**, lateral view of a right valve, A-1, BE2 (GeoZS6193); **U**, lateral view of a right valve, A-1, BE2 (GeoZS6194). Scale bars: 100 µm.



more tapered and less elongate posterior end, terminal postero-dorsal concavity and posterior border slightly pointed upward. The size dispersal shown in Fig. 5E indicates the presence of several ontogenetic stages. Owing to the size difference of the right and left valves of *P? karavankensis* Forel, n. sp., at least three ontogenetic stages are recognized, A-2 to Adult. The ontogenetic development of this species is mainly characterized by the strengthening of the lateral asymmetry of the valves, the increase of the maximum of height, enlargement of anterior margin and posterior border becoming pointed upward.

Superfamily CYTHEROIDEA Baird, 1850  
Family CYTHERURIDAE Müller, 1894

Genus *Citrella* Oertli, 1959

TYPE SPECIES. — *Citrella nitida* Oertli, 1959 by original designation.

*Citrella?* *carniana* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019  
(Fig. 7D)

*Citrella?* *carniana* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019a: 39, figs 20K-O.

*Cytheropteron?* cf. *triassica* — Kozur in Kristan-Tollmann et al. 1991a: 201, pl. 4, fig. 4.

EXAMINED MATERIAL. — One right valve.

OCCURRENCE. — Middle Carnian, Late Triassic, Transdanubian Midmountains, Western Hungary (Kristan-Tollmann et al. 1991a); *Tetraporobrachia haekeli* radiolarian Zone, Julian, Carnian, Late Triassic, Mersin Mélange, southern Turkey, Hügül Tuffite (Forel et al. 2019a); *Nicoraella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, sample BE2 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — L = 345 µm, H = 223 µm (BE2 [GeoZS6177]).

#### DISCUSSION

*Citrella?* *carniana* has only been found in sample BE2 of Belca section, where it is rare (Fig. 3). This species is until now only known from the Carnian stage. The specimens from the type locality in Turkey range from 250 to 400 µm in length and from 169 to 238 µm in height (Forel et al. 2019a). The specimen obtained from the Belca section might therefore not be an adult but rather a late juvenile.

Genus *Judahella* Sohn, 1968  
emend. Whatley & Boomer (2000)

TYPE SPECIES. — *Judahella tsorfatia* Sohn, 1968, by original designation.

#### DISCUSSION

We follow the revision of Whatley & Boomer (2000) in considering *Mostlerella* Kozur in Bunza & Kozur, 1971 as a

junior synonym of *Judahella* Sohn, 1968 and in considering subgenera of *Judahella* as not valid.

*Judahella dizluense* Kristan-Tollmann in Kristan-Tollmann, Tollmann & Hamedani, 1980  
(Fig. 7E, F)

*Judahella* (*Judahella*) *dizluense* Kristan-Tollmann in Kristan-Tollmann, Tollmann & Hamedani, 1980: 190, pl. 9, fig. 16. — Forel et al. 2019a: 35, fig. 18I.

*Mostlerella dizluense* — Kristan-Tollmann in Mette & Mohtat-Aghai 1999: 55, 56, pl. 6, figs 11, 12.

EXAMINED MATERIAL. — Four right valves, two left valves.

OCCURRENCE. — Rhaetian, Late Triassic, Bagerabad, Iran (Kristan-Tollmann et al. 1980); Rhaetian, Late Triassic, Tyrol, Austria (Mette & Mohtat-Aghai 1999); *Tetraporobrachia haekeli* radiolarian Zone, Julian, Carnian, Late Triassic, Mersin Mélange, southern Turkey, Hügül Tuffite (Forel et al. 2019a); *Nicoraella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18, 21 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

#### DISCUSSION

*Judahella dizluense* occurs in samples BE17 to BE21, in which it is not abundant (Fig. 3). Because of the preservation state of the material in Belca, the specimens were not measured. The present record is the second Carnian occurrence of this species.

Genus *Kerocythere* Kozur & Nicklas, 1970

TYPE SPECIES. — *Kerocythere raibliana* (Gümbel, 1869) subsequently designated by Kozur & Nicklas (1970: 313).

*Kerocythere raibliana* (Gümbel, 1869)  
(Fig. 7J)

*Cythere raibliana* Gümbel, 1869: 184, pl. 6, figs 36a, b.

*Kerocythere raibliana* — Urlich 1972: 685, pl. 2, figs 9-13 only. — Liebermann 1979: 102, pl. 5, fig. 4. — Kolar-Jurkovič 1990: 84, 85, pl. 14, fig. 5. — Monostori 1994: 319, figs 5/1-3, 6/4.

*Kerocythere* (*Kerocythere*) *raibliana* *raibliana* — Kristan-Tollmann 1972: 44, 45, pl. 1, figs 5-7. — Kristan-Tollmann et al. 1991b: 203, 204, pl. 2, figs 1-3.

EXAMINED MATERIAL. — Four right valves, two left valves.

OCCURRENCE. — Early Carnian, Late Triassic, Raibl, Southern Alps, Italy (Gümbel 1869); Early Carnian, Late Triassic, Raibl Beds, Raibl, Southern Alps, Italy (Kristan-Tollmann 1972); Norian-Rhaetian, Late Triassic, Kössen Beds, Austria (Urlich 1972); Carnian, Late Triassic, Italian Alps (Liebermann 1979); Carnian, Late Triassic, Beli potok, Slovenia (Kolar-Jurkovič 1990); Carnian, Late Triassic, Transdanubian range, Hungary (Kristan-Tollmann et al. 1991b); Early Carnian, Late Triassic, Balaton Highland, Hungary (Monostori 1994); *Nicoraella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, sample BE18 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

## DISCUSSION

This rare species has only been found in sample BE18 of the Belca section (Fig. 3). Because of their preservation state, the specimens from Belca were not measured. Of the six specimens illustrated from the Norian-Rhaetian, Late Triassic, of Austria (Urlich 1972), Kristan-Tollmann *et al.* (1991b: 203, 204) rejected two specimens (Urlich 1972: pl. 2, figs 11, 12), questioned three others (Urlich 1972: pl. 2, figs 9, 10, 13) and considered only one specimen (Urlich 1972: pl. 2, fig. 14) as belonging to *Kerocythere raibliana* (Gümbel, 1869). However, they provided no discussion to support this choice. Here we do not follow this taxonomic choice and rather reject the specimen shown on the plate 2, figure 14 in Urlich 1972 because it displays an anteromarginal ridge, which is lacking in *K. raibliana* but is present in *K. hartmanni* (Bolz & Kozur in Bunza & Kozur, 1971).

### *Kerocythere reticulata* Kristan-Tollmann, 1972 (Fig. 7K, M)

*Kerocythere reticulata* Kristan-Tollmann, 1972: 46, pl. 2, figs 4, 5.

EXAMINED MATERIAL. — Five right valves, three left valves.

OCCURRENCE. — Early Carnian, Late Triassic, Cave del Predil, Julian Alps, Italy (Kristan-Tollmann 1972); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

## DISCUSSION

*Kerocythere reticulata* Kristan-Tollmann, 1972 has been retrieved from samples BE17 to 23/1 of Belca section, where it is relatively rare (Fig. 3). The present record is the first occurrence of this species outside Italy.

### *Kerocythere tuvalica* Kozur in Bunza & Kozur, 1971 (Fig. 7N, O)

*Kerocythere tuvalica* Kozur in Bunza & Kozur, 1971: 51, 52, pl. 4, fig. 15. — Forel *et al.* 2019a: fig. 20C.

EXAMINED MATERIAL. — Four left valves, several fragments.

OCCURRENCE. — Tuvalian, Carnian, Late Triassic, Veszprem, Bakony, Hungary (Bunza & Kozur 1971); *Tetraporobrachia haeckeli* radiolarian Zone, Julian, Carnian, Late Triassic, Mersin Mélange, southern Turkey, Hüglü Tuffite (Forel *et al.* 2019a); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

## DISCUSSION

*Kerocythere tuvalica* Kozur in Bunza & Kozur, 1971 is present in samples BE17 to 23/1 of the Belca section, where it is rare (Fig. 3).

## Family LIMNOCYTHERIDAE Klie, 1938

### Genus Simeonella Sohn, 1968

TYPE SPECIES. — *Simeonella brotzenorum* Sohn, 1968 by original designation.

### *Simeonella daginikella* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019 (Fig. 7R, S)

*Simeonella daginikella* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019a: 41, 43, figs 22A-E.

EXAMINED MATERIAL. — Two right valves, one left valve.

OCCURRENCE. — *Tetraporobrachia haeckeli* radiolarian Zone, Julian, Carnian, Late Triassic, Mersin Mélange, southern Turkey, Hüglü Tuffite (Forel *et al.* 2019a); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, sample BE18 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — L = 393-430 µm, H = 236-359 µm (this work).

## DISCUSSION

This rare species has only been found in sample BE18 of the Belca section, where it is not abundant (Fig. 3). *Simeonella daginikella* is very close to *S. brotzenorum* Sohn, 1968 from the Carnian, Late Triassic, of Israel (Sohn 1968) from which it differs by its narrower posterior border bearing a series of small spines and its overall smaller dimensions (*S. brotzenorum*: L = 420-510 µm, H = 260-310 µm; *S. daginikella*: L = 326-400 µm, H = 179-256 µm). The specimens of *S. brotzenorum* Sohn, 1968 from the Carnian of Israel documented by Gerry *et al.* (1990) show the same size difference compared to *S. daginikella*. *Simeonella brotzenorum norica* Bunza & Kozur, 1971 was subsequently described from the late Norian, Late Triassic, of Austria (Bunza & Kozur 1971) based on its stronger lateral inflation, absence of eye-knot and broader ventral margin compared to *S. brotzenorum* Sohn, 1968. *Simeonella daginikella* is very close to *S. brotzenorum norica* Bunza & Kozur, 1971 from which it differs by its posterior spines. The synonymy between *S. daginikella* and *S. brotzenorum norica* should be carefully considered by investigating specimens from the type locality using SEM given that *S. brotzenorum norica* was only drawn.

## Family indet.

### Genus Renngartenella Schneider in Mandelstam, Schneider, Kuznetsova & Katz, 1957

TYPE SPECIES. — *Renngartenella pennata* Schneider in Mandelstam Schneider, Kuznetsova & Katz, 1957 by original designation.

*Rennartenella sanctaeru*

*Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973*  
(Figs 7T, U; 8A-E)

*Rennartenella sanctaeru* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973: 215, 217-219, pl. 8, figs 1-6; pl. 11, figs 1, 3, 5, 6; pl. 12, fig. 10 — Liebermann 1979: 215, pl. 5, fig. 2 — Basha 1982: pl. 1, fig. 15 — Gerry et al. 1990: 96, pl. 1, figs 11-13 — Monostori 1994: 320, 322, figs 5/5-7 — Keim et al. 2001: fig. 8C.

EXAMINED MATERIAL. — More than 60 isolated valves.

OCCURRENCE. — Julian, early Carnian, Late Triassic, Heiligkreuz Formation, Italy (Kristan-Tollmann & Hamedani 1973); Carnian, Late Triassic, Italian Alps (Liebermann 1979); Cordevolian, Carnian, Late Triassic, Jordan (Basha 1982); Carnian, Late Triassic, Devora-2A and Ramallah-1 boreholes, Israel (Gerry et al. 1990); Early Carnian, Late Triassic, Balatón Highland, Hungary (Monostori 1994); Carnian, Late Triassic, Heiligkreuz Formation, Dolomites, Northern Italy (Keim et al. 2001); *Nicorella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE2, 18 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 9.

## DISCUSSION

*Rennartenella sanctaeru* has been found in samples BE2 and BE18 of the Belca section (Fig. 3). While it is rare in sample BE18, it is very abundant in sample BE2. In the present state of our knowledge, *R. sanctaeru* is restricted to the Julian, early Carnian, Late Triassic. The length and height of all specimens available in the literature and in the present work are plotted in Fig. 9. The size range of left valves is wider than that of right valves, the smallest and largest known specimens being left valves. There is no overlap of the size of the left valves between Belca and other localities, those found in Belca being significantly smaller. The same is not true for right valves as the size of the type material from Italy (Kristan-Tollmann & Hamedani 1973) overlaps the range of the Belca specimens. To reconstruct the ontogeny of *R. sanctaeru*, we used the ontogenetic information provided in the literature and complete carapaces provide correlation points. Fig. 9 first shows that the size difference between left and right valves of complete carapaces is not important: this limited dispersal is an additional tool to discuss the possible ontogenetic stages of *R. sanctaeru*. The anchor points ensured by complete carapaces allow the identification of the largest two stages, identified as A-1 and Adult (Fig. 9). The upper limit of the large scatter plot preceding A-1 is very close for both valves so that these larger specimens might correspond to A-2. The youngest juveniles

identified are left valves, as shown by their significant size difference with the smallest right valves. However, in the absence of additional characters such as inner structures, it is nearly impossible to further subdivide this large scatter plot. A common lower limit can be identified as shown by the dashed line in Fig. 9 but no inner boundary can be recognized.

Monostori (1994) formulated the hypothesis of sexual dimorphism for *R. sanctaeru* occurring in Hungary, elongate adults with narrowly arched posterior possibly being males. In Belca, only one right valve of adult has been identified so that the pattern discussed by Monostori (1994) cannot be recognized for adults at this locality. However, these two morphologies are visible in the present material, which also occur in the type material from the Heiligkreuz Formation in Italy (Kristan-Tollmann & Hamedani 1973). The first morphology has asymmetric anterior and posterior margins, with posterior end slightly subtriangular and maximum of curvature located lower than anterior one (Kristan-Tollmann & Hamedani 1973: pl. 8, figs 1-3, 5; Fig. 8C, E). The second morphology is more rectangular in outline, with posterior end located higher and more rounded to subvertical at some specimens (Kristan-Tollmann & Hamedani 1973: pl. 8, figs 4, 6; Fig. 8A, B, D). In the present state of our reconstruction, the two morphologies are visible very early in the development of this species. Following Monostori (1994), we interpret the first morphology as being males and the second one as being females.

Superfamily SIGILLIOIDEA Mandelstam, 1960  
Family SIGILLIDAE Mandelstam, 1960

Genus *Cardobairdia* van den Bold, 1960  
emend. McKenzie (1967)

TYPE SPECIES. — *Cardobairdia ovata* van den Bold, 1960 by original designation.

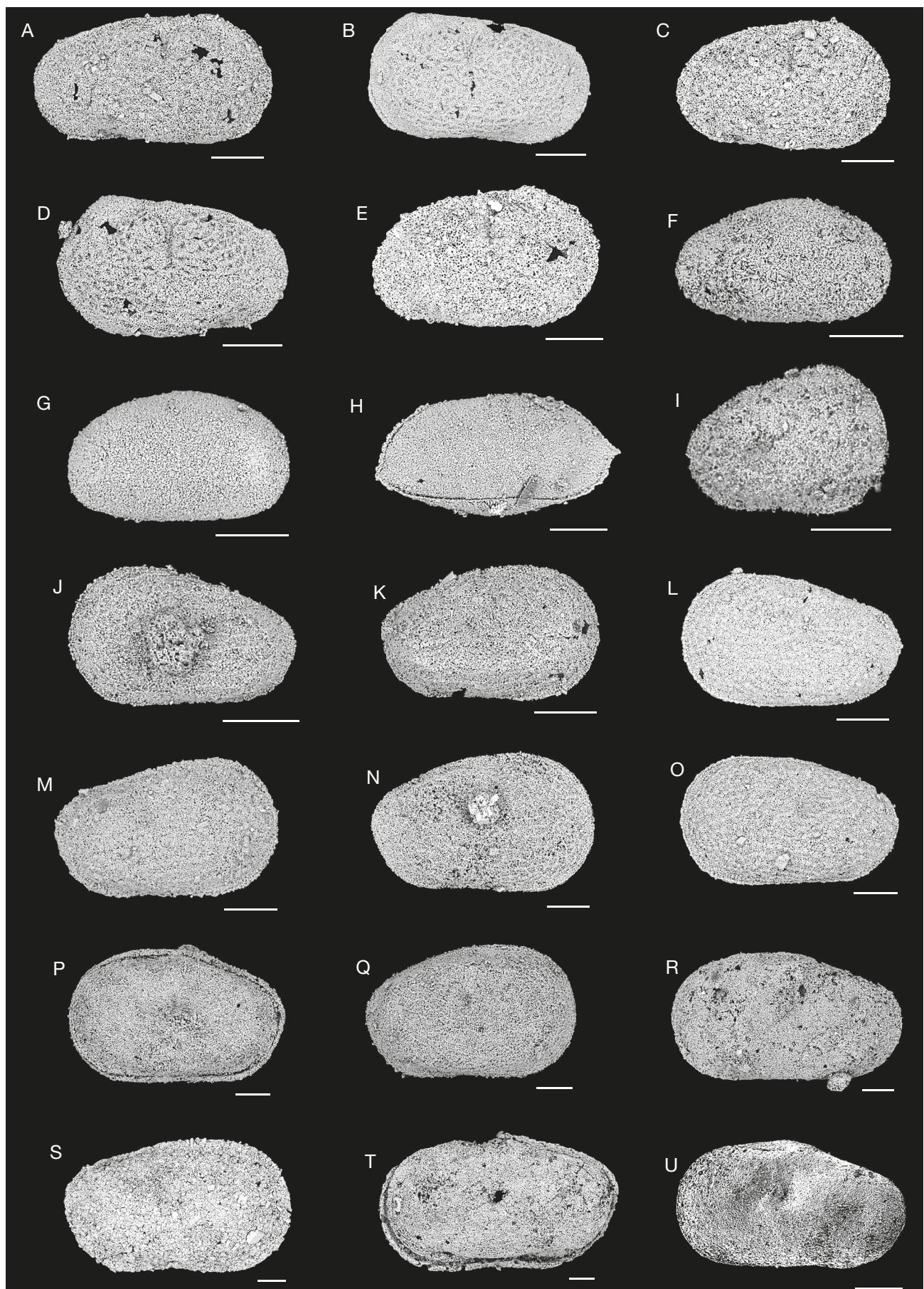
*Cardobairdia?* sp.  
(Fig. 8H)

EXAMINED MATERIAL. — One complete carapace and one right valve.

OCCURRENCE. — *Nicorella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE17, 18 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — L = 425 µm, H = 208 µm (BE17 [GeoZS6202]).

Fig. 8. — Ostracods from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. All specimens are deposited in the micropalaeontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number: **A-E**, *Rennartenella sanctaeru* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973; **A**, lateral view of a right valve, BE2 (GeoZS6195); **B**, lateral view of a left valve, BE2 (GeoZS6198); **C**, lateral view of a right valve, BE2 (GeoZS6197); **D**, lateral view of a left valve, BE2 (GeoZS6200); **G**, *Hungarella* sp. 1, lateral view of a right valve, BE18 (GeoZS6201); **H**, *Cardobairdia?* sp., right lateral view of a complete carapace, BE17 (GeoZS6202); **I-U**, *Issacharella bisulcata* Kozur, 1972 emend. Kristan-Tollmann in Kristan-Tollmann et al. 1991b; **I**, lateral view of a right valve, BE18 (GeoZS6203); **J**, lateral view of a left valve, A-5, BE21 (GeoZS6204); **K**, lateral view of a right valve, A-4, BE2 (GeoZS6205); **L**, lateral view of a left valve, A-4, BE2 (GeoZS6206); **M**, lateral view of a right valve, BE2 (GeoZS6207); **N**, lateral view of a right valve, BE18 (GeoZS6208); **O**, lateral view of a left valve, A-3, BE2 (GeoZS6209); **P**, left lateral view of a carapace, A-2, BE17 (GeoZS6210); **Q**, lateral view of a right valve, BE21 (GeoZS6211); **R**, lateral view of a left valve, A-1, BE17 (GeoZS6212); **S**, lateral view of a right valve, A-1, BE2 (GeoZS6213); **T**, left lateral view of a carapace, Adult, BE17 (GeoZS6214); **U**, lateral view of a left valve, Adult, BE18 (GeoZS6215). Scale bars: 100 µm.



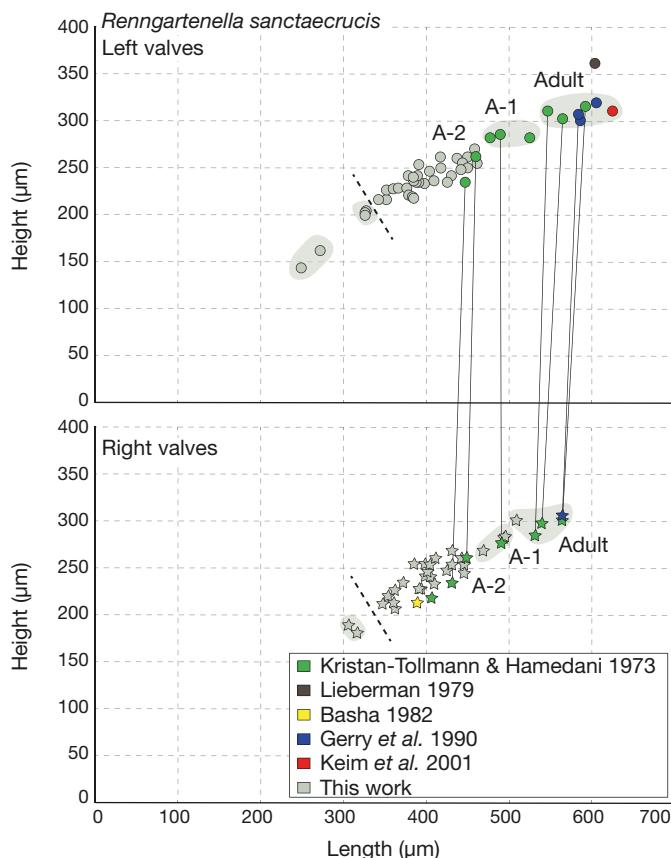


Fig. 9. — Height/Length scatter plots of *Renngartenella sanctaeccruis* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973. The dimensions of right and left valves of complete carapaces are linked.

## DISCUSSION

This species is rare in the sampled section and has only been found in samples BE17 and 18 (Fig. 3). The genus *Cardobairdia* was described from the Middle Eocene of Trinidad (van den Bold 1960). Since then, it has been abundantly reported from Jurassic layers of western Tethys (e.g., Apostolescu 1959; Szczechura & Blaszyk 1968; Boomer 1991, 1992; Harloff & Jäger 1994; Monostori 1996; Boomer et al. 1998; Ainsworth & Boomer 2001; Olempska & Blaszyk 2001; N’Zaba-Makaya et al. 2003; Beher 2004). Until now, the oldest *Cardobairdia* was documented from the Early Jurassic of southern England (Lord & Boomer 1988), of the Fastnet Basin off southwestern Ireland (Ainsworth 1986, 1987), of northern Wales (Boomer 1991) and of the continental slope off western Australia (Lord et al. 1993). Noteworthy, the doubt on the generic attribution of the Belca’s specimens refers to the impossibility to observe their inner structures of the specimens and to confirm that the present material belongs to *Cardobairdia* such as described from Cenozoic deposits. However, the lateral morphology of *Cardobairdia?* sp. from Belca conforms to the morphology of Jurassic occurrences, for which inner structures are most of the time not observed as well. In the present state of our knowledge, *Cardobairdia?* sp. from the Belca section is the oldest occurrence of this genus worldwide.

Order PLATYCOPIDA Sars, 1866  
Suborder PLATYCOPINA Sars, 1866  
Superfamily CYTHERELLOIDEA Sars, 1866  
Family CYTHERELLIDAE Sars, 1866

Genus *Issacharella* Sohn, 1968

TYPE SPECIES. — *Issacharella blakei* Sohn, 1968 by original designation.

***Issacharella bisulcata* Kozur, 1972**  
emend. Kristan-Tollmann in Kristan-Tollmann et al. (1991b)  
(Fig. 8I-U)

*Issacharella bisulcata* Kozur, 1972: 22, pl. 1, figs 1, 5-7 — Kristan-Tollmann et al. 1991b: 205, pl. 3, fig. 2; pl. 4, figs 1-3, 5-7.

EXAMINED MATERIAL. — More than 100 specimens, including isolated valves and complete carapaces.

OCCURRENCE. — Carnian, Late Triassic, Veszprem, Balaton highland, Hungary (Kozur 1972); Carnian, Late Triassic, Transdanubian range, Hungary (Kristan-Tollmann et al. 1991b); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE2, 17, 18, 21, 23/1 (Fig. 3), Belca section, ‘Raibl Beds’, Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 10.

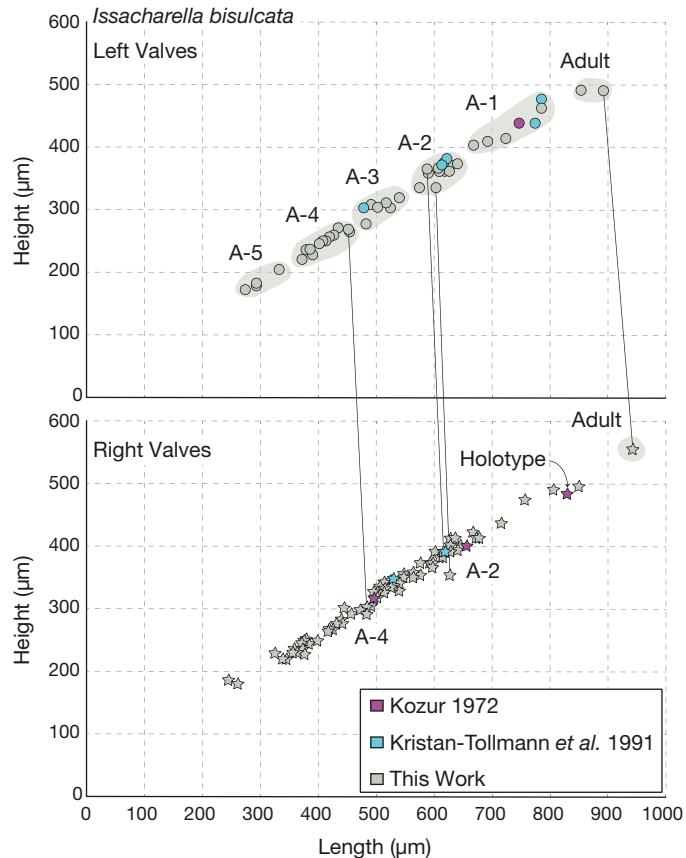


Fig. 10. — Height/Length scatter plots of *Issacharella bisulcata* Kozur, 1972 emend. Kristan-Tollmann in Kristan-Tollmann *et al.* (1991b). The dimensions of right and left valves of complete carapaces are linked.

## DISCUSSION

*Issacharella bisulcata* Kozur, 1972 emend. Kristan-Tollmann in Kristan-Tollmann *et al.* (1991b) has been found in all samples of the Belca section, where it is relatively abundant except for sample BE23/1 (Fig. 3). Until the present record, this species was only recorded from the Carnian of Hungary. Kristan-Tollmann *et al.* (1991b) considered that this species was described on early juveniles and that the holotype designated by Kozur (1972) was a late juvenile. The largest known specimen is recorded from Belca section and confirms the diagnostic of Kristan-Tollmann *et al.* (1991b) that the holotype of *I. bisulcata* is not an adult. The only four carapaces of this species, all from the Belca section, show that the overlap is present quite early in the development of this species (Fig. 10). As was already identified by Kristan-Tollmann *et al.* (1991b), the ontogeny of *I. bisulcata* is mainly marked by the enlargement of the posterior margin, which is narrow in young specimens and becomes larger during the ontogeny. The carapaces of young juveniles are therefore more assymetric in lateral view (e.g., Fig. 8I-K) than older juveniles and adults (e.g., Fig. 8R-U), with slightly less convex ventral margin and a straight to only slightly convex dorsal margin.

## Genus *Leviella* Sohn, 1968

TYPE SPECIES. — *Leviella bentori* Sohn, 1968 by original designation.

### *Leviella boggschi* Kozur, 1972

(Fig. 11A-J)

*Leviella boggschi* Kozur, 1972: 20, pl. 1, fig. 4; pl. 2, figs 1-7. — Kristan-Tollmann *et al.* 1991b: 206, pl. 3, figs 1, 3.

EXAMINED MATERIAL. — More than 100 specimens, including isolated valves and complete carapaces.

OCCURRENCE. — Carnian, Late Triassic, Veszprem, Balatón highland, Hungary (Kozur 1972); Carnian, Late Triassic, Transdanubian range, Hungary (Kristan-Tollmann *et al.* 1991b); *Nicoraella? budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE2, 17, 18, 21, 23/1 (Fig. 3), Belca section, 'Raibl Beds', Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 12.

## DISCUSSION

*Leviella boggschi* Kozur, 1972 has been found in all samples of the Belca section. It is rare in samples BE2 and BE23/1 but is moderately abundant in samples BE17 to BE21 (Fig. 3). This species is another species typical of the Carnian that was only known from Hungary until the Belca record. The dispersal of the sizes of both left and right valves in Belca is the largest observed until now for this species, with the smallest known specimens and the largest documented left valve. Kristan-Tollmann *et al.* (1991b) stated that the holotype of this species described by Kozur (1972) is not a mature stage:

this observation is confirmed with the specimens from Belca, for both valves (Fig. 12). Until now, three complete carapaces of *L. bogschi* are known to science [one from Kozur (1972), two from this work]. The gaps between the successive scatter plots in *L. bogschi* are well marked and allow the distinction of six ontogenetic stages for the left valves (A-5 to Adult) and seven for the right valves (A-6 to Adult). In early juveniles, the valves are very assymetric with narrow posterior end and weakly developed lateral ridges. The ontogenetic development of *L. bogschi* is marked by the progressive enlargement of the posterior end of the carapaces and strengthening of the lateral ridges and sulcus. The three carapaces known from this species belong to the Adult, A-1 and A-5 stages (Fig. 12). Although rare, these carapaces show that the overlap of RV over LV occurs as early as A-5 and increases through the ontogenetic development.

#### *Leviella vegiae* Kozur, 1972 (Fig. 11K-T)

*Leviella vegiae* Kozur, 1972: 21, pl. 1, fig. 3; pl. 2, figs 8-14.

*Leviella raibiana* – Kristan-Tollmann & Hamedani 1973: 213, pl. 12, figs 1, 2.

*Leviella fraterna* – Kristan-Tollmann et al. 1991b: 206, pl. 3, fig. 7.

EXAMINED MATERIAL. — More than 100 specimens, including isolated valves and complete carapaces.

OCCURRENCE. — Carnian, Late Triassic, Veszprem, Balatón highland, Hungary (Kozur 1972); Late Carnian, Late Triassic, marl layer in the middle part of the Opponitzer Limestone Formation, Göstling/Ybbs, Austria (Kristan-Tollmann & Hamedani 1973); Carnian, Late Triassic, Raibl, Southern Alps, Italy (Kristan-Tollmann & Hamedani 1973); Carnian, Late Triassic, Transdanubian range, Hungary (Kristan-Tollmann et al. 1991b); *Nicoraella?* *budaensis* conodont zone, late Julian-?earliest Tuvalian, Carnian, Late Triassic, samples BE2, 17, 18, 21, 23/1 (Fig. 3), Belca section, 'Raibl Beds', Karavanke Mountains, Slovenia (this work).

DIMENSIONS. — Fig. 13.

#### DISCUSSION

*Leviella vegiae* Kozur, 1972 has been retrieved from all studied samples in Belca section. It is moderately abundant in BE2, abundant in samples BE17 to BE21 and rare in BE23/1 (Fig. 3). All the specimens available from the literature are gathered in Fig. 13. At least six ontogenetic stages are reconstructed from the right valves, where the gaps between the successive scatter plots are more clearly visible than for the left ones. Thanks to the complete carapaces documented from the present work, the stages A-1, A-2 and A-4 are constrained

for right valves as well. On the basis of the ontogenetic stages here reconstructed, the holotype of *L. vegiae* (a right valve) is an adult. The ontogenetic development of *L. vegiae* is very similar to *L. bogschi* in that it mainly witnesses the progressive enlargement of the posterior end of the carapaces as well as the development of the lateral structures.

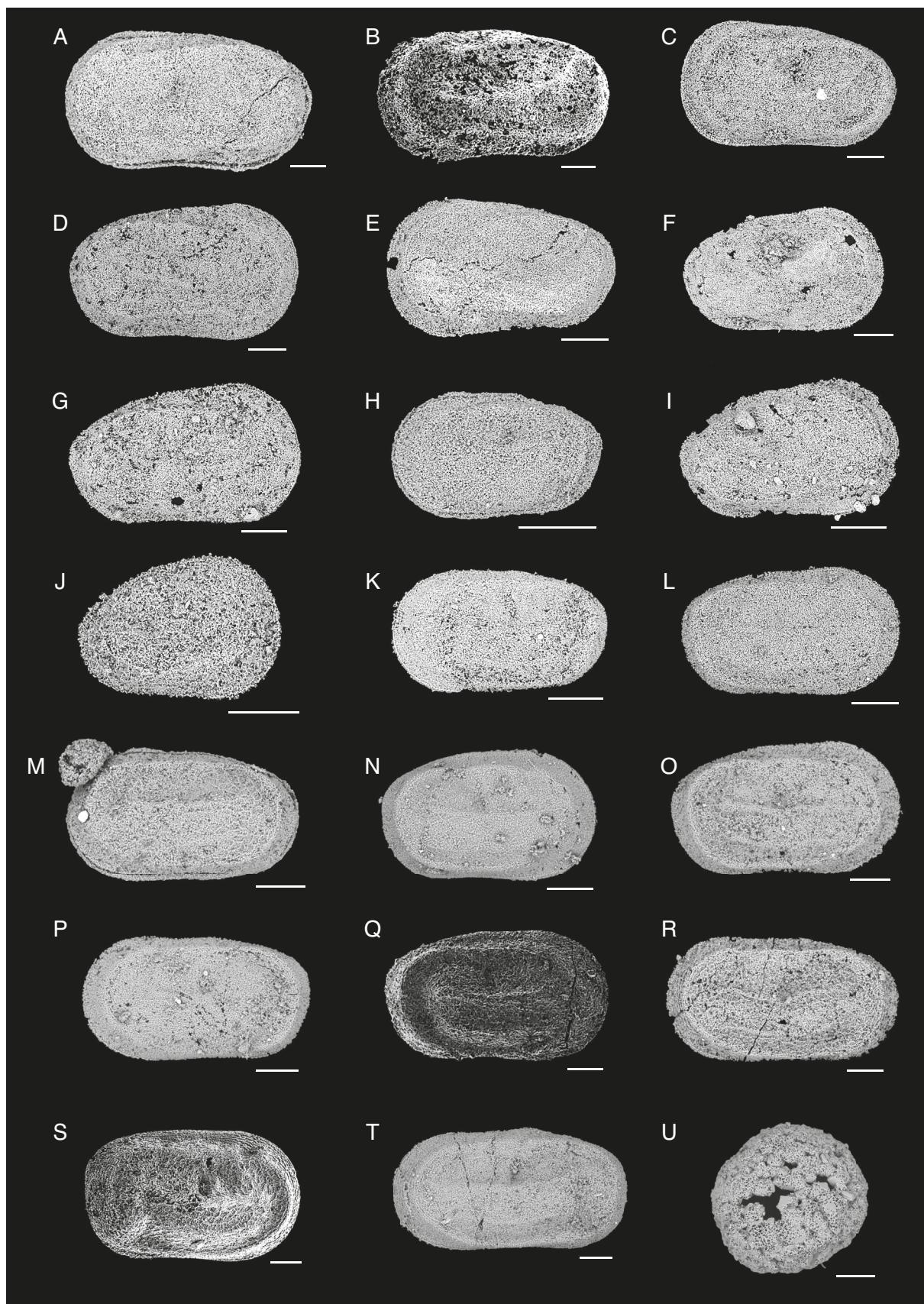
#### DISCUSSION

##### DIVERSITY OF OSTRACODS AT BELCA SECTION

Although ostracods have been previously documented from Triassic layers in Slovenia (e.g., Kolar-Jurkovšek 1990, 1991), the present contribution is the first complete taxonomic and palaeoecologic analysis of ostracod assemblages from the Carnian, Late Triassic, of this area. For the present work, five samples (BE2, 17, 18, 21, 23/1) from the 'Raibl Beds' outcropping in the Karavanke Mountains in northwestern Slovenia have yielded ostracods: a total of 12 families, 21 genera and 39 species have been found (Table 1; Fig. 3). At the species level, two species are new to science (*Dicerobairdia buseri* Forel, n. sp. and *Pontocypris?* *karavankensis* Forel, n. sp.), 14 were previously documented from other Triassic localities (*Bairdia balatonica* Méhes, 1911; *B. cassiana* (Reuss, 1869); *B. cf. perpusilla* sensu Forel et al. (2019a); *Citrella?* *carniana* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019; *Issacharella bisulcata* Kozur, 1972 emend. Kristan-Tollmann in Kristan-Tollmann et al. 1991b; *Judabella dizluense* Kristan-Tollmann, 1980; *Kerocythere raibiana* (Gümbel, 1869); *K. reticulata* Kristan-Tollmann, 1972; *K. tuvalica* Kozur in Bunza & Kozur, 1971; *Leviella bogschi* Kozur, 1972; *L. vegiae* Kozur, 1972; *Mirabairdia longispinosa* Kristan-Tollmann, 1978; *Renngartenella sanctaecrucis* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973; *Simeonella daginikella* Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019) and 23 are compared to other species or kept in open nomenclature due to poor preservation and/or paucity of material.

In the present state of our knowledge, the new species *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris?* *karavankensis* Forel, n. sp. are endemic to Slovenia during the Carnian. Ten of the 14 species previously known from the literature are also restricted to the Carnian stage: *Bairdia* cf. *perpusilla*, *Citrella?* *carniana*, *Issacharella* *bisulcata*, *Kerocythere* *reticulata*, *K. tuvalica*, *Leviella bogschi*, *L. vegiae*, *Mirabairdia longispinosa*, *Renngartenella sanctaecrucis*, *Simeonella daginikella*. Several of these species are restricted to the northwestern Palaeo-Tethys area, as shown in the Systematic Palaeontology section. *Bairdia* cf. *perpusilla*, *Citrella?* *carniana*, *Kerocythere* *tuvalica*, *Mirabairdia longispinosa* and *Simeonella daginikella*

Fig. 11. — Ostracods from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic. All specimens are deposited in the micropalaentontology collections of the Geological Survey of Slovenia, under the numbers GeoZS6132 to GeoZS6239, preceded by sample number: **A–J**, *Leviella bogschi* Kozur, 1972; **A**, left lateral view of a carapace, A-1, BE21 (GeoZS6216); **B**, lateral view of a left valve, A-1, BE18 (GeoZS6217); **C**, lateral view of a left valve, A-2, BE18 (GeoZS6218); **D**, lateral view of a right valve, A-2, BE18 (GeoZS6219); **E**, lateral view of a left valve, A-3, BE18 (GeoZS6220); **F**, lateral view of a right valve, A-3, BE18 (GeoZS6221); **G**, lateral view of a right valve, A-3, BE18 (GeoZS6222); **H**, left lateral view of a carapace, A-5, BE21 (GeoZS6223); **I**, lateral view of a right valve, A-5, BE17 (GeoZS6224); **J**, lateral view of a right valve, A-6, BE18 (GeoZS6225); **K–T**, *Leviella vegiae* Kozur, 1972; **K**, lateral view of a left valve, A-5, BE18 (GeoZS6226); **L**, lateral view of a right valve, A-5, BE18 (GeoZS6227); **M**, left lateral view of a carapace, A-4, BE21 (GeoZS6228); **N**, lateral view of a right



valve, A-4, BE17 (GeoZS6229); **O**, lateral view of a right valve, A-3, BE18 (GeoZS6230); **P**, lateral view of a left valve, A-3, BE18 (GeoZS6231); **Q**, lateral view of a right valve, A-2, BE21 (GeoZS6232); **R**, lateral view of a left valve, A-1, BE18 (GeoZS6233); **S**, lateral view of a right valve, A-1, BE18 (GeoZS6234); **T**, lateral view of a left valve, Adult, BE18 (GeoZS6235); **U**, *Polycope* sp., lateral view of a complete carapace, BE2 (GeoZS6236). Scale bars: 100 µm.

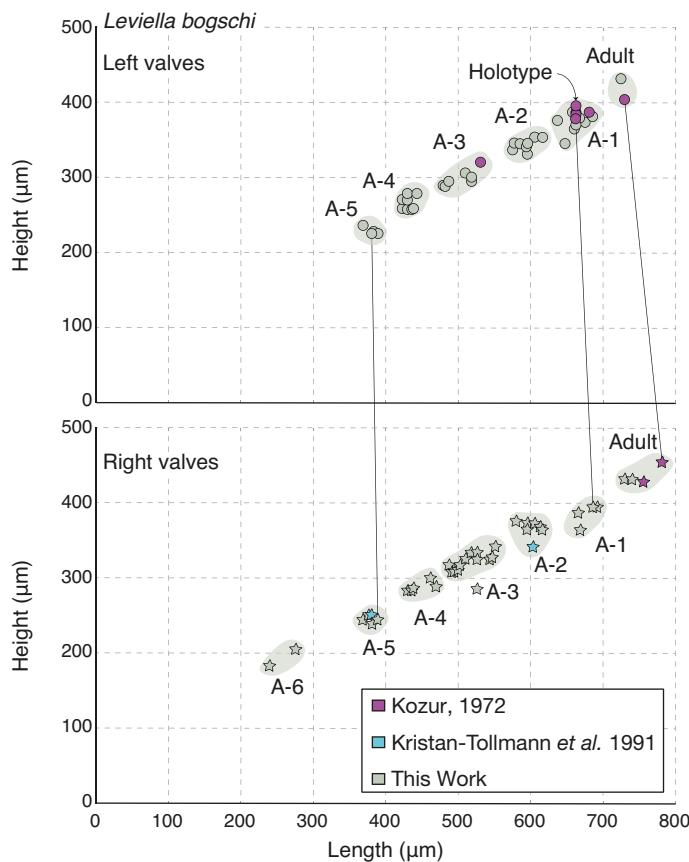


FIG. 12. — Height/Length scatter plots of *Leviella boggschi* Kozur, 1972. The dimensions of right and left valves of complete carapaces are linked.

extend southwards to the Mersin Mélange in southern Turkey (Forel *et al.* 2018, 2019a), and *Renngartenella sanctaecrucis* also occurs in Jordan (Basha 1982) and Israel (Sohn 1968; Gerry *et al.* 1990). The distribution of these taxa during the Carnian therefore encompasses the northwestern margin of the Palaeo-Tethys and extends southwards to the southwestern margin and to the Cimmerian Blocks.

As for the stratigraphic distribution of the encountered taxa, the case of *Bairdia balatonica* Méhes, 1911 is interesting. Its earliest occurrence has been reported from the Spathian-Anisian interval of Tibet (Forel & Crasquin 2011; Forel *et al.* 2011) and it seems that this species later spread to the north-western margin of the Palaeo-Tethys from the Anisian to the Carnian (Hungary, Italy, Slovenia; Méhes 1911; Széles 1965; Kristan-Tollmann 1978; Monostori 1995; Monostori & Tóth 2013; Crasquin *et al.* 2018). Only *Judahella dizluense* and *Kerocythere raibliana* extend higher in the Late Triassic (Kristan-Tollmann 1972; Kristan-Tollmann *et al.* 1980; Mette & Mohtat-Aghai 1999).

The generic diversity of ostracod assemblages in Belca ranges from six in BE23/1 to 19 in BE18; the species diversity ranges from nine in BE2 and BE23/1 to 33 in BE18 (Fig. 3). Genera and species both document an increase in diversity in the lower part of the Belca section (samples BE2 to BE18), a peak in BE18, followed by a decrease towards the top of the section. Following Fürsich & Wendt (1977), Nützel & Kaim (2014) and Haussmann & Nützel (2015),

the specimens of each species were counted articulated plus higher number of left or right valves. Individual rarefaction analyses and diversity indices (Shannon-Wiener and Simpson) were calculated with PAST (Hammer *et al.* 2001). Rarefaction curves show the expected number of taxa as a function of the number of specimens in each sample: they are illustrated in Fig. 14A. The rarefaction curve for sample BE2 flattens out gradually and demonstrate that further sampling would not have provided a significant number of new species so that the assemblage in BE2 represents the original diversity of the ostracod fauna. On the opposite, the rarefaction curves for BE17, 18, 21 and in particular for BE23/1, indicate that taxa count is not representative of the entire fauna and that a larger sample would have given better counts and higher diversity levels. Sample BE23/1 is poor displays a low abundance compared to other assemblages of the Belca section. Diversity was calculated for each sample using the Simpson and Shannon-Wiener indices (Fig. 14B). Shannon-Wiener index ( $H$  in Fig. 14B; Shannon & Weaver, 1949), is relatively insensitive to sample size and allows for a deeper analysis of species richness taking into account the number of specimens of each species. To further reduce the effect of sample size, we compared  $H$  with the Simpson index of dominance ( $1-D$  in Fig. 14B; Simpson, 1949) whose high values indicate low diversity. This index is close to 1 when the species in a community are evenly distributed and drops towards 0 when the community is dominated by one or few

TABLE 1. — Taxonomic list of all ostracod species identified from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic.

Class OSTRACODA Latreille, 1802	Family LIMNOCYTHERIDAE Klie, 1938
Order PODOCOPIDA Sars, 1866	<i>Simeonella daginikella</i> Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019 [BE18]
Suborder PODOCOPINA SARS, 1866	Family indet.
Superfamily BAIRDIOIDEA SARS, 1887	<i>Renngartenella sanctaerucis</i> Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973 [BE2, 18]
Family BAIRDIIDAE Sars, 1887	Superfamily SIGILLIOIDEA Mandelstam, 1960
<i>Acratia</i> cf. <i>goemeri</i> Kozur, 1970 emend. Forel et al. (2019a) [BE18, 21]	Family SIGILLIDAE Mandelstam, 1960
<i>Acratia</i> sp. 1, 2 [BE18]	<i>Cardobairdia?</i> sp. [BE17, 18]
<i>Bairdia balatonica</i> Méhes, 1911 [BE17, 23/1]	Suborder METACOPINA Sylvester-Bradley, 1961
<i>Bairdia cassiana</i> (Reuss, 1868) [BE17, 18, 21, 23/1]	Superfamily HEALDIOIDEA Harlton, 1933
<i>Bairdia</i> cf. <i>perpusilla</i> Bolz, 1971 sensu Forel et al. (2019a) [BE17, 18]	Family Healdiidae Harlton, 1933
<i>Bairdia</i> sp. 1, 3 [BE18]	<i>Hungarella</i> sp. 1, 2 [BE18]
<i>Bairdia</i> sp. 2 [BE23/1]	Order PLATYCOPIDA Sars, 1866
<i>Bairdiacypris</i> sp. [BE18]	Suborder PLATYCOPINA Sars, 1866
<i>Dicerobairdia belcaensis</i> Forel, n. sp. [BE17, 18, 21]	Superfamily CYTHERELLOIDEA Sars, 1866
<i>Isobythocypris?</i> sp. 1 [BE2]	Family CYTHERELLIDAE Sars, 1866
<i>Isobythocypris?</i> sp. 2 [BE18]	<i>Issacharella bisulcata</i> Kozur, 1972 emend. Kristan-Tollmann in Kristan-Tollmann et al. (1991b) [BE2, 17, 18, 21, 23/1]
<i>Mirabairdia longispinosa</i> Kristan-Tollmann, 1978 [BE2, 17, 18, 21, 23/1]	<i>Leviella boggschi</i> Kozur, 1972 [BE2, 17, 18, 21]
Family BYTHOCYPRIDIADA Maddocks, 1969	<i>Leviella veghae</i> Kozur, 1972 [BE2, 17, 18, 21, 23/1]
<i>Bythocypris?</i> sp. 1 [BE17, 18]	Order MYODOCOPIDA Sars, 1866
<i>Bythocypris?</i> sp. 2 [BE18]	Suborder MYODOCOPINA Sars, 1866
<i>Bythocypris?</i> sp. 3 [BE17, 18, 23/1]	Superfamily POLYCOPOIDEA Sars, 1866
Superfamily CYPRIDOIDEA Baird, 1845	Family POLYCOPIDAE Sars, 1866
Family Paracyprididae Sars, 1866	<i>Polycope</i> sp. [BE2]
<i>Paracypris</i> sp. [BE18]	
Family PONTOCYPRIDIADA Müller, 1894	
<i>Pontocyprella</i> sp. [BE18]	
<i>Pontocypris?</i> <i>karavankensis</i> Forel, n. sp. [BE18, 21]	
Superfamily CYTHEROIDEA Baird, 1850	
Family BYTHOCYTERIDAE Sars, 1928	
<i>Monoceratina</i> sp. [BE18, 21]	
Family CYTHERURIDAE Müller, 1894	
<i>Citrella?</i> <i>carniana</i> Forel in Forel, Tekin, Okuyucu, Bedi, Tuncer & Crasquin, 2019 [BE2]	
<i>Judahella</i> <i>dizluense</i> Kristan-Tollmann, 1980 [BE17, 18, 21]	
<i>Judahella</i> cf. <i>galli</i> Kozur & Bolz in Bunza & Kozur, 1971 [BE2, 18]	
<i>Judahella</i> sp. [BE18]	
<i>Kerocythere</i> cf. <i>hartmanni</i> Bolz & Kozur in Bunza & Kozur, 1971 [BE18]	
<i>Kerocythere</i> <i>raibiana</i> (Gümbel, 1869) [BE18]	
<i>Kerocythere</i> <i>reticulata</i> Kristan-Tollmann, 1972 [BE17, 18, 21, 23/1]	
<i>Kerocythere</i> <i>tuvalica</i> Kozur, 1971 [BE17, 18, 21, 23/1]	
<i>Kerocythere</i> sp. [BE21]	

species. Consequently, diversity indices in Belca (Fig. 14B) substantify part of the generic and specific patterns described above: a pronounced increase of diversity (and decrease of the dominance) from BE2 to BE18, which records the maximum of specific diversity of the Belca section, followed by an important reduction of the diversity up to BE21. The confidence intervals of the species diversity in BE21 and BE23/1 are large so that any difference is undistinguishable and the diversity patterns of the assemblages in the upper part of the Belca section are biased. The taxa involved in

the observed diversity changes are discussed below, as well as their palaeoenvironmental implications.

#### COMPOSITION OF THE OSTRACOD ASSEMBLAGES

The most diversified assemblage in terms of species and genera occurs in sample BE18, with 11 families. The familial composition of the successive Carnian ostracod assemblages at Belca section is shown in Fig. 15. The most diversified family is Bairdiidae (genera *Acratia*, *Bairdia*, *Bairdiacypris*, *Dicerobairdia*, *Isobythocypris*, *Mirabairdia*): they occur in

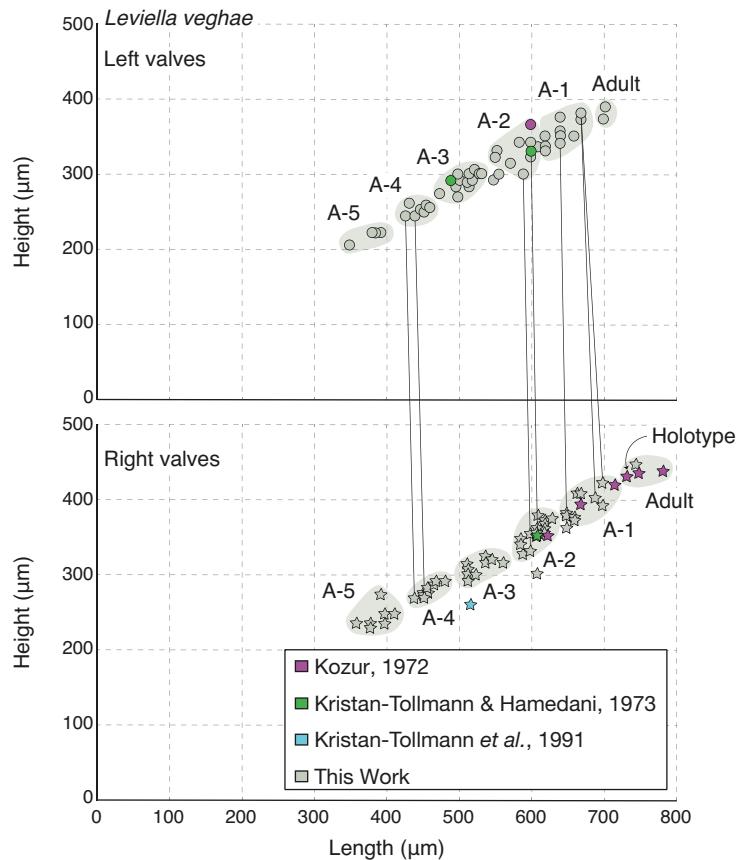


FIG. 13. — Height/Length scatter plots of *Leviella veghae* Kozur, 1972. The dimensions of right and left valves of complete carapaces are linked.

all studied samples, ranging from 25% (sample BE2) to 44% (sample BE23/1) of the species and from 25% (sample BE2) to 40% (sample BE21) of the genera. The second most diversified family is Cytheruridae (genera *Citrella*, *Judahella*, *Kerocythere*), which represent between 21% (sample BE18) and 31% (sample BE21) of the species, and between 11% (sample BE18) to 25% (sample BE2) of the genera. Cytherellidae (genera *Issacharella*, *Leviella*) is the third most diversified family with 9% (sample BE18) to 33% (sample BE2) of the species and 11% (sample BE18) to 33% (sample BE23/1) of the genera. The fourth family is Bythocyprididae (genus *Bythocyparis*), being between 9% (sample BE18) and 15% (sample BE17) of the species, and between 5% (sample BE18) and 17% (sample BE23/1) of the genera. Pontocyprididae (genera *Pontocypris*, *Pontocyprella*) are between 6% (sample BE18) and 8% (sample BE21), and around 10% of the genera in samples BE18 and 21. Sigillidae (genus *Cardobairdia*) are between 3% (sample BE18) and 7% (sample BE17) of the species, and between 5% (sample BE18) and 11% (sample BE17) of the genera. The indeterminate family (genus *Rennergartenella*) represents between 3% (sample BE18) and 11% (sample BE2) of the species, and between 5% (sample BE18) and 12.5% (sample BE2) of the genera. Polycopidae (genus *Polycopis*) are 11% of the species and 12.5% of genera of

sample BE2. Healdiidae (genus *Hungarella*) are 6% of the species and 5% of the genera of sample BE18. Finally, Limnocytheridae (genus *Simeonella*) and Paracyprididae (genus *Paracypris*) each represents 3% of the species and 5% of the genera of sample BE18.

The assemblage in sample BE2 differs from all other assemblages in Belca in being composed in equal proportions of Bairdiidae (genera *Dicerobairdia*, *Isobythocyparis*), Cytheruridae (genera *Citrella*, *Judahella*) and Cytherellidae (genera *Issacharella*, *Leviella*), each being 25% of the genera (Fig. 15). In terms of species, Cytherellidae are slightly more diversified with 33% of the assemblage, while Bairdiidae and Cytheruridae each account for 22%. Polycopidae (genus *Polycopis*) and the indeterminate family (genus *Rennergartenella*) represent equal secondary proportions of the assemblage. The abundances of each species further underline the specificity of the sample BE2, with the massive dominance of *Rennergartenella sanctaecrucis* and *Issacharella bisulcata* (Fig. 3), which is further substantiated by the diversity indices (Fig. 14). *Issacharella bisulcata* is still present in the following samples but its abundance slightly decreases. Conversely, *Rennergartenella sanctaecrucis* is extremely rare in sample BE18 and absent from the other assemblages. The samples BE17 to 23/1 furthermore record the diversification of the Bairdiidae and Cytheruridae.

## PALAEOENVIRONMENTAL IMPLICATIONS

The influence of transportation from shallower and/or deeper areas needs to be discussed before any paleoenvironmental interpretation of the recovered assemblages can be proposed. The autochthonous or allochthonous nature of ostracod assemblages can be determined using the proportion of carapaces *versus* isolated valves as well as the demographic structure of populations (e.g., Boomer *et al.* 2003). In all Belca samples, the ostracod assemblages are *in situ* with no preferred alignment or orientation, indicating little or no post-mortem transportation. With the exception of the sample BE23/1 that yielded few specimens, all studied assemblages consist of a mixture of adults and juveniles as shown for several of the species reported here (Figs 5, 9, 10, 12). In all studied samples, adults as well as juveniles are mainly disarticulated valves that correspond to a wide range of large and small instars, although the smallest specimens are mostly lacking. These elements all point to a moderate energy thanatocoenosis with some post-mortem disturbance but the assemblages are still good indicators of palaeoenvironment (Boomer *et al.* 2003). This observation is in line with the thin valves of the bivalve *Posidonia*: they are found in both marlstone and limestone layers and are generally articulated with the convex side oriented downward, pointing to a relatively quiet sedimentary environment.

As shown in the previous section, the taxonomic composition of the successive ostracod assemblages in Belca section records an important shift upward. The base of the section (sample BE2) records the thriving of *Renngartenella sanctaecrucis* and *Issacharella bisulcata*. The upper part of the section (samples BE17 to 23/1) is marked by the disappearance of *Renngartenella sanctaecrucis*, a much higher diversity of Bairdiidae and high abundance of other Cytherellidae (*Leviella boggschi*, *L. vegiae*).

The large dominance of the *Renngartenella sanctaecrucis* and *Issacharella bisulcata* in BE2 suggests an atypical depositional environment probably related to salinity issues. This interpretation is substantiated by the sudden lithological change near sample BE2. This suggests strong inputs of land-derived terrigenous material, possibly from river input, which influenced the water salinity. However, some of the associated species, although not abundant, are typical of open marine conditions (*Leviella*, *Mirabairdia*) and suggest some mixing with normal marine waters. Gerry *et al.* (1990) have interpreted the typically Carnian species *R. sanctaecrucis* as stenohaline. Later, Monostori (1994) considered that it might be euryhaline because of its association with *Simeonella brotzenorum* Sohn, 1968. In the Carnian of Hungary, Monostori (1994) further considered that the dominance of *R. sanctaecrucis* might indicate a lesser salinity deviation than the dominance of *S. brotzenorum*. All these elements strengthen the conclusion of a salinity depletion occurring in sample BE2. It is worth noting that *I. bisulcata* was traditionally considered as an open marine taxon. The co-dominance of *I. bisulcata* and *R. sanctaecrucis* in sample BE2 and the abundant persistence of *I. bisulcata* through

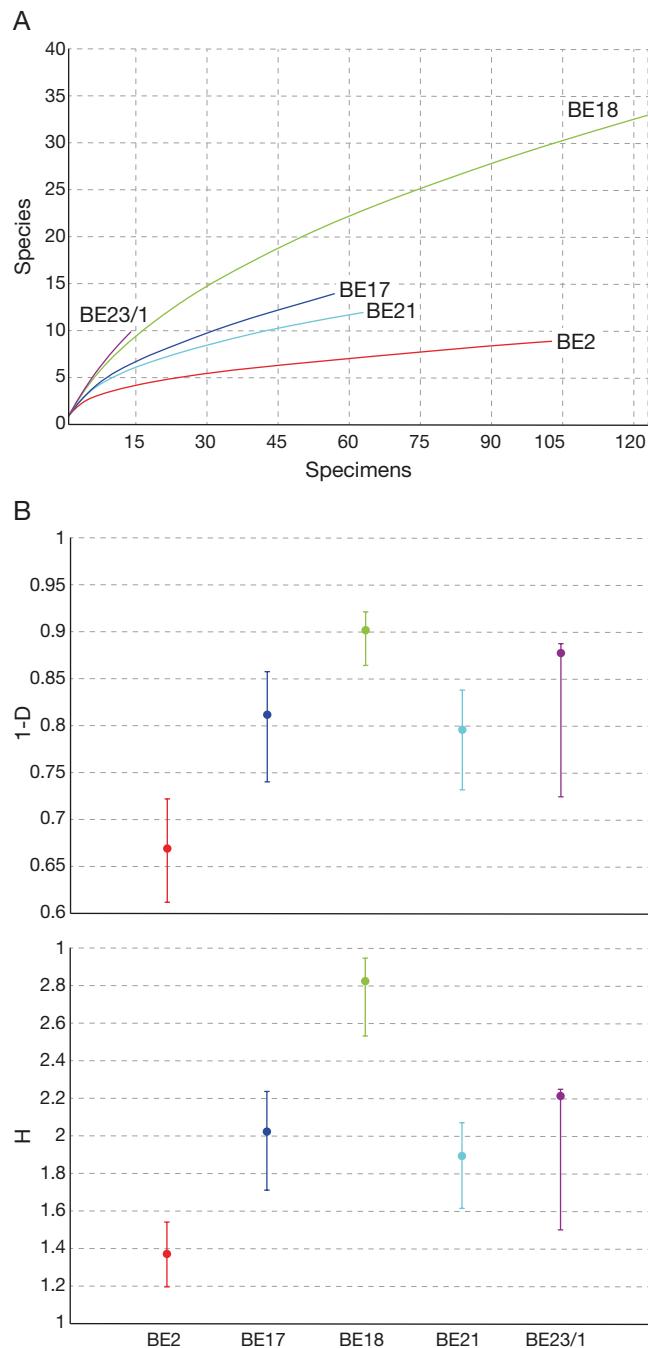


FIG. 14. — A, individual rarefaction curves, B, diversity indices (Shannon-Wiener and Simpson) of ostracods assemblages from the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic.

the Belca section highlights the environmental plasticity of this species. The thriving of *R. sanctaecrucis* associated to high abundances of Cytherellidae in Belca is reminiscent of the assemblages described by Monostori (1994) from the Carnian of Hungary. In Hungary, this assemblage is furthermore associated with the abundance of *S. brotzenorum*, indicating a stronger salinity deviation. *Kerocythere raibiana* has furthermore been interpreted by Monostori (1994) as appearing in normal saline environments: the salinity deviation in sample BE2 is here further confirmed

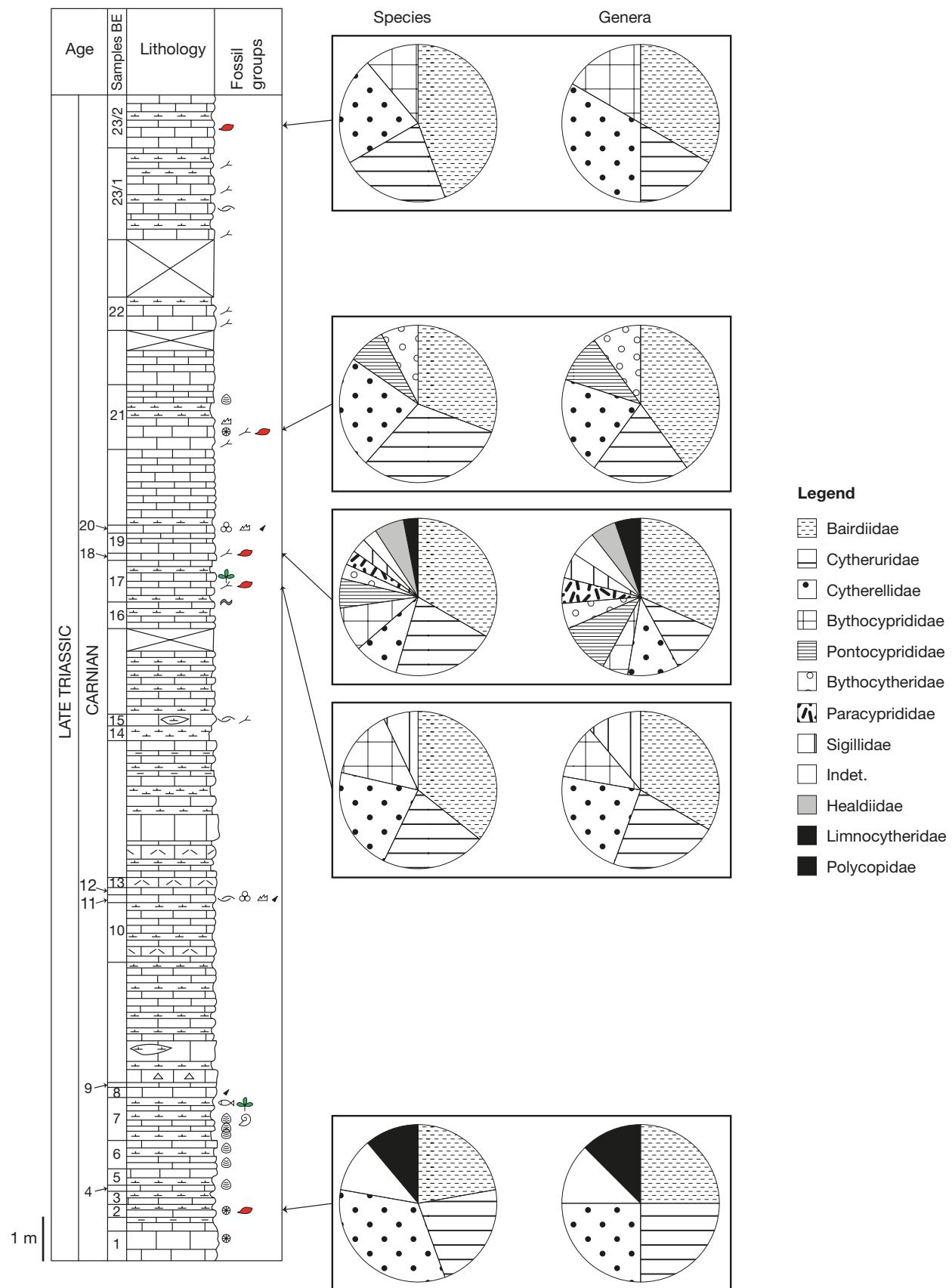


FIG. 15. — Circular diagrams of faunal composition of ostracod assemblages from examined samples of the Belca section, Karavanke Mountains, northwestern Slovenia, Carnian, Late Triassic.

by the absence of such species, which only occur higher in the Belca section (Fig. 3).

The increase in normal saline, open marine taxa in the upper part of the Belca section (samples BE17 to 23/1), including the genera *Bairdia*, *Dicerobairdia*, *Issacharella*, *Judahella*, *Leviella*, *Mirabairdia* (e.g., Sohn 1968; Monostori 1994), documents the shift to open marine, normal salinity conditions. The occurrence of shallow sublittoral forms (*Dicerobairdia*, *Judahella*; Sohn 1968; Monostori 1994) develops in BE17 onwards. The oldest lower Jurassic *Cardobairdia* from southern England, northern Wales, the Fastnet Basin off south-western Ireland and the continental slope off western Australia, are thought to have lived on muddy bottoms of the sublittoral zone (Ainsworth 1986, 1987; Lord & Boomer 1988; Boomer 1991; Lord *et al.* 1993). This aspect is further substantiated by the persistent occurrence of *Kerocythere tuvalica* from samples 17 to 23/1, which has been identified as marine soft bottom dwellers (Bunza & Kozur 1971). The occurrence of taxa closely related to deep-shelf forms (*Acratia* cf. *goemoeryi*; Fig. 4A, B) as well as posteriorly elongate *Acratia* (*Acratia* sp. 2; Fig. 4D) might indicate a relatively deep position on the shelf for assemblages of samples BE18 and 21 (Kozur 1971; Kozur *et al.* 1974; Monostori 1994). These elements point to a relatively intermediate position within the sublittoral zone for the upper part of the Belca section (samples BE17 to BE23/1).

*Mirabairdia longispinosa* Kristan-Tollmann, 1978 is until now only known from the Carnian of the Cassian Formation exposed at Pralongia section in Italy (Kristan-Tollmann 1978) and of the Huğlu Tuffite in Turkey (Forel *et al.* 2018). The Upper Triassic Cassian Formation has been described as a carbonate platform to basinal deposit (e.g., Fürsich & Wendt 1977; Wendt & Fürsich 1980; Wendt 1982). On the other hand, the studied sample at the Huğlu Tuffite corresponds to a moderately shallow subtidal environment submitted to short-lived environmental instabilities (e.g., Forel *et al.* 2018). The occurrence of *Mirabairdia longispinosa* Kristan-Tollmann, 1978 throughout the Belca section spanning the salinity restriction in BE2 further substantiates the plasticity of this typically Carnian taxa.

## CONCLUSIONS

Ostracods of Carnian, Late Triassic, age have been retrieved from the ‘Raibl Beds’ cropping out at the Belca section located in the Karavanke Mountains in northwestern Slovenia. Thirty-nine species are found, including 2 newly described: *Dicerobairdia buseri* Forel, n. sp. and *Pontocypris? karavankensis* Forel, n. sp. We describe the ontogeny of several species in Belca and confirm the occurrence of sexual dimorphism for the typical Carnian species *Renngartenella sanctaercuris* Kristan-Tollmann in Kristan-Tollmann & Hamedani, 1973. We report a major shift in diversity and dominance of the ostracod assemblages upward, witnessing a major shift from low-salinity levels related to the input

of land-derived material to normal marine conditions in the intermediate sublittoral zone in the upper portion of Belca section.

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