

## Deep-water ostracods from the Middle Anisian (Reifling Formation) of the Northern Calcareous Alps (Austria)

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**ABSTRACT** – A diverse silicified ostracod assemblage from Middle Anisian, Middle Triassic, intra-shelf basin deposits (Reifling Formation) is described. It comprises 32 species, of which 5 are new species (*Bairdia biforis* n. sp., *B. schneebergiana* n. sp., *Mirabairdia praepsychrosphaerica* n. sp., *M. plurispinosa* n. sp., *Bairdiacypris aequisymmetrica* n. sp.). The assemblage consists of both neritic species and deep-water taxa which have been considered as representatives of the ‘Thuringian Ecotype’ or the ‘Palaeopsychrospheric Fauna’. Lithofacies, palaeogeographical setting and taxonomic composition are suggestive of a deep neritic to upper bathyal depositional environment. ‘Archaic’ faunal elements are relatively rare and include the genera *Spinomicrocheilinella* and *Processobairdia*, which were formerly known only from the Palaeozoic and are now recorded for the first time from the Mesozoic.

**KEYWORDS:** *Ostracods, Reifling Formation, Anisian, Northern Calcareous Alps, Austria*

### INTRODUCTION

The ostracod record for the alpine Middle Triassic is still poor in comparison to that from the Upper Triassic, which has been intensively studied and documented in several publications during the past decades by various authors (e.g. Kollmann, Kristan-Tollmann, Bolz, Urlichs, Bunza & Kozur). This discrepancy is primarily due to the predominance of indurated calcareous lithofacies in the alpine Middle Triassic, which makes the extraction of calcareous microfossils very difficult. Middle Triassic ostracods are, however, highly important with regard to the evolution of this group. Indeed, recent studies have shown that the major biotic turnover between Palaeozoic and Mesozoic taxa did not occur at the Permian/Triassic boundary as formerly suggested, but extended from the latest Permian until the early Middle Triassic (e.g. Crasquin-Soleau *et al.*, 2007; Crasquin & Forel, 2013). This evolutionary changeover was controlled by different environmental conditions. As reported by the latter authors, deep-water taxa disappeared at the end of the Permian and reoccurred during the Middle Triassic as Lazarus taxa. In this context the alpine Middle Triassic is particularly interesting because this area provides the opportunity to study the evolutionary change of the shallow-marine as well as the contemporary deep-water fauna. Another important scientific question is the ecological interpretation of this deep-water fauna. There are two different models concerning the ecology of Palaeozoic and early Mesozoic deep-water ostracod assemblages: (1) The ‘Thuringian Ecotype’ (Becker in Bandel & Becker, 1975) and the ‘Palaeopsychrospheric Fauna’ (Kozur, 1972, 1991). These models are of high significance with regard to palaeoclimatic and palaeoceanographical reconstructions. More intensive research of deep-marine ostracods in combination with sedimentological and geochemical research is therefore required to find out which model is valid. In this present study the first deep-water assemblage from the north-alpine Middle Triassic is described.

### GEOLOGICAL SETTING, STRATIGRAPHY AND FACIES

The silicified ostracod fauna described herein was recovered from the southeastern slope of the Schneeberg Mountain near Puchberg in Niederösterreich (Fig. 1) in the lowermost bed of the Grafensteigkalk (Hohenegger & Lein, 1977). This unit, of Anisian to Early Ladinian age, comprises a 200–340 m thick regional sub-formation of the Middle Triassic Reifling Formation, which conformably overlies the Gutenstein Formation, occurring in the southeastern part of the Northern Calcareous Alps as part of the Schneeberg-Nappe and Mürzalpen-Nappe. This lowermost bed (sample 86/109) has been dated by L. Krystyn (Vienna) as Middle Anisian (Pelsonian), denoted by the occurrence of the conodonts *Paragondolella bulgarica* Budurov & Stepanov, 1975 and *P. cf. bifurcata* Budurov & Stepanov, 1972 which is in accordance with the stratigraphic range of the ostracods (Fig. 2). A characteristic feature of the Grafensteigkalk is the planar bedding of the limestone, the intercalations of thin limestone turbidites, plus the frequent occurrence of siliceous nodules. The Reifling Formation is a succession of deep-marine limestones containing siliceous nodules and abundant radiolaria (Bechstädt & Mostler, 1974). Interbedded within the limestones are generally green tuffitic beds, indicative of volcanic activity, which was probably the primary source for the silica (Bechstädt *et al.*, 1978).

The Reifling Formation has been interpreted as an intra-shelf basin facies due to the lateral interfingering with dysoxic deep-marine sediments (Partnach Formation) and the reefal and carbonate platform deposits (Wettersteinkalk) (Bechstädt & Mostler, 1974; Haas *et al.*, 1995; Ruffer & Zamparelli, 1997; Mandl, 2000; Ruffer, 2008; Michalik, 2011). According to Tollmann (1985), the depositional environment of the Reifling Formation has been mainly interpreted as a deep-marine (hemipelagic to epibathyal) and, in parts, poorly ventilated (subeuxinic) basin. This would correspond to water depths of between 200 and about 800–1000 m. Bechstädt & Mostler (1974) and Bechstädt *et al.* (1978) described

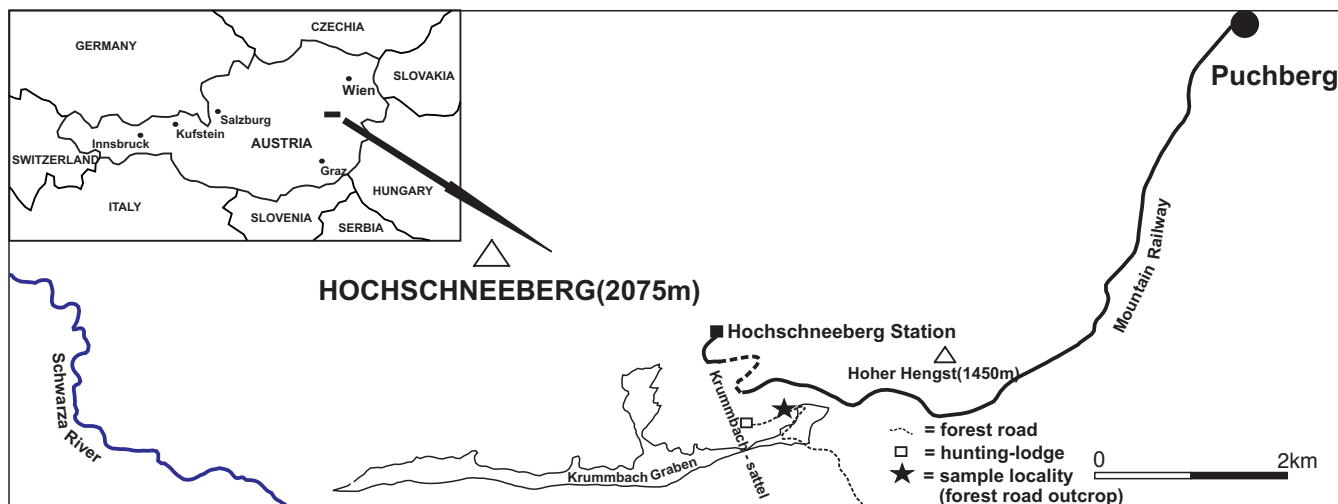


Fig. 1. Location map.

the frequent occurrences of ‘pyschrospheric’ ostracods in the lower Reifling Formation and concluded that the water depth was around 500m. The occurrence of deep-water holothurians, agglutinated foraminifera and siliceous sponges indicates water depth at and below 200m for sediments from the Illyrian upwards (Mostler, 1977). The depositional environment for the Grafensteigkalk was interpreted as a broad basin of at least 8km which was bordered to the north and south by carbonate platforms (Wetterstein Formation). This facies model is based on the lateral interfingering with the Wetterstein Formation and intercalation of limestone turbidites. According to Hohenegger & Lein (1977), the fossil record in the Grafensteigkalk is suggestive of a faunal exchange with the Meliata-Hallstatt Basin in the south, probably by narrow passages through the reef and lagoonal areas.

## MATERIAL

The ostracods described in this paper belong to unpublished material of a single sample which was prepared and picked by Dr E. Kristan-Tollmann. The fauna was recovered from a siliceous limestone bed of the lowermost Reifling Formation (sample number 86/109) sampled by Dr G. Mandl (Geologische Bundesanstalt, Vienna). The type material is deposited at the Institute of Geology at Innsbruck University (collection number Me 2013).

## SYSTEMATIC DESCRIPTIONS

The following species from sample 86/109 are not described in the systematic part because they are already described in detail elsewhere and/or they are represented by too little material:

*Acanthoscapha bogschi* Kozur, 1971, *Acratia goemoeryi* (Kozur, 1970), *Bairdia cassiana* (Reuss, 1868), *Bairdia* sp. 3, *Cryptobairdia atudorei* (Crasquin-Soleau & Gradinaru, 1996), *Nodobairdia martinsonii* (Kozur, 1971), *Paraberounella oertlii* Kozur, 1972, *Polycope cincinnata* Apostolescu, 1959, *Praemacrocypris mocki* Kozur, 1971 and *Spinocypris vulgaris* Kozur, 1971. Their abundance (number and percentage of specimens) and stratigraphic range is, however, documented in Figures 2–5.

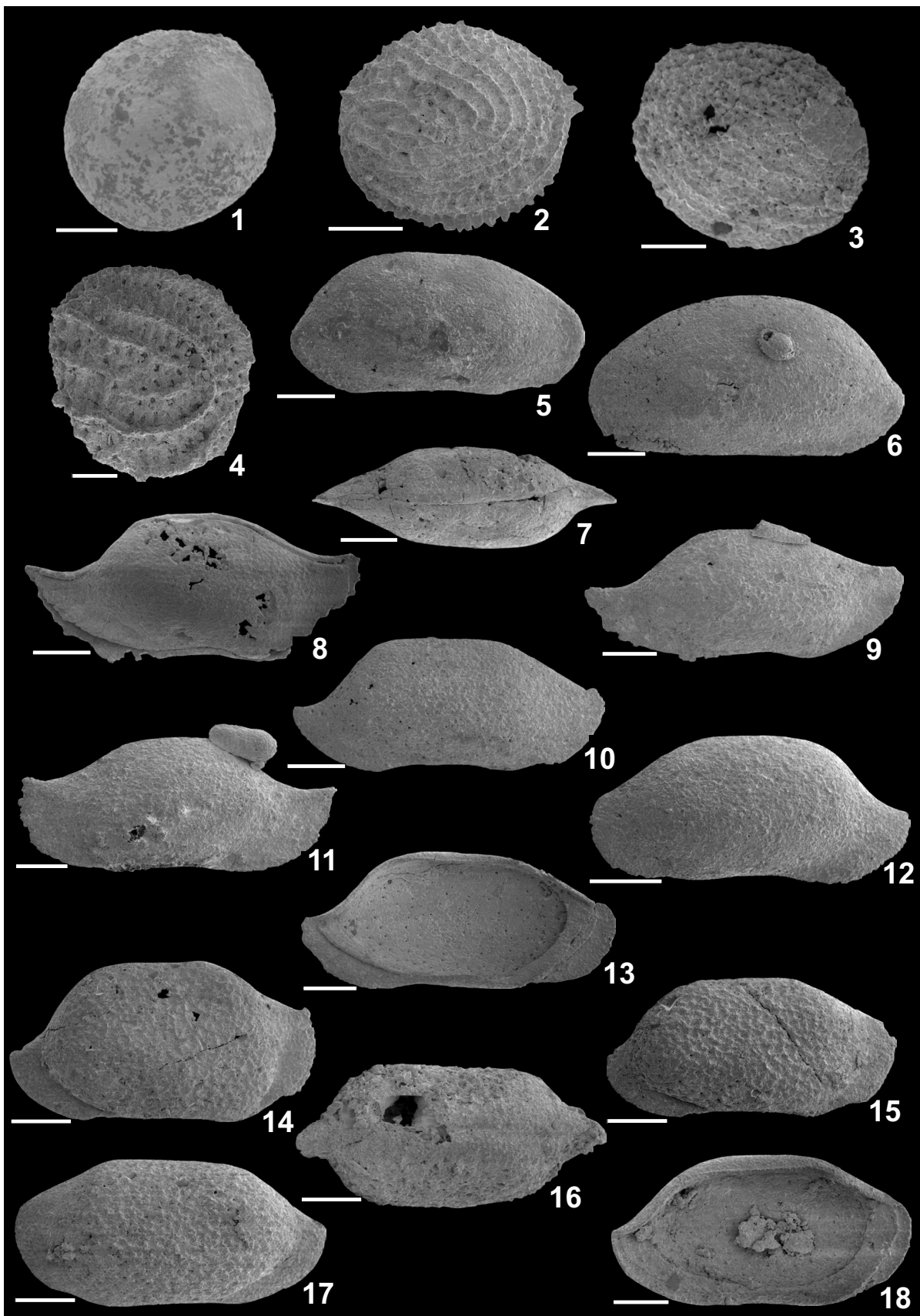
References for the species which are not described herein: *Cryptobairdia atudorei* – Crasquin-Soleau & Gradinaru (1996), Kozur *et al.* (2000) and this paper; *Nodobairdia martinsonii* – Kozur (1971a), Monostori (1995) and this paper; *Paraberounella oertlii* – Kozur (1972), Goel *et al.* (1984) and this paper. For references and synonymy lists of the other species, see Monostori & Tóth (2013).

The ostracod classification used here follows Martin & Davis (2001) and Becker (2000b, 2001, 2002, 2005). Abbreviations: L/H denotes length/height ratio.

Class **Ostracoda** Latreille, 1802  
 Subclass **Myodocopa** Sars, 1866  
 Order **Halocyprida** Dana, 1852  
 Suborder **Cladocopina** Sars, 1866  
 Superfamily **Polycopoidea** Sars, 1866  
 Family **Polycopidae** Sars, 1866  
 Genus *Polycope* Sars, 1866

*Polycope* cf. *bourquinae* Crasquin-Soleau & Gradinaru, 1996  
 (Pl. 1, fig. 1)

**Explanation of Plate 1.** **fig. 1.** *Polycope* cf. *bourquinae* Crasquin-Soleau & Gradinaru, 1996. Carapace, left lateral view, Me 2013-8/1. **fig. 2.** *Polycope cincinnata* Apostolescu, 1959. Right valve, Me 2013-3/14. **fig. 3.** *Polycope* aff. *ladinica* Kolar-Jurkovsek, 1988. Carapace, right lateral view, Me 2013-8/4. **fig. 4.** *Polycope* sp. 1. Left valve, Me 2013-3/1. **figs 5-6.** *Bairdia anisica* Kozur, 1970: **5**, right valve, Me 2013-93/26; **6**, left valve, Me 2013-93/22. **figs 7-13.** *Bairdia biforis* n. sp.: **7**, carapace, dorsal view, Me 2013-93/36; **8**, carapace, right lateral view (Paratype), Me 2013-9/26; **9**, right valve, Me 2013-93/42 (Paratype); **10**, right valve, Me 2013-93/41; **11**, left valve, Me 2013-9/31 (holotype); **12**, left valve, Me 2013-9/39 (paratype); **13**, left valve, internal view, Me 2013-9/41. **figs 14-18.** *Bairdia schneebergiana* n. sp.: **14**, right valve, Me 2013-7/11 (holotype); **15**, right valve, Me 2013-9/40 (paratype); **16**, carapace, dorsal view, Me 2013-93/46 (paratype); **17**, left valve, Me 2013-93/44 (paratype); **18**, left valve, internal view, Me 2013-93/47. Scale bars: figs 1-4 = 100 µm; figs 5-18 = 200 µm.



**Material.** 14 carapaces.

**Dimensions** (mm). Length: 0.20–0.41; height: 0.23–0.39; L/H: 0.87–1.0.

**Occurrence.** Lower Anisian, Romania (Crasquin-Soleau & Gradinaru, 1996); Middle Anisian, Schneeberg, Austria.

**Remarks.** This species differs from *Polycopsis kroemmelbeini* Kozur, 1971 and *P. levis* Kozur, 1970 in the absence of crenulation along the free margin and the greater carapace size. The assignment to *Polycope bourguinae* Crasquin-Soleau & Gradinaru, 1996 is questionable because of the much smaller carapace size. The figured specimen of *Polycope* sp. *sensu* Kozur, 1971 (in Bunza & Kozur, 1971) corresponds in carapace shape and size to the present authors' specimens.

*Polycope* aff. *ladinica* Kolar-Jurkovsek, 1988/89  
(Pl. 1, fig. 3)

**Material.** 4 carapaces.

**Dimensions** (mm). Length: 0.34–0.43; height: 0.33–0.38; L/H: 1.1.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** The species shows similarity with *Polycope ladinica* Kolar-Jurkovsek, 1988/89 with respect to the relatively dense and 'elongated reticulation'. The poor preservation of the present material precludes a definite species assignment. *Polycope densoreticulata* Monostori & Tóth, 2013 and *P. aghdarbandensis* Kristan-Tollmann, 1991 show a similar rib pattern and are therefore regarded as possible junior synonyms of *P. ladinica*.

*Polycope* sp. 1  
(Pl. 1, fig. 4)

**Material.** 2 valves.

**Dimensions** (mm). Length: 0.33, 0.47; height: 0.36; L/H: 0.92.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** This species is similar to *Polycope arcuacostata* Monostori & Tóth, 2013 with regard to the reticulation pattern and possession of two prominent semi-circular ribs. In contrast to the latter species the present specimens also possess two prominent straight ribs extending from the central to the edge of the valve surface.

Subclass **Podocopa** Müller, 1894  
Order **Podocopida** Sars, 1866  
Suborder **Podocopina** Sars, 1866  
Superfamily **Bairdioidea** Sars, 1888  
Family **Bairdiidae** Sars, 1888  
Genus *Bairdia* McCoy, 1844

*Bairdia anisica* Kozur, 1970  
(Pl. 1, figs 5, 6)

1970b *Bairdia anisica* Kozur: 444; pl. 3, figs 1–4.

2006 *Bairdia anisica* Kozur 1970; Crasquin-Soleau *et al.*: 60; pl. 1, fig. 9.

2011 *Bairdia anisica* Kozur 1970; Forel & Crasquin: 252; fig. 4F.

**Material.** 12 carapaces, 81 valves.

**Dimensions** (mm). Left valve, carapace – length: 0.81–1.29; height: 0.40–0.67; L/H: 1.93–2.03.

**Occurrence.** Upper Anisian, Germany (Kozur, 1970b); Spathian to late Anisian, Gunagxi, south China (Crasquin-Soleau *et al.*, 2006); Lower Anisian, Tibet (Forel & Crasquin, 2011); Middle Anisian, Schneeberg, Austria.

**Remarks.** The present material displays some variability in the concavity of the postero-dorsal margin and also the convexity of the dorsal margin of the left valve. The right valve is less distinctly pointed posteriorly than the material from Germany. These differences are interpreted as intraspecific variability. With regard to the lateral carapace outline, *Bairdia anisica* shows similarity with *B. parvula* (Mehes, 1911) from the Upper Ladinian of Hungary (Monostori & Tóth, 2013). Monostori & Tóth (2013) also pointed out that the species shows a large variability in the shape of the posterior process and also the antero- and postero-dorsal margins. The present species differs by the possession of marginal projections along the antero- and postero-ventral margins.

*Bairdia biforis* n. sp.  
(Pl. 1, figs 7–13)

**Derivation of name.** From the Latin *biforis*, meaning two-winged, referring to the presence of two wing-like extensions.

**Diagnosis.** A species of *Bairdia* with two distinct flat wing-like extensions situated at the anterior and posterior margins. The lateral surface shows a weakly formed irregular reticulation.

**Holotype.** A right valve, Me 2013-9/31 (Pl. 1, fig. 11).

**Paratypes.** Me 2013-9/26 (Pl. 1, fig. 8), Me 2013-93/42 (Pl. 1, fig. 9), Me 2013-9/39 (Pl. 1, fig. 12), Me 2013-9/34.

**Material.** More than 150 valves and carapaces.

**Type locality.** The southeastern slope of the Schneeberg near Puchberg, forest road outcrop [UTM 563129E, 5289077N], Niederösterreich (Austria).

**Type horizon.** A limestone with siliceous nodules, basal bed of the Grafensteigkalk, Reifling Formation, Middle Anisian (Pelsonian).

**Description.** The right valve is characterized by a relatively long, straight dorsal margin which is more or less distinctly angled against the straight antero- and postero-dorsal margins and parallel to the concave ventral margin. The inclination of the postero-dorsal and antero-dorsal margins is about 45° and 30°, respectively. At the anterior and posterior margins there are flat and more or less distinct wing-like extensions which are broadly convex ventrally and pointed at mid-height or a little above mid-height. On the left valve the dorsal margin is gently convex to straight, while the antero- and postero-dorsal cardinal angles are less distinct. The anterior and posterior wing-like extensions are

broader and usually directed upwards. The left valve overlaps the right valve along all margins, most strongly at the antero- and postero-dorsal margins. In dorsal view the carapace shows a gently convex outline with laterally compressed extremities. The lateral surface shows a weakly formed irregular reticulation. Internal details not observed.

**Dimensions** (mm). Left valve – length: 1.02–1.3; height: 0.44–0.57; L/H: 2.0–2.5. Right valve – length: 1.06–1.3; height: 0.42–0.56; L/H: 2.2–2.6. Carapace width: 0.36–0.43.

**Occurrence.** As type locality and type horizon.

**Remarks.** Similar species of *Bairdia* have not been recorded from the Triassic. *Acanthoscapha blessi* Kozur, 1985 from the Upper Permian of Hungary has a similar lateral outline. The present specimens possess neither a posterior spine nor a longitudinal rib, also differing in the reticulation on the valve surface plus the possession of a moderately broad inner lamella.

*Bairdia schneebergiana* n. sp.  
(Pl. 1, figs 14–18)

**Derivation of name.** Referring to Schneeberg, the name of the type locality.

**Diagnosis.** A species of *Bairdia* with a coarsely reticulate valve surface which is clearly delimited from the smooth antero- and postero-ventral valve surface due to a strong inflation of the shell.

**Holotype.** A right valve, Me 2013-7/11 (Pl. 1, fig. 14).

**Paratypes.** Me 2013-9/40 (Pl. 1, fig. 15), Me 2013-93/44 (Pl. 1, fig. 17), Me 2013-5/34, Me 2013-93/46 (Pl. 1, fig. 16).

**Material.** 14 carapaces, 45 valves.

**Type locality.** The southeastern slope of the Schneeberg near Puchberg, forest road outcrop [UTM 563129E, 5289077N], Niederösterreich (Austria).

**Type horizon.** A limestone with siliceous nodules, basal bed of the Grafensteigkalk, Reifling Formation, Middle Anisian (Pelsonian).

**Description.** Left and right valves are of nearly the same size and show a symmetrical lateral outline. Dorsal margins of both valves are angled against the straight to slightly concave and gently inclined antero-dorsal margin and the strongly concave and more steeply inclined postero-dorsal margin. At the posterior end a short wing-like extension occurs, which is pointed at mid-height. The anterior margin is angled at mid-height (right valve) or above mid-height (left valve) and also shows a short extension. The ventral margin is concave in the right valve and straight to slightly concave in the left valve. The postero-ventral and antero-ventral marginal zones are laterally compressed and delimited from the lateral surface which is strongly inflated. The left valve overlaps the right valve only slightly along the dorsal margin, more strongly along the posterior and posteroventral

margins. The lateral surface is coarsely reticulate. Internal details not observed.

**Dimensions** (mm). Left valve – length: 0.99–1.18; height: 0.48–0.59; L/H: 1.89–2.15. Right valve – length: 0.98–1.09; height: 0.47–0.56; L/H: 1.88–2.08. Carapace width: 0.48.

**Occurrence.** As type locality and type horizon.

**Remarks.** A very similar species is *Lobobairdia? zapfei* Kozur, 1971 from Anisian of Balaton Area in Hungary (Kozur, 1971c; Monostori, 1995). In contrast to *L.? zapfei*, the right dorsal margin of *Bairdia schneebergiana* n. sp. is strongly angled, while the valve surface is less strongly delimited from the compressed antero- and postero-ventral lateral zones.

*Bairdia* sp. 1  
(Pl. 2, figs 2, 3)

**Material.** 4 valves.

**Dimensions** (mm). Left valve – length: 0.73–0.75; height: 0.38–0.40; L/H: 1.85–1.97.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** The present species is similar to *Bythocypris triassica* Kozur, 1968, from the Ladinian Muschelkalk in Germany (Kozur, 1968a). It differs from the latter species in the concave ventral margin in the left valve and the anterior angulation of the dorsal margin which is situated in a more anterior position.

*Bairdia* sp. 2  
(Pl. 2, figs 4, 5)

**Material.** 5 valves, 1 carapace.

**Dimensions** (mm). Left valve – length: 0.98–1.18; height: 0.58–0.7; L/H: 1.69.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** This species is similar to *Ptychobairdia kristanae praecursor* (Kozur, 1971a) with regard to the carapace outline. In contrast to the latter species it does not possess the dorsal and ventral ribs, the antero- and postero-dorsal margins are denticulate, while the valve surface exhibits a pustulose ornamentation.

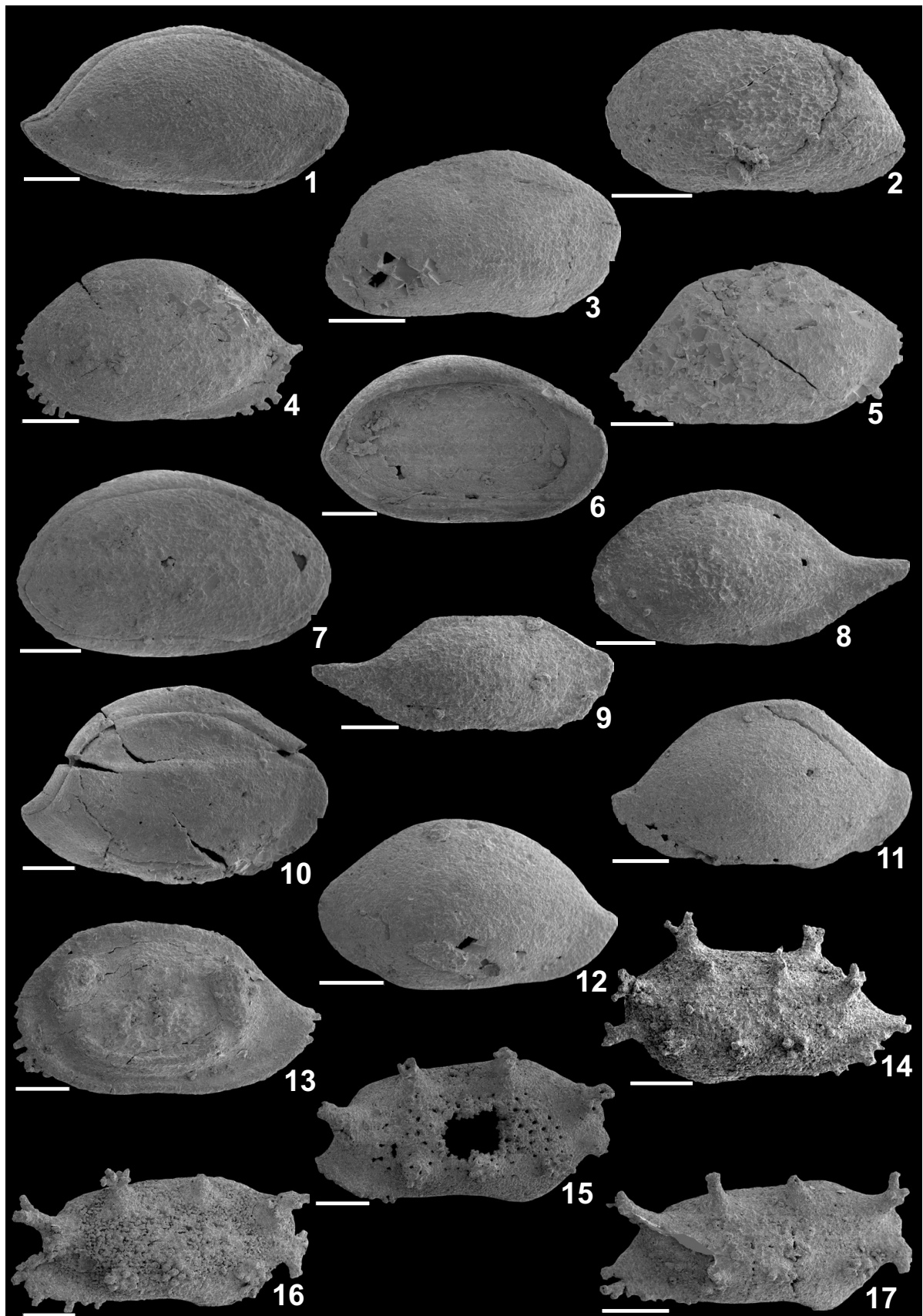
Genus *Urobairdia* Kollmann, 1963

*Urobairdia* sp. 1  
(Pl. 2, figs 8, 9)

**Material.** 11 valves, 2 carapaces.

**Dimensions** (mm). Left valve – length: 0.93–1.08; height: 0.46–0.5; L/H: 2.0–2.06.

**Occurrence.** Middle Anisian, Schneeberg, Austria.



**Remarks.** The left valve of the present material has a similar lateral outline close to *Urobairdia austriaca* Kollmann, 1963, but differs in the shape of the ventral margin which is almost straight and locally possessing a weak concavity mid-ventrally. It differs furthermore from the left valve of *U. austriaca* Kollmann, 1963 in the presence of a rim along the dorsal margin. In contrast to *U. austriaca* the dorsal and ventral margins of the right valve of *Urobairdia* sp. 1 are subparallel. Other conspicuous differences are the smaller carapace size, higher length/height ratio and the absence of a latero-ventral carapace inflation in our material. Although the present material is probably a new species, it is left in open nomenclature due to the low number of specimens and the poor preservation.

Genus *Ptychobairdia* Kollmann, 1960

*Ptychobairdia kristanae praecursor* (Kozur, 1971)  
(Pl. 2, figs 10–12)

1971a *Triebelina kristanae praecursor* Kozur: 10–11; fig. 3A, B, E, F.

**Material.** 7 adult valves, 2 adult carapaces, 16 juvenile valves, 2 juvenile carapaces.

**Dimensions** (mm). Left valve, carapace – length: 1.18–1.23; height: 0.63–0.76; L/H: 1.55–1.79. Right valve – length: 1.05–1.2; height: 0.59–0.69; L/H: 1.74–2.0.

**Occurrence.** Upper Anisian (Illyrian), Hungary (Kozur, 1971a); Middle Anisian, Schneeberg, Austria.

**Remarks.** The present material corresponds to the subspecies described as *Ptychobairdia kristanae praecursor* from the Anisian of Hungary (Kozur, 1971a) in the shape of the valves and type of ornamentation. In the present material the dorsal rib is less strongly developed, while the valve size is larger. These differences could be caused by ecological factors related to water depth. According to the description and illustrations in Kozur (1971a), this subspecies differs strongly from *Ptychobairdia kristanae* Kollmann, 1960 in the much narrower ventral surface, the angulation of the dorsal margin, the different shape of the right valve and smaller carapace size. It should therefore be re-described as a new species if the type material is still available.

Genus *Mirabairdia* Kollmann, 1963

*Mirabairdia praepsychrosphaerica* n. sp.  
(Pl. 2, figs 14–17)

**Derivation of name.** Indicating that this species represents a precursor to *Nodobairdia psychrosphaerica* (Kozur, 1973).

**Diagnosis.** A species of *Mirabairdia* characterized by the presence of seven prominent and distally bifurcated spines and three tubercles on the left valve, with five spines and three tubercles on the right valve. Along the posteroventral margin there is a coarse denticulation.

**Holotype.** A left valve, Me 2013-92/16 (Pl. 2, fig. 14).

**Paratypes.** Me 2013-1/29 (Pl. 2, fig. 16), Me 2013-92/20 (Pl. 2, fig. 17), Me 2013-92/11, Me 2013-1/39.

**Material.** 54 valves.

**Type locality.** The southeastern slope of the Schneeberg near Puchberg, forest road outcrop [UTM 563129E, 5289077N], Niederösterreich (Austria).

**Type horizon.** A limestone with siliceous nodules, basal bed of the Grafensteigkalk, Reifling Formation, Middle Anisian (Pelsonian).

**Description.** The dorsal margin on both valves possesses clear cardinal angulations at the antero- and postero-dorsal borders. In the left valve the dorsal margin is straight and subparallel to the slightly concave ventral margin. The angle of the dorsal margin with the straight antero-dorsal margin is about 30° and with the straight postero-dorsal margin is at about 45°. Along the anterior margin there is a narrow convexity situated above mid-height with a gentle convexity situated below mid-height. The posterior margin is pointed below mid-height, with a slight posteroventral convexity, gradually extending into the ventral margin. The right valve differs from the left valve in a more slender lateral outline, a gentle backward inclination of the dorsal margin and a more poster-ventrally positioned pointed posterior end.

The ornamentation of the left and right valve differs. On the dorsal and anterior margins, and on the lateral valve surface, are five to seven strong spines and three tubercles. The spines and tubercles are split into two or more secondary spines. On the left valve there are seven spines and three tubercles. Two spines are situated at the antero- and postero-dorsal cardinal angles. Towards the dorsal margin are four spines, two of which are located in the central sub-dorsal area, and one each towards the antero-dorsal and postero-dorsal margins, immediately above mid-height. Another strong and bifurcated spine is situated at the anterior margin at or just below mid-height. Ventro-laterally, close to the antero-ventral margin are three tubercles. The tubercles show a secondary ornamentation towards their terminal ends consisting of several short spines. The right valve shows a corresponding surface ornamentation similar to the left valve but lacking the two spines situated at the antero- and postero-dorsal angulations. The postero-ventral margin possesses a coarse

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**Explanation of Plate 2. fig. 1.** *Bairdia cassiana* (Reuss, 1868). Carapace, right lateral view, Me 2013-9/16. **figs 2–3.** *Bairdia* sp. 1: **2**, left valve, Me 2013-93/55; **3**, right valve, Me 2013-93/57. **figs 4–5.** *Bairdia* sp. 2: **4**, left valve, Me 2013-6/50; **5**, right valve, Me 2013-7/43. **figs 6–7.** *Cryptobairdia atudoreii* (Crasquin-Soleau & Gradinaru, 1996): **6**, left valve, internal view, Me 2013-91/29; **7**, carapace, right lateral view, Me 2013-7/2. **figs 8–9.** *Urobairdia* sp. 1: **8**, left valve, Me 2013-1/12; **9**, right valve, Me 2013-1/11. **figs 10–12.** *Ptychobairdia kristanae praecursor* (Kozur, 1971): **10**, carapace, right lateral view, Me 2013-93/62; **11**, right valve, Me 2013-93/64; **12**, left valve, Me 2013-93/63. **fig. 13.** *Nodobairdia martinsonii* (Kozur, 1971). Left valve, Me 2013-1/7. **figs 14–17.** *Mirabairdia praepsychrosphaerica* n. sp.: **14**, left valve, Me 2013-92/16 (holotype); **15**, right valve, Me 2013-92/10; **16**, right valve, Me 2013-1/29 (paratype); **17**, right valve, Me 2013-92/20 (paratype). Scale bars = 200 µm.

denticulation. Well-preserved specimens have a coarse valve surface reticulation. Internal features are not described due to poor preservation. The hinge is not differentiated, while the calcareous inner lamella is narrow.

**Dimensions** (mm). Left valve – length: 1.12–1.27; height: 0.52–0.64; L/H: 1.98–2.34. Right valve – length: 1.12–1.27; height: 0.49–0.0.53; L/H: 2.11–2.59.

**Occurrence.** As type locality and type horizon.

**Remarks.** The present species has a similar type of ornamentation to *Vavilovella psychrosphaerica* Kozur, 1973, from the Rhaetian of Austria (Kozur, 1973) and *Mirabairdia longispinosa* Kristan-Tollmann, 1978 from the Carnian Kassian Formation of Italy (Kristan-Tollmann, 1978) and is therefore suggested to represent a closely related early precursor of the Carnian and Rhaetian species. It can be distinguished from *V. psychrosphaerica* by the presence of tubercles instead of spines along the ventro-lateral surface and a much coarser denticulation at the postero-ventral margin. *Mirabairdia praepsychrosphaerica* n. sp. furthermore lacks the long spine situated at the posterior end which is typical for *V. psychrosphaerica*. Instead of an incurved spine, *M. praepsychrosphaerica* n. sp. possesses a straight and bifurcated spine at the anterior margin just below mid-height. This present species can be distinguished from *M. longispinosa* by the more robust and distally bifurcated dorsal and subdorsal spines and reticulation upon the valve surface.

As suggested by Kristan-Tollmann (1978), species of *Mirabairdia* and *Nodobairdia* show gradual differences in surface ornamentation. The genera, therefore, cannot be clearly separated only on the basis of ornamentation. It seems probable that *Mirabairdia* is synonymous with *Nodobairdia*. An emendation of these taxa should, however, consider internal features, such as muscle scar patterns and hinge structures, which are not well known at present.

*Mirabairdia plurispinosa* n. sp.  
(Pl. 3, figs 1–6)

**Derivation of name.** Referring to the large number of spines on the lateral valve surface and along the dorsal margin of the left valve.

**Diagnosis.** A species of *Mirabairdia* with a large number of spines situated along the dorsal margin of the left valve and a strong reticulation of the lateral valve surface.

**Holotype.** A left valve, Me 2013-5/2 (Pl. 3, fig. 1).

**Paratypes.** Me 2013-5/21 (Pl. 3, fig. 4), Me 2013-5/4 (Pl. 3, fig. 2), Me 2013-5/13 (Pl. 3, fig. 5), Me 2013-5/14 (Pl. 3, fig. 6).

**Material.** 92 valves.

**Type locality.** The southeastern slope of the Schneeberg near Puchberg, forest road outcrop [UTM 563129E, 5289077N], Niederösterreich (Austria).

**Type horizon.** A limestone with siliceous nodules, basal bed of the Grafensteigkalk, Reifling Formation, Middle Anisian (Pelsonian).

**Description.** The dorsal margin of the left valve is straight and parallel to the slightly concave ventral margin. Its straight antero- and postero-dorsal margins are distinctly angled to the dorsal margin and are inclined at about 45° towards the posterior end and about 30° towards the anterior end. The anterior margin of the left valve is narrowly rounded at mid-height and gently convex antero-ventrally. The posterior margin is pointed below mid-height and gently convex postero-ventrally. The right valve is more elongate in lateral view and possesses a gentle inclination of the straight dorsal margin against the posterior end. The anterior, posterior and ventral margins of the right valve have a similar shape to the left valve.

The left valve possesses numerous spines which are concentrated along the dorsal and ventral margins. The spines along the dorsal margin are relatively long and prominent. Along the ventro-lateral surface numerous spines are situated on a ventro-lateral ridge which runs parallel to the ventral and antero-ventral margins. These spines are much smaller and shorter than the dorsal spines and increase in length anteriorly. Close to the antero- and postero-dorsal margins are two very broad and prominent spines bearing several short secondary spines. The anterior margin bears a prominent broad and bifurcated spine, while the postero-ventral margin possesses four to five simple or bifurcated relatively strong spines. The central part of the lateral surface is characterized by a coarse reticulation and a number of irregularly arranged tubercles. The ornamentation of the right valve differs from the left valve by the absence of spines along the dorsal margin and the occurrence of three sub-dorsal spines parallel to the dorsal margin. These sub-dorsal spines are also distally bifurcated into secondary spines. Below the posteriormost of the sub-dorsal spines are two or three tubercles arranged in a vertical row. The hinge is not differentiated. The calcareous inner lamella is narrow.

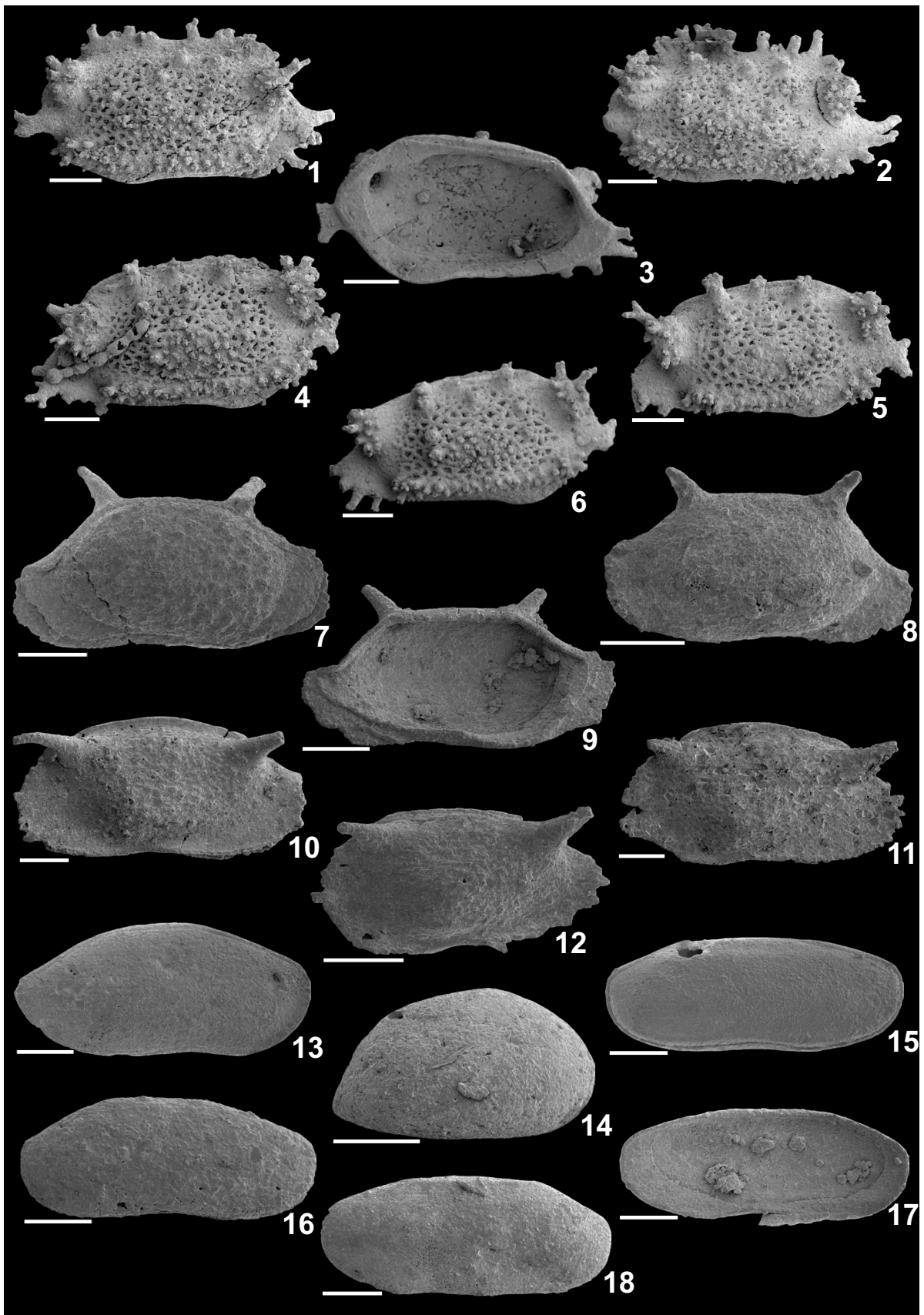
**Dimensions** (mm). Right valve – length: 0.92–1.13; height: 0.46–0.56; L/H: 1.75–2.04 (average: 1.91). Left valve – length: 0.95–1.07; height: 0.46–0.57; L/H: 1.7–2.02 (average: 1.87).

**Occurrence.** As the type locality and type horizon.

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**Explanation of Plate 3. figs 1–6.** *Mirabairdia plurispinosa* n. sp.: 1, left valve, Me 2013-5/2 (holotype); 2, left valve, Me 2013-5/4 (paratype); 3, right valve, internal view, Me 2013-5/22; 4, right valve, Me 2013-5/21 (paratype); 5, right valve, Me 2013-5/13 (paratype); 6, right valve, Me 2013-5/14 (paratype). **figs 7–9.** *Petasobairdia longispinosa* (Kozur, 1971): 7, carapace, right lateral view, Me 2013-92/30; 8, left valve, Me 2013-92-25; 9, left valve, internal view, Me 2013-92/31. **figs 10–12.** *Processobairdia* sp. 1: 10, left valve, Me 2013-1/19; 11, left valve, Me 2013-1/17; 12, left valve, juvenile, Me 2013-3/32. **fig. 13.** *Bairdiacypris anisica* Kozur, 1971. Carapace, right lateral view, Me 2013-9/43. **fig. 14.** *Bairdia* sp. 3. Right valve, Me 2013-91/27. **figs 15–18.** *Bairdiacypris aequisymmetrica* n. sp.: 15, carapace, right lateral view, Me 2013-91/60 (holotype); 16, right valve, Me 2013-91/57 (paratype); 17, right valve, internal view, Me 2013-91/59 (paratype); 18, left valve, Me 2013-91/58 (paratype). Scale bars = 200 µm.





**Remarks.** The most conspicuous difference between the present species and other species of *Mirabairdia* is the presence of numerous spines along the dorsal margin of the left valve instead of two antero- and postero-dorsal spines. *Mirabairdia plurispinosa* n. sp. shows a similar type of ornamentation to *M. pernodosa illyrica* (Kozur, 1971) from the Anisian of Slovakia (Kozur, 1971a), but differs from that species by the occurrence of spines along the postero-ventral margin and the more distinct reticulation on the lateral valve surface. The present species can be distinguished from *M. spinosa* (Kozur, 1971) by the different shape of the left valve, the absence of three prominent ventral knobs in the right valve and the irregular arrangement of tubercles in the left valve. Despite these differences the two species from the Anisian of Slovakia are probably closely related to *Mirabairdia plurispinosa* n. sp.

Genus *Petasobairdia* Chen in Chen & Shi, 1982

*Petasobairdia longispinosa* (Kozur, 1971)  
(Pl. 3, figs 7–9)

- 1971a *Ceratobairdia longispinosa* Kozur: 4; pl. 1, fig. e.  
1984 *Ceratobairdia longispinosa* Kozur; Salaj & Jendrejáková: pl. 1, fig. 12, pl. 3, figs 1–4.  
?1996 *Ceratobairdia* cf. *longispinosa* Kozur; Crasquin-Soleau & Gradinaru: pl. 5, fig. 6.  
2013 *Ceratobairdia longispinosa* Kozur; Monostori & Tóth: 314; pl. 3, fig. 1.  
2013 *Ceratobairdia longispinosa* Kozur; Sebe *et al.*: 520; pl. 3, fig. 11.

**Material.** 25 valves, 10 carapaces.

**Dimensions** (mm). Left valve, carapace – length: 0.86–0.93; height: 0.41–0.45; L/H: 1.91–2.16.

**Occurrence.** Upper Anisian (Illyrian) (Kozur, 1971a); Slovakia; Middle Triassic, Romania (Salaj & Jendrejáková, 1984); Lower Anisian, Romania (Crasquin-Soleau & Gradinaru, 1996; Sebe *et al.*, 2013); Ladinian, Hungary (Monostori & Tóth, 2013); Middle Anisian, Schneeberg, Austria.

**Remarks.** In contrast to the type species of *Ceratobairdia* in Sohn (1954), the present species does not show a ventrolateral alate ridge and a flat ventral surface, while the hinge of the left valve is not differentiated into a bar and grooves. Furthermore the anterior and posterior marginal zones are laterally compressed. Therefore this species is removed from *Ceratobairdia* and assigned to *Petasobairdia*, which is very similar with regard to the carapace outline. According to the similar carapace outline, *Ceratobairdia crassa* Kristan-Tollmann, 1970 should probably also be assigned to *Petasobairdia*. The hinge structure of *Petasobairdia*, however, is not yet known. The material includes specimens with a strong pustulose ornamentation on the inflated part of the lateral surface. Because of the low quantity of material and poor preservation it is questionable if these specimens represent a different species or if the ornamentation is due to intra-specific variability.

Genus *Processobairdia* Blumenstengel, 1965

*Processobairdia* sp. 1  
(Pl. 3, figs 10–12)

**Material.** 4 broken left valves (2 adults, 2 juveniles).

**Dimensions** (mm). Length: 1.23; height: 0.57–0.61; L/H: 2.0–2.2.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** The present specimens are the first representatives of the genus *Processobairdia* from the Mesozoic. The species is characterized by two long spines which are situated close to the antero-dorsal and postero-dorsal margins of the left valve. The antero-dorsal spine is gently curved and directed forwards. The postero-dorsal spine is straight and has a postero-dorsal inclination. The dorsal margin of the left valve is gently convex while the ventral margin is concave. The left valve's anterior margin is broadly rounded. The left valve's posterior margin consists of an oblique postero-dorsal part and a narrowly rounded postero-ventral part. On the centro- and dorso-lateral surface are coarse pustules. The anterior and posterior parts of the lateral surface are smooth. The left valve's dorsal margin is delimited from the lateral surface by a narrow frill. Along the anterior and postero-ventral margins are coarse denticles. *Processobairdia* sp. 1 differs from the other species of this genus by this type of ornamentation. The only comparable species is *Processobairdia dreeseni* Bless, 1985, which was reported from the Upper Devonian of Belgium (Dreesen *et al.*, 1985). The present species can be distinguished from the latter species by the different orientation of the spines, the lack of a second antero-dorsal spine and the convex dorsal margin.

Genus *Bairdiacypris* Beadfield, 1935

*Bairdiacypris anisica* Kozur, 1971  
(Pl. 3, fig. 13)

- 1971c *Bairdiacypris anisica* n. sp.; Kozur: 4–5; figs 2B, C, E–G.  
1984 *Bairdiacypris anisica* Kozur; Salaj & Jendrejáková: pl. 1, fig. 2.  
1995 *Bairdiacypris anisica* Kozur; Monostori: 46; pl. 5, fig. 3.  
?1996 *Bairdiacypris galbruni* n. sp. Crasquin-Soleau & Gradinaru: 83–84; pl. 5, figs 1–5.  
2010 *Bairdiacypris anisica* Kozur; Crasquin *et al.*: 353; fig. 22Y-A.  
2011 *Bairdiacypris anisica* Kozur; Forel & Crasquin: pl. 1.  
2011 *Bairdiacypris anisica* Kozur; Forel *et al.*: pl. 1, fig. 5.  
2013 *Bairdiacypris anisica* Kozur; Monostori & Tóth: 312, pl. 3, figs 6, 9, 12, 14.  
2013 *Bairdiacypris anisica* Kozur; Sebe *et al.*: 516; pl. 3, fig. 3.

**Material.** 17 carapaces, 22 valves.

**Dimensions** (mm). Left valve, carapace – length: 1.01–1.15; height: 0.46–0.51; L/H: 2.06–2.39.

**Occurrence.** Upper Anisian (lower Illyrian), Hungary (Kozur, 1971c); ?Middle Triassic, Romania (Salaj & Jendrejáková, 1984); Anisian, Hungary (Monostori, 1995); Lower to Middle Anisian, Romania (Crasquin-Soleau & Gradinaru, 1996; Sebe *et al.*, 2013); uppermost Permian (Changhsingian)–lowermost Triassic (Griesbachian), Meishan, China (Crasquin *et al.*, 2010; Forel & Crasquin, 2011); Lower–Middle Triassic (Olenekian–Anisian),

South Tibet (Forel *et al.*, 2011); Ladinian, Hungary (Monostori & Tóth, 2013); Middle Anisian, Schneeberg, Austria.

**Remarks.** The present material shows some intra-specific variability in the lateral carapace outline. Some specimens display a more asymmetrical convexity along the antero-ventral margin of the left valve and a more distinctly pointed posterior end than the type material. Furthermore the present specimens have a 15% lower average length/height ratio than the type material of Kozur (1971c). These differences are, however, interpreted as intraspecific variability.

*Bairdiacypris aequisymmetrica* n. sp.  
(Pl. 3, figs 15–18)

**Derivation of name.** Referring to the very similar shape of the anterior and posterior margins of the carapace.

**Diagnosis.** A species of *Bairdiacypris* with an almost symmetrical shape for both the anterior and posterior margins, left and right valves and an almost symmetrical convexity of the dorsal margin.

**Holotype.** A carapace, Me 2013-91/60 (Pl. 3, fig. 15).

**Paratypes.** Me 2013-91/57 (Pl. 3, fig. 16), Me 2013-91/58 (Pl. 3, fig. 18), Me 2013-91/59 (Pl. 3, fig. 17).

**Material.** 5 carapaces, 5 valves.

**Type locality.** The southeastern slope of the Schneeberg near Puchberg, outcrop [UTM 563129E, 5289077N], Niederösterreich (Austria).

**Type horizon.** A limestone with siliceous nodules, basal bed of the Grafensteigkalk, Reifling Formation, Middle Anisian (Pelsonian).

**Description.** The right and left valves of this species are almost symmetrical in lateral outline. The right valve possesses a gently convex dorsal margin which is divided into three straight sections of almost equal length separated by two weak angulations. The middle section runs parallel to the ventral margin, the anterior section is slightly inclined, while the posterior section is a little more steeply inclined. The anterior and posterior margins are distinctly angled against the dorsal margin and are more or less symmetrical to each other. The ventral margin is concave and merges gradually into the anterior and posterior margins. The left valve's anterior and posterior ends are more asymmetrical to each other due to an oblique antero-ventral convexity. Furthermore the ventral concavity is less distinct in the left valve. The left valve overlaps the right valve along all margins except for mid-dorsally. Mid-ventrally the overlap is most distinct. In dorsal view the carapace is lens-shaped.

**Dimensions** (mm). Carapace, left valve – length: 0.89–1.03; height: 0.39–0.4; L/H: 2.3–2.6. Right valve – length: 0.93–1.0; height: 0.36–0.39.

**Occurrence.** As the type locality and type horizon.

**Remarks.** With regard to the lateral valve outline the present material is comparable with *Bairdiacypris* sp. *C sensu* Bolz, 1971 from the Rhaetian of Austria. The latter species is not described in detail and, unfortunately, the carapace is not illustrated. According to the illustrations in Bolz (1971), the present species is less strongly angled along the dorsal margin and also shows a less distinct ventral concavity.

*Bairdiacypris* cf. *triassica* Kozur, 1971  
(Pl. 4, figs 1, 2)

**Material.** 2 carapaces, 3 valves.

**Dimensions** (mm). Carapace, left valve – length: 0.73–0.91; height: 0.33–0.4; L/H: 2.18–2.28.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks:** This species corresponds to *Bairdiacypris triassica* Kozur, 1971c from Anisian of Hungary in its lateral valve outline; however, the dorsal overlap is less distinct in the present specimens. Furthermore the length/height ratio of the present specimens is higher. It is not clear if this deviation is due to intraspecific variability, because the present species is represented by only a few specimens.

Superfamily **Cytheroidea** Baird, 1850  
Family **Bythocytheridae** Sars, 1866  
Genus *Nemoceratina* Gründel & Kozur, 1971

*Nemoceratina* sp. 1  
(Pl. 4, fig. 8)

**Material.** 3 valves, 1 carapace.

**Dimensions** (mm). Carapace, left valve – length: 0.5–0.59; height: 0.21–0.23; L/H: 2.4–2.6.

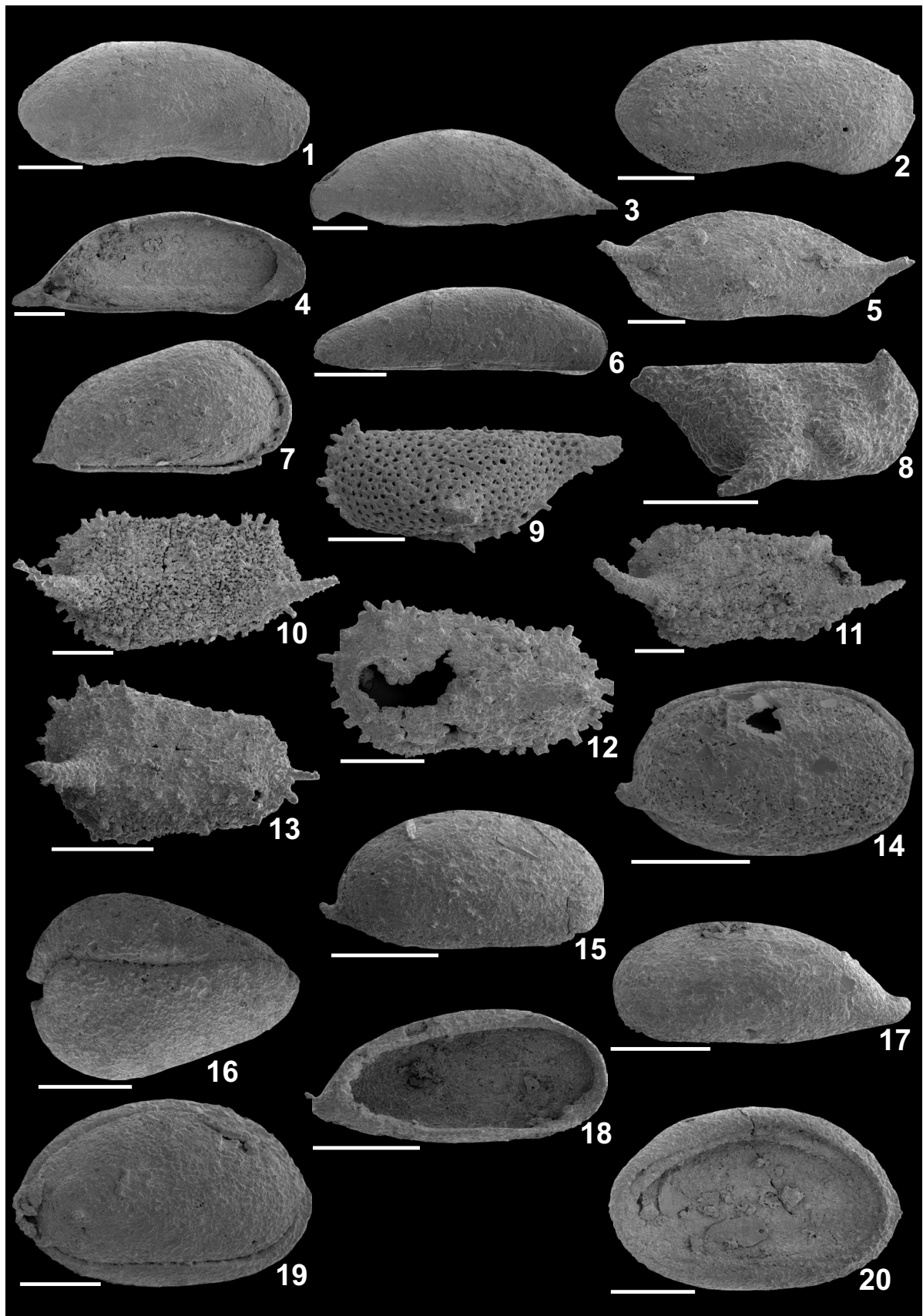
**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** The present species exhibits a similar lateral carapace outline and type of ornamentation to *Nemoceratina triassica* (Kozur, 1970). In contrast to the latter species from the Upper Anisian of Hungary (Kozur, 1970a), the present specimens do not have a knob-like protruberance immediately in front of the prominent ventro-lateral spine. Furthermore, the long ventro-lateral spine is less pointed, while the lateral surface shows a regular reticulation. *Nemoceratina* sp. 1 probably represents a new species; however, the amount and preservation of the material is not sufficient for the definition of a new taxon.

Cytheroidea gen. et sp. indet.  
(Pl. 4, figs 10–13)

**Material.** 6 left valves.

**Description.** According to the lateral valve outline, the present material is assigned to the Cytheroidea. The anterior margin is broadly and symmetrically convex, gradually extending into both the straight dorsal margin and concave ventral margin. The posterior margin is narrowly convex postero-ventrally and



straight postero-dorsally. This species is characterized by the occurrence of a prominent forwards-directed spine situated close to the anterior margin at or just below mid-height and another long backwards-directed spine close to the postero-ventral margin. The lateral surface and the anterior margin are ornamented by numerous smaller spines. Along the posterior margin are a variable number of spines which may be due to differential preservation.

**Dimensions** (mm). Length: 0.64–0.9; height: 0.36–0.5; L/H: 1.78–1.84.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** The species most probably represents a new genus of Cytheroidea because there is no comparable taxon recorded in the Triassic.

Superfamily **Bairdiocypridoidea** Shaver, 1961  
Family **Pachydomellidae** Berdan & Sohn, 1961  
Genus *Spinomicrocheilinella* Kozur, 1991

*Spinomicrocheilinella* sp. 1  
(Pl. 4, figs 14–16)

**Material.** 3 carapaces, 8 valves.

**Dimensions** (mm). Carapace, left valve – length: 0.46–0.52; height: 0.25–0.31; L/H: 1.59–1.84; width (carapace): 0.41. Right valve – length: 0.4–0.53; height: 0.21–0.27; L/H: 1.9–1.96.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** Both valves possess a relatively strong convex dorsal outline, while the ventral outline is more gently convex. The relatively straight dorsal margin is slightly inclined towards the posterior margin. The greatest width is situated behind mid-length. Along the postero-ventral margin of both valves there is a short but distinct upward-directed spine. The left valve strongly overlaps the right valve, except postero-ventrally. The present material is the first record of this genus in the Mesozoic.

*Spinomicrocheilinella* sp. 2  
(Pl. 4, figs 17, 18)

**Material.** 3 left valves.

**Dimensions** (mm). Length: 0.53–0.56; height: 0.25; L/H: 2.1–2.2.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** In contrast to *Spinomicrocheilinella* sp. 1, the present species possesses a moderate dorsal convexity, while the maximum width is situated at mid-length. The dorsal margin is more distinctly inclined towards the posterior end. In lateral view the valves taper towards the posterior margin, with a strong and blunt postero-ventral spine which curves upwards.

Suborder **Metacopina** Sylvester-Bradley, 1961  
Superfamily **Healdioidea** Harlton, 1933  
Family **Healdiidae** Harlton, 1933  
Genus *Hungarella* Méhés, 1911

*Hungarella* cf. *problematica* (Méhés, 1911)  
(Pl. 4, figs 19, 20)

**Material.** 14 carapaces, 17 valves.

**Dimensions** (mm). Carapace, left valve – length: 0.59–0.73; height: 0.39–0.48; L/H: 1.47–1.58.

**Occurrence.** Middle Anisian, Schneeberg, Austria.

**Remarks.** In contrast to *Hungarella problematica* (Méhés, 1911) in Monostori & Tóth (2013) and *Hungarella (Healdia) felsooerensis* Kozur, 1970a, the present specimens do not show a lateral compression of the posterior end, while the length/height ratio of the carapace is a little higher. Furthermore a posterior spine is recorded in only one specimen. The postero-lateral compression and posterior spines were not reported for the type material in Méhés (1911). According to Monostori & Tóth (2013), most specimens exhibit a posterior spine but the lateral compression is more or less distinct. Therefore the differences may be the result of intraspecific variability and different preservation.

#### PALAEOECOLOGY AND EVOLUTIONARY ASPECTS OF THE OSTRACOD ASSEMBLAGE

Ostracod faunas that are characteristic of deep water, low energy, environments and differ from their contemporary neritic forms by their thin tests and/or the presence of delicate or long spines were described as ‘palaeopsychrospheric ostracods’ (Kozur, 1972, 1991) and the ‘Thuringian Ecotype’ (Bandel & Becker, 1975). The term ‘palaeopsychrospheric’ was proposed by Kozur (1972) to indicate this special kind of ostracod assemblage recorded in the Early Palaeozoic–Early Mesozoic interval. The interpretation as ‘palaeopsychrospheric’ was based on morphological analogy

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**Explanation of Plate 4.** **fig. 1, 2.** *Bairdiocypris* cf. *triassica* Kozur, 1971: **1**, carapace, right lateral view, Me 2013-91/62; **2**, right valve, Me 2013-91/63. **figs 3–4.** *Acratia goemoeryi* (Kozur, 1970): **3**, left valve, Me 2013-91/1; **4**, left valve; internal view, Me 2013-2/13. **fig. 5.** *Acanthoscapha bogschi* Kozur, 1971. Left valve, Me 2013-1/24. **fig. 6.** *Praemacrocypris mocki* Kozur, 1971. Carapace, right lateral view, Me 2013-2/5. **fig. 7.** *Spinocypris vulgaris* Kozur, 1971. Carapace, right lateral view, Me 2013-91/23. **fig. 8.** *Nemoceratina* sp. 1. Right valve, Me 2013-2/30. **fig. 9.** *Paraberounella oertlii* Kozur, 1972. Left valve, Me 2013-7/29. **figs 10–13.** Cytheroidea gen. et sp. indet.: **10**, left valve, Me 2013-1/13; **11**, left valve, Me 2013-1/15; **12**, left valve, juvenile, Me 2013-1/14; **13**, left valve, juvenile, Me 2013-1/16. **figs 14–16.** *Spinomicrocheilinella* sp. 1: **14**, carapace, right lateral view, Me 2013-91/47; **15**, right valve, Me 2013-3/29; **16**, carapace, ventral view, Me 2013-7/36. **figs 17–18.** *Spinomicrocheilinella* sp. 2: **17**, left valve, Me 2013-7/56; **18**, left valve, internal view, Me 2013-7/35. **figs 19–20.** *Hungarella* cf. *problematica* (Méhés, 1911): **19**, carapace, right lateral view, Me 2013-91/50; **20**, left valve, internal view, Me 2013-91/41. Scale bars = 200 µm.

with the Cenozoic to modern psychrospheric ostracod fauna indicating water depth below 200–500m (e.g. an absence of eye tubercles in those taxa which usually possess eye tubercles in shallow waters) and on taxonomic disparity between deep- and shallow-marine faunas. The modern psychrosphere is defined as the lower cold level of the modern ocean, as opposed to the thermosphere, the less dense and warmer upper level (more than 10°C) (Benson & Sylvester-Bradley, 1971; Benson, 1972, 1975). Another main argument for this hypothesis was the high percentage of ‘archaic’ and cosmopolitan taxa which would not be possible under thermospheric conditions. The ‘Thuringian Ecotype’ was originally interpreted as an endemic deep-water fauna in the Devonian hemipelagic facies of the Rheinisches Schiefergebirge (Bandel & Becker, 1975). Later Becker (1979, 1981, 1982) stated that the ‘Thuringian Ecotype’ is not just restricted to Central Europe basinal environments but also occurs in protected low-energy settings of shallow-water environments. Becker (2000a) concluded that the main controlling factor for the different ecotypes is not primarily the water depths but the water energy levels.

During the Late Devonian–Carboniferous, Dinantian interval, deep-marine ostracods interpreted as palaeopsychrospheric forms are associated with bathyal, cold water environments and probably with low oxygen content (Lethiers & Crasquin, 1987; Crasquin-Soleau *et al.*, 1989; Lethiers & Feist, 1991). Similar assemblages were described from the Early Permian of Timor (Gründel & Kozur, 1975; Bless, 1987), the Middle Permian of Sicily (Kozur, 1991; Crasquin *et al.*, 2008), the latest Permian of South China (Yuan *et al.*, 2007), as well as in the Early and Middle? Triassic of the Alps (Kozur, 1972) and of Romania (Crasquin-Soleau & Gradinaru, 1996; Sebe *et al.*, 2013). The modern psychrospheric fauna is restricted to deep-water environments, from 500m to 5000m deep, in connection with a global ocean supplied with cold water by ice caps. The ostracod record suggests that a psychrosphere existed twice before the Eocene (Lethiers, 1998): the first one occurred during the Ordovician–Silurian (Blumenstengel, 1963, 1965) and the second one from the Late Devonian to the Carboniferous, Dinantian. Lethiers (1998) linked the existence of a two-layer ocean in the Palaeozoic with the presence of large ice caps and thermohaline circulation. The functioning of this system during the Late Permian and the Early Mesozoic, however, remains unexplained.

#### Characteristics of Middle Triassic deep- and shallow-water ostracod assemblages

Middle Triassic deep-marine (deep neritic to bathyal) ostracod assemblages have been described mainly from the Anisian and Ladinian of Hungary (Méhés, 1911; Kozur, 1970a, 1971a, b; Bunza & Kozur, 1971; Monostori, 1995; Monostori & Tóth, 2013). Other relatively large deep-marine assemblages were recorded from the Anisian of Romania (Mirăuță *et al.*, 1984, 1993; Crasquin-Soleau & Gradinaru, 1996; Sebe *et al.*, 2013). A few taxa of deep shelf environments are also known from Slovakia, Austria (Kozur, 1971a; Bunza & Kozur, 1971) and Turkey (Kozur *et al.*, 2000). There are, however, very few ostracod taxa of deep shelf or bathyal environments documented from outside of Europe. As stated by Kozur (1991), palaeopsychrospheric ostracod assemblages should be characterized by taxa with a cosmopolitan or at least wide geographical distribution. Since there are palaeobiogeographical data for Middle Triassic

deep-water ostracods of Europe only, it is not possible to decide if these faunas have a cosmopolitan character or not. Crasquin-Soleau & Gradinaru (1996: 94) suggested a ‘great homogeneity of faunas in the lower Anisian’ because four species from Romania are also recorded from Hungary, while a single species is also reported from the Permian of Timor.

Shallow-marine Middle Triassic ostracod assemblages are documented mainly from Germany, Poland and Italy (Knüpfer & Kozur, 1968; Kozur, 1968a, b; Kristan-Tollmann, 1970, 1971a, b; Styk, 1972, 1982). A few shallow-marine assemblages have been described from Slovakia and Hungary (Kozur, 1970a, 1971a, b), Spain (Kozur *et al.*, 1974), Jordan (Basha, 1982), Israel (Hirsch & Gerry, 1974; Honigstein & Crasquin, 2011), Russia (Gramm, 1970, 1975a, b), Canada (Sohn, 1987), India (Goel *et al.*, 1984), Iran (Kristan-Tollmann, 1991) and China (Guan, 1985; Kristan-Tollmann, 1983). Brackish-marine ostracods have also been described from the Middle Triassic of Germany (Kozur, 1968a, b, 1969, 1970b, 1974).

Despite this relatively poor faunal record the deep and shallow marine can be distinguished by some general characteristics. As already stated by Kozur (1970a), Monostori (1995) and Monostori & Tóth (2013), the deep-marine assemblages are dominated by smooth Bairdioidea and Healdiidae which are adapted to deep and calm environments. Another typical faunal element are the elongated and smooth taxa, such as *Acanthoscapa*, *Acratia*, *Praemacropypris*, *Spinocypris*, Cytheroidea with delicate spines, such as *Nagyella*, *Paraberounella*, and polycopids. Gründel & Kozur (1975) further stated that ‘psychrospheric’ assemblages show a high species diversity but low abundance of specimens. Other authors (Becker, 1982; Lethiers & Crasquin, 1987), however, reported a decreasing species diversity with increasing water depth. Shallow-water assemblages on the other hand are characterized by the predominance of thick-shelled and/or coarsely sculptured Bairdioidea and Cytheroidea.

#### Taxonomic composition, ecology and evolution

The present ostracod material which was picked by E. Kristan-Tollmann has been analysed with respect to the stratigraphic and geographical range (Fig. 2), and the relative and absolute abundance of the species (Figs 3–5) and families (Fig. 6). Some 43% (14 species) of the taxa are definitely recorded from Anisian localities outside of Austria (Fig. 2). The assemblage is characterized by a very strong dominance of the Bairdioidea (78.2% of specimens) and a very low abundance of the Cytheroidea (1.7% of specimens) (Figs 3, 4, 6). The present authors’ assemblage is a mixture of species which are reported from either neritic or deep-marine environments (Fig. 5).

*Shallow-water taxa.* Those species interpreted as shallow-water taxa comprise in total 41.5% of specimens. The most frequent taxon (20% of specimens) is *Bairdia cassiana* which is recorded by Kristan-Tollmann (1978) from the Ladinian–Carnian Cassian Formation in the Dolomites, described as a carbonate platform to basinal deposit (Fürsich & Wendt, 1977). The association with thick-shelled and strongly ornamented forms suggests a shallow basin environment. Other common species (more than 5% of specimens) are *Bairdia anisica* and *Mirabairdia plurispinosa* n. sp. The former has been reported from the Middle Triassic shallow-water facies (‘Muschelkalk’) of the Germanic Basin (Kozur,

	Upper Permian	Lower Triassic		Middle Triassic		Upper Triassic			Lower Jurassic
		Induan	Olenekian	Anisian	Ladinian	Carnian	Norian	Rhaetian	
<i>Polycope cincinnata</i> Apostolescu 1959				A / H / T	A / H			A	E / F / GE
<i>Polycope</i> cf. <i>bourquinae</i> Crasq.-S. & Grad. 1996				A / (R)					
<i>Bairdia anisica</i> Kozur 1970			C	A / C / GE					
<i>Bairdia cassiana</i> (Reuss 1868)				A / H / R	IT				
<i>Ptychobairdia kristanae praecursor</i> (Kozur 1971)				A / H					
<i>Cryptobairdia atudorei</i> Crasq.-S. & Grad. 1996				A / R / T					
<i>Petasobairdia longispinosa</i> (Kozur 1971)				A / R / SK	H				
<i>Nodobairdia martinsonii</i> Kozur 1971				A / H					
<i>Bairdiacypris</i> cf. <i>triassica</i> Kozur 1971				A / (H) / R	(H)	(H)			
<i>Bairdiacypris anisica</i> Kozur 1971	C	C	C	A / C / H / R	H				
<i>Spinocypris vulgaris</i> Kozur 1971			C	A / C / R / T	H				
<i>Acratia goemoeryi</i> (Kozur 1970)		A / C / GR / H / SK		A / C / H / R	H				
<i>Acanthoscapha bogschi</i> Kozur 1971				A / H / R	H				
<i>Praemacrocypris mocki</i> Kozur 1971				A / H / SK	H				
<i>Paraberounella oertlii</i> Kozur 1972				A / H / (IN)					
<i>Hungarella</i> cf. <i>problematica</i> (Méhés 1911)				A (H / R)	(H)	(H)			

Fig. 2. Stratigraphic and palaeogeographical ranges of ostracod species recorded outside of Austria. Symbols: A, Austria; C, China; F, France; GE, Germany; GR, Greece; H, Hungary; IN, India; IT, Italy; R, Romania; SK, Slovakia; T, Turkey; parentheses denote occurrence of similar and possibly conspecific taxa.

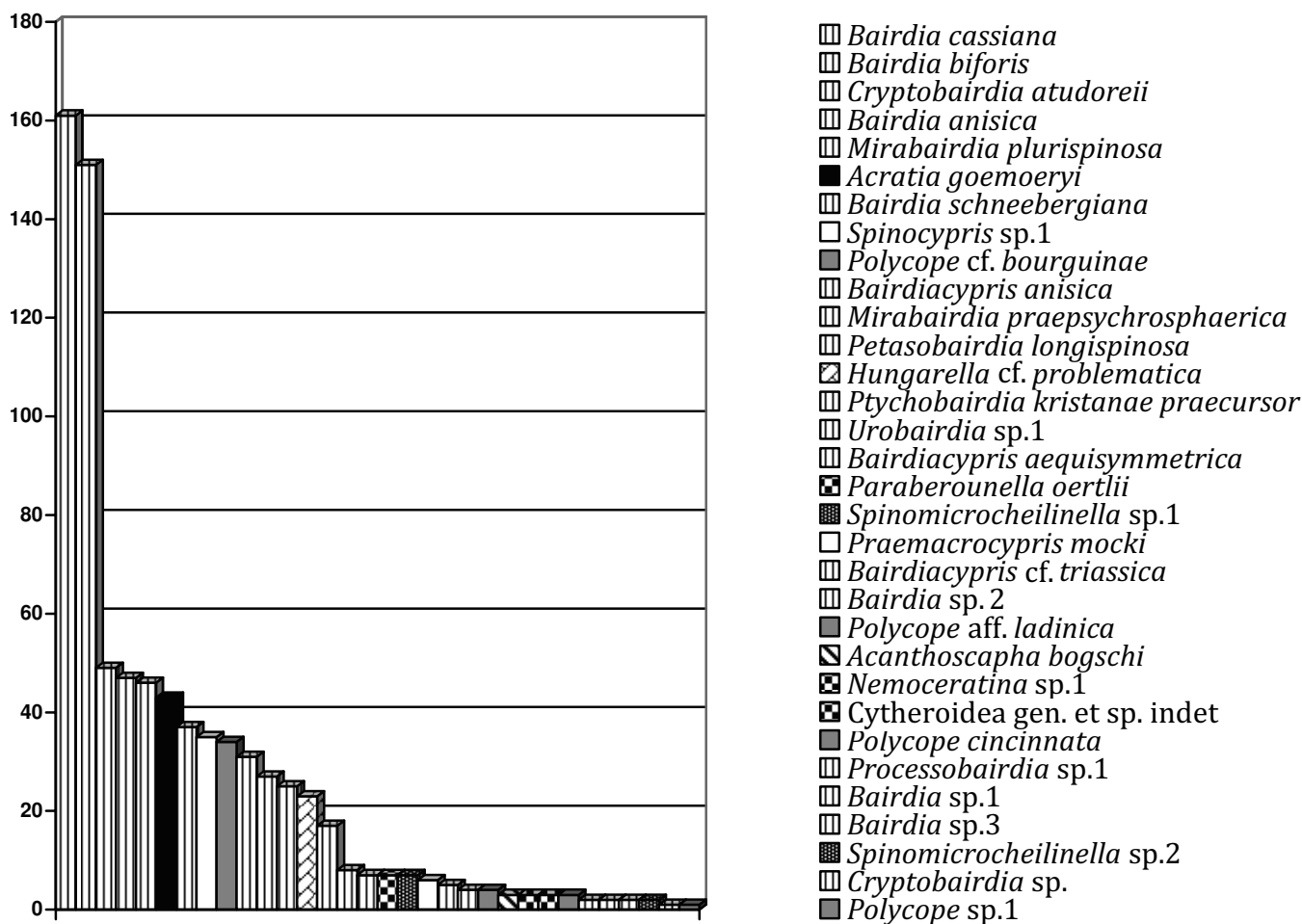


Fig. 3. Absolute abundance (number of specimens; one specimen corresponds to one carapace or two valves) of the ostracod species and taxonomic groups (species names are arranged according to their abundance from top to bottom; shading key in fig. 6).

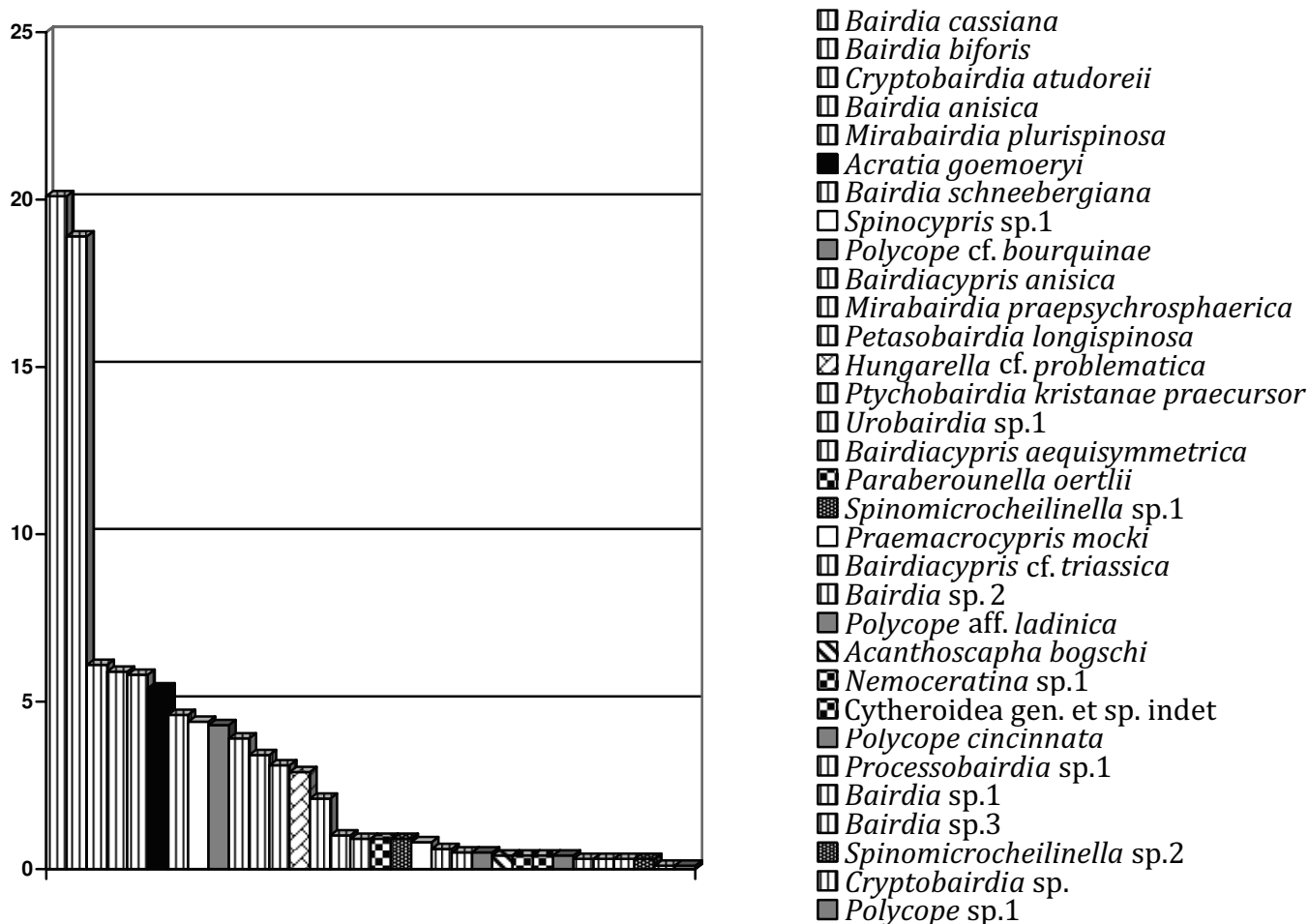


Fig. 4. Relative abundance (percentage of specimens) of the ostracod species and taxonomic groups (species names are arranged according to their abundance from top to bottom; shading key in fig. 6).

1970b), the Lower Anisian of Tibet (Forel & Crasquin, 2011) and the Spathian to Upper Anisian of China (Crasquin-Soleau *et al.*, 2006). The latter taxon is closely related to *Mirabairdia spinosa* and *M. pernodosa illyrica*, from the Anisian of Slovakia, which is a thick-shelled representative of the Bairdiidae adapted to shallow warm waters (Kozur, 1971a). *Bairdia schneebergiana* n. sp. may also be adapted to shallow-marine turbulent water because of morphological similarity with *Lobobairdia? zapfei*, which occurs in the Anisian shallow-marine crinoidal limestone of Hungary (Kozur, 1971a). Further species interpreted as shallow-marine taxa are *Petasobairdia longispinosa* and *Ptychobairdia kristanae praecursor*. The former taxon from the Anisian of Slovakia was assigned to a shallow low-energy environment, while the latter from the Anisian of Hungary to highly agitated shallow water (Kozur, 1971a). The above-mentioned species from shallow-marine deposits of Hungary and Slovakia were, however, only recorded from a single locality and therefore the total depth ranges of these species are poorly constrained.

*Deep-water taxa.* Besides these shallow-marine ostracods, several of the present authors' taxa have been interpreted as deep-marine

or palaeopsychrospheric forms (Kozur, 1972; Monostori, 1995; Crasquin-Soleau & Gradinaru, 1996; Monostori & Tóth, 2013; Sebe *et al.*, 2013) and are predominantly recorded from the Middle Triassic of Hungary and Romania. These taxa include *Cryptobairdia atudoreii*, *Bairdiacypris anisica*, *Acratia goemoeryi*, *Praemacrocypris mocki*, *Spinocypris vulgaris*, *Acanthoscapha bogschi*, *Hungarella problematica* and *Paraberounella oertlii*. Further species which were most probably adapted to deep-marine environments are *Mirabairdia praepsychrosphaerica* n. sp., *Nemoceratina* sp. 1, *Processobairdia* sp. 1 and *Cytheroidea* gen. et sp. indet. The total relative abundance of taxa assigned to the deep-marine environments is 34.6% of the specimens. *Mirabairdia praepsychrosphaerica* n. sp. is closely related to *Vavilovella psychrosphaerica*, which was interpreted as a deep shelf to upper bathyal species (150–500 m) (Kozur, 1973). *Nemoceratina* sp. 1 shows a close relationship to *N. triassica*, which has been described from the Upper Anisian deep-water facies of Hungary (Kozur, 1970a). *Processobairdia* is so far known only from Silurian–Devonian deep-marine deposits and assigned to the Thuringian Ecotype (Becker, 2000a). Bless & Michel (1967) suggested a free swimming life habit due to the wide geographical



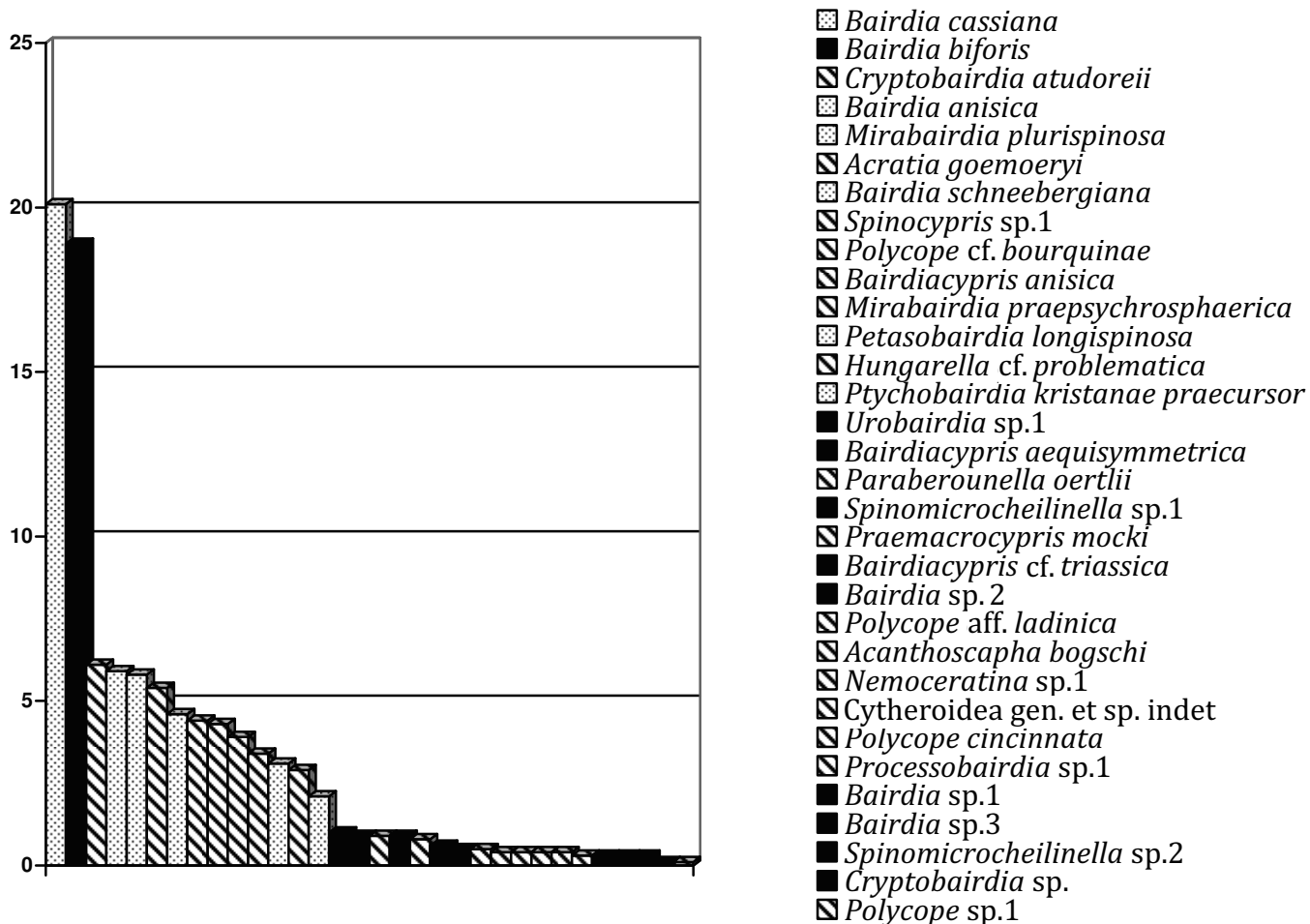


Fig. 5. Relative abundance (percentage of specimens) of shallow-water species (dots), deep-water species (oblique hatching) and species of unknown depth range (black); species names are arranged according to their abundance from top to bottom.

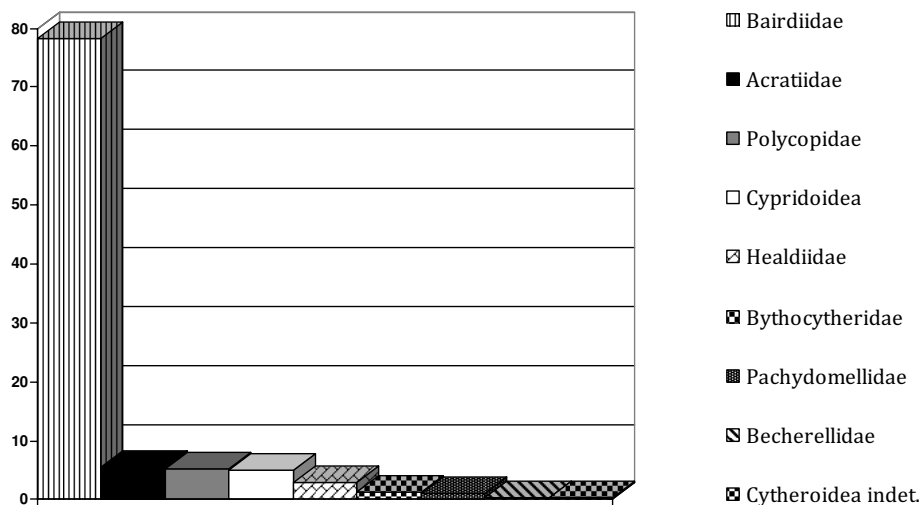


Fig. 6. Relative abundance (percentage of specimens) of ostracod families. Key: black, Acratiidae; white, Cypridoidea; grey, Polycopidae; vertical hatching, Bairdiidae; oblique hatching, Becherellidae; dots, Pachydomellidae; brick pattern, Healdiidae; checked pattern, Cytheroidea.

range of some of its species and the type of ornamentation. Cytheroidea gen. et sp. indet. shows characteristic morphological features of the ‘palaeopsychrospheric ostracods’ and ‘Thuringian Ecotype’, such as the ornamentation with numerous delicate spines and a thin-shelled carapace, and so is most probably adapted to deep and low-energy conditions. Another important part of the assemblage are species of the genus *Polycope*: *P. cf. bourquinae*, *P. aff. ladinica*, *P. cincinnata* and *P. sp. 1*. These species are not palaeopsychrospheric *sensu stricto* but are commonly associated with deep-marine assemblages (see Kozur, 1991; Crasquin-Soleau & Gradinaru, 1996; Sebe *et al.*, 2013).

The depth range of other species is questionable. Ostracods with a similar carapace morphology to *Bairdia biforis* n. sp (from the Upper Carboniferous deposits of Hungary) are interpreted as shallow-water taxa (Kozur, 1985). *Spinomicrocheilinella* was reported from the Permian deep-water sediments of Sicily (Kozur, 1991), but Kozur (1991) noted that younger species are found in shallow-water deposits. Species from the latest Permian of South China were considered as palaeopsychrospheric taxa by Yuan *et al.* (2007).

The high abundance of neritic species (41.6%) on the one hand and the occurrence of several deep-marine species on the other hand (Fig. 4) suggest a deep neritic or transitional neritic–upper bathyal environment which corresponds to an estimated water depth of 200–500 m. Transport of shallow-water species by turbidity currents or tempestites cannot be excluded; however, there is no clear indication of long-distance transport. Taphonomic criteria, such as adult/juvenile ratio, are not applicable because it is unclear if the different moult stages were completely picked. This ecological interpretation must therefore be verified by additional quantitative micropalaeontological research.

*Comparison with other Middle Triassic deep-water assemblages.* The abundance of the most typical deep-water taxa (*Acanthoscapha bogtschi*, *Acratia goemoeryi*, *Praemacrocypis mocki*, *Bairdiacypris anisica*, *Paraberounella oertlii*) comprises 10.5% of specimens and is similar to the Ladinian fauna of Hungary (Monostori & Tóth, 2013). The present assemblage, however, most probably reflects shallower conditions than the Anisian and Ladinian material from Hungary (Kozur, 1970a; Monostori & Tóth, 2013) because of the higher abundance of sculptured Bairdiidae of shallow-water origin (12.6% of specimens) and the much lower percentage of smooth Healdiidae (2.9% of specimens).

The relatively low abundance (8.6% of specimens) of genera with Palaeozoic affinity (*Acratia*, *Paraberounella*, *Spinomicrocheilinella*, *Acanthoscapha* and *Processobairdia*) is similar to that reported from the Ladinian deep-water fauna of Hungary (Monostori & Tóth, 2013). The relatively low abundance of Palaeozoic elements also suggests that the fauna is a mixture of deep-marine environments and inhabitants of the open-marine shelf which would be consistent with a deep neritic to upper bathyal environment.

*Evolutionary aspects.* *Spinomicrocheilinella*, which was formerly described from the Carboniferous–Permian, and *Processobairdia*, previously known from the Silurian–Devonian, are recorded for the first time from the Mesozoic. This remarkable occurrence of Lazarus taxa and the presence of other Palaeozoic genera in the Middle Anisian and in the Ladinian (Monostori & Tóth, 2013) show that the Palaeozoic–Mesozoic faunal turnover of the deep-marine ostracod fauna continued throughout the Middle Triassic,

while the turnover of the neritic genera was completed by the Early Anisian (Crasquin-Soleau *et al.*, 2007; Crasquin & Forel, 2013). This discrepancy can be explained by the fact that evolutionary rates are controlled strongly by the stability of environmental conditions and the higher stability of deep-marine environments. The absence of the Palaeozoic genera in the Lower Triassic is most likely due to unfavourable conditions (oxygen deficiency) in deep environments (Crasquin & Forel, 2013) or by the restriction of cold water circulation which is indicated by the absence of siliceous deposits (chert gap) in the Lower Triassic (Beauchamp & Baud, 2002). In any case there must have been deep-marine refugia for these taxa which are either not yet detected or not preserved in the geological record.

## CONCLUSIONS

The present ostracod assemblage shows a high species diversity and is a mixture of taxa which were formerly interpreted as ‘palaeopsychrospheric’ or ‘Thuringian Ecotype’ ostracods and shallow-marine species. It is unclear if the shallow-marine ostracods represent an autochthonous faunal element or if they were transported by tempestites or turbidity currents. The faunal association is thus ecologically comparable with Anisian assemblages of Hungary (Monostori, 1995) which are also regarded as a mixture of deep- and shallow-marine ostracods. The present material differs, however, from the other Middle Triassic deep-marine assemblages by the higher dominance of Bairdiidae (78% of specimens) and a very low percentage of Healdiidae (2.9% of specimens) and Polycopidae (5.3% of specimens).

From the ostracod palaeoecology, lithofacies and palaeogeographical considerations, a deep neritic to upper bathyal palaeoenvironment with water depth between 200 and 500 m seems the most reasonable estimate. Such a transitional palaeoenvironmental setting is also supported by the relative low abundance of ‘archaic’ faunal elements.

The occurrence of Lazarus taxa among the ‘archaic’ faunal elements suggests that undetected or unpreserved deep-marine refugia existed in the Early Triassic.

The occurrence of Palaeozoic genera in the Middle Anisian and Ladinian deep-water assemblages suggests that the evolutionary turnover from the Palaeozoic to the Mesozoic ostracod fauna took a longer time interval in the deep sea than in neritic environments. This could be due to higher environmental stability in the deep neritic–bathyal zone.

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