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# Cosmopolitan myodocope ostracods from the Silurian of Uzbekistan, Central Asia

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**Abstract** – Four species of myodocope ostracod are documented from the Silurian Ludlow Series of the Aburtkan gorge on the southern slope of Dzhalpak Mountain, Uzbekistan: namely, *Parabolbozoe bohémica* (Barrande, 1872), *Bolbozoe anomala* Barrande, 1872, *Silurocypridina calva* Perrier, Vannier and Siveter, 2011 and *Richteria migrans* (Barrande, 1872). These species have a palaeogeographically widespread trans-oceanic distribution, which supports the notion that Silurian myodocopes signify the earliest zooplanktonic ostracods. *Richteria migrans* (Barrande, 1872), in particular, provides a precise intercontinental biostratigraphic marker that identifies rocks of the upper Gorstian to upper Ludfordian stages.

**Keywords:** Ludlow Series / Myodocopa / Ostracoda / palaeobiogeography / plankton / Silurian

**Résumé** – Les ostracodes myodocopes cosmopolites du silurien Asie centrale. Quatre espèces d'ostracodes myodocopes sont documentées dans le Silurien (Ludlow) des gorges d'Aburtkan sur le versant sud de la montagne Dzhalpak en Ouzbékistan: *Parabolbozoe bohémica* (Barrande, 1872), *Bolbozoe anomala* Barrande, 1872, *Silurocypridina calva* Perrier, Vannier et Siveter, 2011, and *Richteria migrans* (Barrande, 1872). Ces espèces ont une distribution paléogéographique trans-océanique durant le Silurien. Cette distribution cosmopolite soutient l'idée que les myodocopes siluriens représentent la première faune d'ostracodes zooplanctoniques. *Richteria migrans* (Barrande, 1872), en particulier, est un marqueur biostratigraphique intercontinental précis qui permet de dater les roches du Gorstien supérieur au Ludfordien supérieur.

**Mots clés :** Ludlow / Myodocopa / Ostracoda / paléobiogéographie / plancton / Silurien

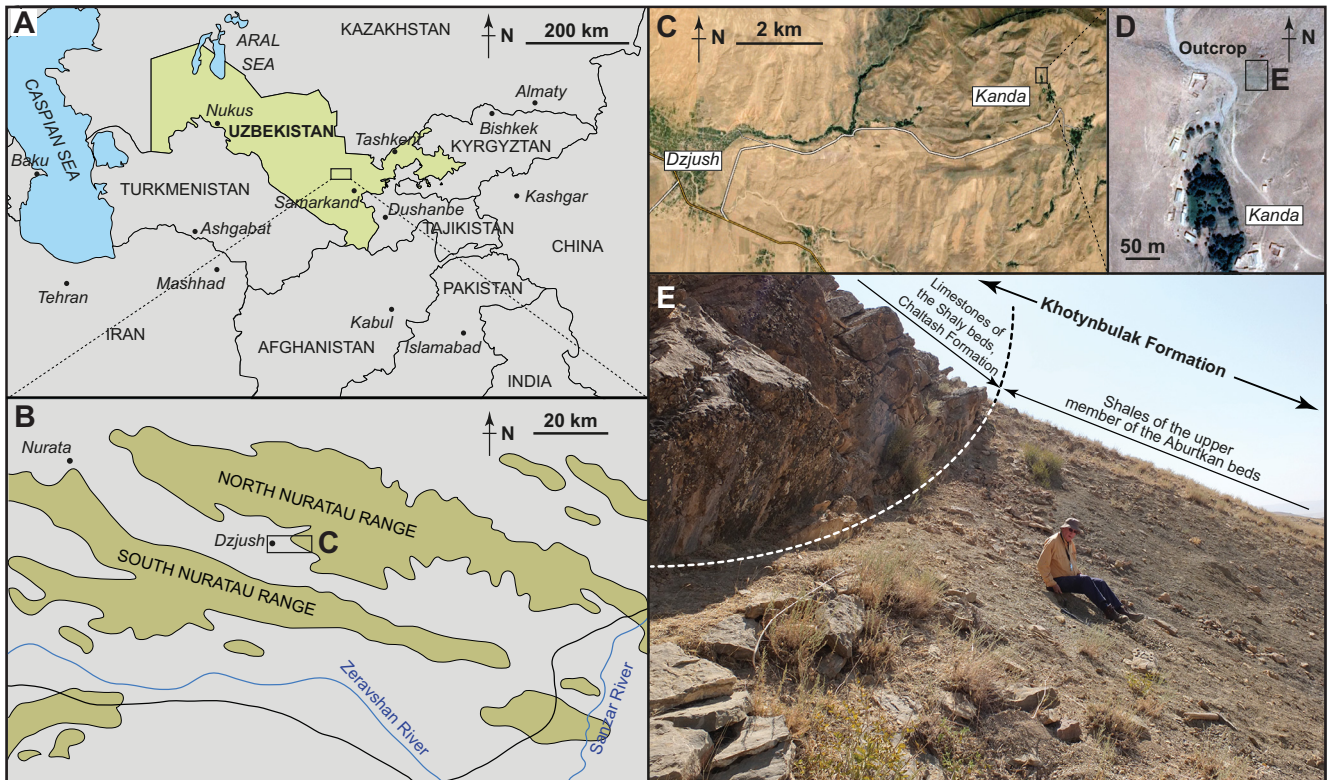
## 1 Introduction

During the 1980s and 1990s analysis of distributional and facies data of Silurian myodocopes suggested that some species had colonised pelagic niches during that time and therefore represented the earliest known record of zooplanktonic ostracods (Siveter, 1984; Siveter *et al.*, 1987, 1991; Siveter and Vannier, 1990; Vannier and Abe, 1992; see also Perrier *et al.*, 2015). Subsequent studies of Silurian myodocopes have focused on their systematics, habitats, lifestyles, and biostratigraphical and palaeogeographical utility (Perrier

*et al.*, 2007, 2011, 2014a–c, 2019a–c; Perrier, 2012; Perrier and Siveter, 2013). These studies are underpinned by the discovery of five exceptionally preserved myodocope ostracod species from the Silurian, in the Herefordshire Lagerstätte, Welsh Borderland, UK, which provides precise data on the soft anatomy of ancient representatives of the group (Siveter *et al.*, 2003, 2007, 2010, 2013, 2015, 2018).

Myodocope ostracods were identified in the Silurian of Uzbekistan as early as 1966, when fieldwork by A.I. Kim and E. Mikhailova yielded material from the Ludlow Series at the village of Kanda in the North Nuratau Ridge. Written records of myodocopes from Uzbekistan are few. Brief mentions occur in the unpublished theses of Mikhailova (1972, 2000), which list three species of *Cypridina* Milne-Edwards, 1840 from the

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**Fig. 1.** A–D, Geographical position of the myodocope-bearing Silurian locality of Kanda, Uzbekistan. E, Outcrop of the Ludlow Series near Kanda showing David Siveter at the contact between the shales of the upper member of the Aburtkan beds, Khotynbulak Formation, and the overlying limestones of the Shaly beds, Chaltash Formation.

Pridoli Series of the Kyzyl-Kum Hills of the Tamdy-Tau massif and from the Devonian Lochkovian Stage of the Turkestan Range and Zeravshan Range respectively; species under the names *Entomozoe* (*Richteria*) cf. *migrans* (Barrande, 1872) from the Ludlow of the North Nuratau Ridge and *Entomozoe* aff. *subphalanga subphalanga* Polonova, 1970 and *Entomozoe* aff. *tuberosa* (Jones, 1861) from the Lochkovian of the Turkestan range; and a new monotypic polycopid genus from the Lochkovian of the Turkestan range. A few myodocope genera (*Bolbozoe*, *Entomozoe* and *Cypridina*) were also listed in Mikhailova's (1981) publication on Pridoli ostracods from the Kyzyl-Kum Hills. Fieldwork undertaken by the present authors in 2014 yielded many additional Silurian myodocope specimens and newly recorded species from the locality at Kanda, and these are the basis of the present paper. Our studies recognise four cosmopolitan myodocope species from the Silurian of Uzbekistan, allowing detailed biostratigraphical correlations with other regions.

## 2 Locality and stratigraphy

The myodocopes were collected from a section outcropping north of the spring at the northern edge of the small hamlet of Kanda, along the side of the Aburtkan gorge on the southern slope of Dzhalpak Mountain. The locality (40°25'40"N, 66°28'05"E; Fig. 1) lies on the southern slopes of the North Nuratau Ridge and is about 10 km east of the small town of Dzjush, and some 100 km north-west of Samarkand. The

outcrops in the area of the villages of Kanda, Shaly, Chashmazrak and others (the Jalpak and Gavalbet mountains) have been known since the middle part of the 20th century but very little has been published on them. The Silurian rock successions are part of the Merishkor synform and collectively are known as the Merishkor sections (Kim, 1966). They consist of richly fossiliferous carbonate and clastic rocks of mostly Silurian Wenlock Series to middle Carboniferous age that have been uplifted and folded during the late Palaeozoic to form part of the southern Tien Shan fold and thrust belt (see, e.g., Biske and Seltmann, 2010; McCann *et al.*, 2013). The myodocope-bearing rocks are cyclically arranged calcareous siltstones and mudstones which, following the Uzbek regional stratigraphic scheme, are termed the upper member of the Aburtkan beds of the Khotynbulak Formation. Associates of the myodocopes are orthoconic nautiliods, graptolites, rare small brachiopods and plant fragments; ichnofossils are also present.

These deposits are considered to have accumulated in a low energy, open deep-water shelf/shelf slope setting (Mikhailova and Tarasenko, 2015).

Graptolites from various outcrops and stratigraphic levels of the upper member of the Aburtkan beds comprise *Pristiograptus* ex gr. *dubius*, *Pristiograptus* cf. *tumescens*, *Saetograptus leintwardinensis*, *Saetograptus chimaera*, *Colonograptus* sp., *Monograptus* ex gr. *haupti*, *Bohemograptus bohemicus*, *Bohemograptus bohemicus tenuis*, *Neodiversograptus nilssoni*, *Linograptus* sp. and *Lobograptus simplex* and *Lobograptus progenitor* (T.N. Koren of VESEGI, St Petersburg; unpublished list of graptolite taxa sent to Uzbek



geologist S. Piven, 1984). According to Koren the lower boundary of the upper member of the Aburtkan beds corresponds to the base of the *Neodiversograptus nilssoni* Biozone and therefore the local base of the Ludlow Series. The precise age of the upper limit of the upper member of the Aburtkan beds is unknown. Based on inter-regional correlation of the myodocope ostracods (see Perrier *et al.*, 2019a, c) that we identify from the locality at Kanda, its Silurian rocks are most likely at the level of the *Saetograptus incipiens*, *Saetograptus leintwardinensis* and *Monograptus formosus* graptolite biozones of the Ludlow Series. The ostracod-bearing strata are succeeded upwards by carbonates of the Shaly beds of the Chaltash Formation, replete with fossils, especially corals, brachiopods, bryozoans, crinoids and podocopid ostracods (Mikhailova, 2000).

### 3 Material and methods

The bivalved carapace of Silurian myodocopes is presumed to have been weakly calcified in life with a probable ligamentous dorsal connection. The myodocopes in our collections occur as internal and external moulds. Due to intense weathering in what is a hot desert area the ostracods are poorly preserved. Among several hundred specimens collected, 71 were firmly identified and are considered in the present paper. Many of the moulds preserve an adductor muscle scar/spot sub-centrally, corresponding to the site of attachment of the adductor muscle. The surface of the carapace may be smooth or have a range of types of ornament, including reticulation, corrugation and punctation. Some valves show post-mortem diagenetic features, such as “rosettes”, similar to features described from Silurian myodocopes of European areas (Siveter *et al.*, 1987).

Rock matrix was removed from the specimens mechanically using fine needles. Casts of external moulds of all of the ostracods recovered were made with silicone rubber (Silcoset 105) using the technique of Siveter (1982). Specimens occurring as internal moulds and casts were coated with a thin layer of ammonium chloride and photographed using a Leitz Aristophot mounted with a Canon EOS 5D camera following the methods of Siveter (1990). Morphological terminology used here follows that of Siveter *et al.* (1987) and Perrier (2012).

The four central Asian Silurian myodocope species reported on here, are also present in the UK and have been fully revised by Perrier *et al.* (2019a). Perrier *et al.* (2019a) presents full synonymies of these four species.

Repositories for the figured ostracods are: Université Claude Bernard Lyon 1, France (FSL), University of Brest, France (LPB), Národní Museum, Prague, Czech Republic (NM-L) and The Polish Academy of Science, Warsaw, Poland (ZPAL). All the newly described and figured material is deposited in Oxford University Museum of Natural History (OUMNH).

### 4 Systematic palaeontology

Class OSTRACODA Latreille, 1802 (*nom. correct*  
Latreille, 1806)

Subclass MYODOCOPA Sars, 1866

Order MYODOCOPIDA Sars, 1866

Suborder MYODOCOPINA Sars, 1866

Superfamily BOLBOZOOIDEA *sensu* BOLBOZOACEA  
Bouček, 1936

Family BOLBOZOIDAE Bouček, 1936

Genus *Bolbozoe* Barrande, 1872

Type species. – *Bolbozoe anomala* Barrande, 1872; subsequent designation by Bassler and Kellett, 1934. Ludlow Series, Silurian, Prague, Czech Republic.

Other species. – *Bolbozoe acuta* Perrier *et al.*, 2011, *Bolbozoe beccata* Perrier *et al.*, 2014c, *Bolbozoe largiglobosa* Wang and Zhang, 1983, *Bolbozoe parvafraga* Perrier *et al.*, 2011, *Bolbozoe psittaca* Perrier *et al.*, 2019a, *Bolbozoe rugosa* Perrier *et al.*, 2011, *Bolbozoe* sp. nov. A of Perrier *et al.*, 2019a, *Bolbozoe* sp. nov. B of Perrier *et al.*, 2019a and possibly *Bolbozoe jonesi* Barrande, 1872.

Stratigraphic and geographic range. – Upper part of the Wenlock Series, Silurian, to Emsian Stage, Devonian; Czech Republic (Perrier *et al.*, 2011), France (Perrier *et al.*, 2011), Sardinia (Gnoli *et al.*, 2009), China (Wang, 2009), Australia (Perrier *et al.*, 2014c), Wales (Perrier *et al.*, 2019a) and Poland (Perrier *et al.*, 2019b).

*Bolbozoe anomala* Barrande, 1872 (Figs. 2D, 2H, 2I, 3C, 3G, 3K, 3O and 3S)

2019a *Bolbozoe anomala* Barrande, 1872; Perrier *et al.*: pl. 3, figs. 1–18 (see p. 26 for full synonymy).

2019b *Bolbozoe anomala* Barrande, 1872; Perrier *et al.*: figs. 2A and 2B.

2019c *Bolbozoe anomala* Barrande, 1872; Perrier *et al.*: fig. 7C.

Type material. – Lectotype (designated Přibyl, 1988: 119), a right valve, NM-L 23572 (ex. CE1194); Barrande, 1872: pl. 24, figs. 29 and 30; Perrier *et al.*, 2011: pl. 1, fig. 1. Paralectotype (designated Přibyl, 1988: p. 119), a left valve, NM-L 13993; Barrande, 1872: pl. 24, figs. 27 and 28; Perrier *et al.*, 2011: pl. 1, fig. 2.

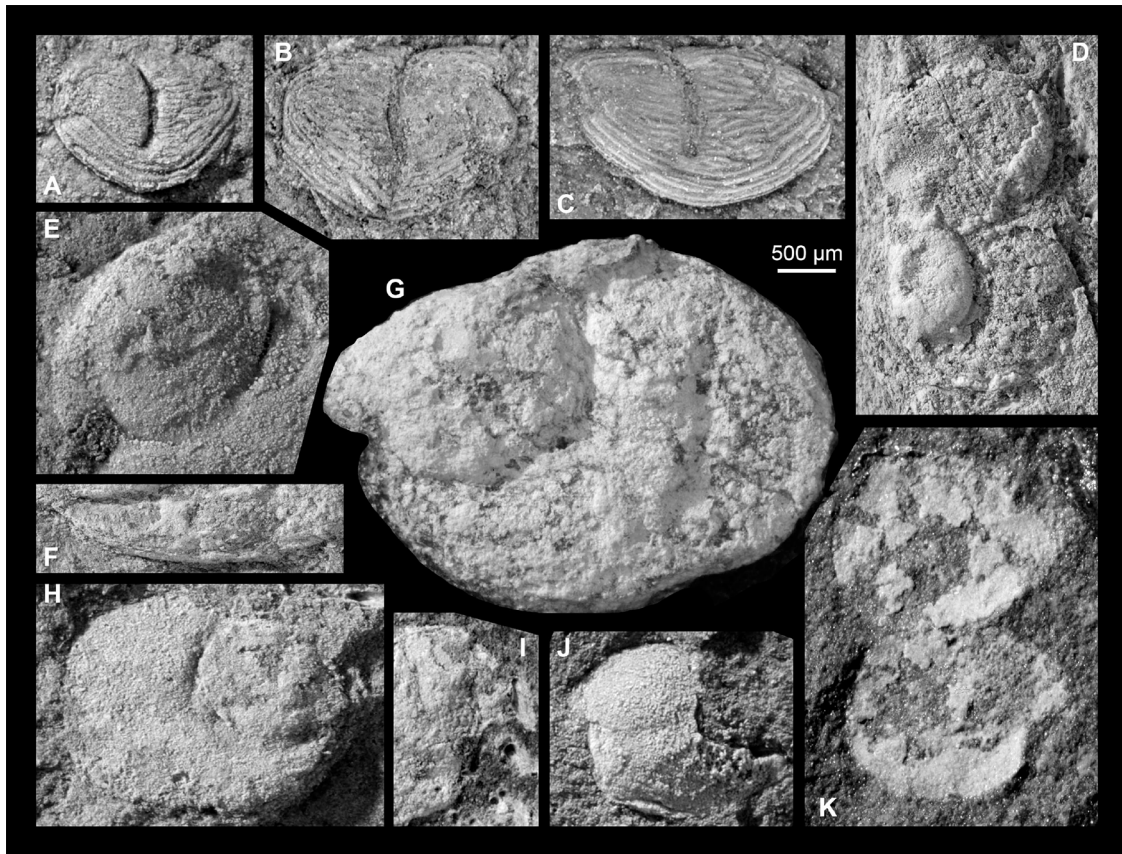
Type locality. – Lochkov suburb of Prague, Czech Republic.

Type horizon. – Požáry Formation, Pridoli Series, stratigraphical division e2 of Barrande, 1872 (Kříž, 1992).

Material. – Twelve valves from the outcrop at Kanda.

Description. – Adult valve sub-ovoid, slightly tapering posteriorly. Anterior third of valve mostly occupied by a large hemispherical bulb forming c. 20–25% of valve area; bulb-centre lies just above valve mid-height and well above other surface areas of valve. Maximum valve length is just above bulb mid-height; maximum valve height is at mid-length and maximum valve width is at central part of bulb. A deep, narrow sulcus surrounds the bulb posteriorly and ventrally. An adductor muscle scar occurs at mid-length within the sulcus. Ridges and furrows typical of the muscle scar pattern of the species are not visible in the Uzbek material. In adults, rostrum is very small, in some cases beak-like or absent. Early ontogenetic stages are more rounded in valve outline and the bulb is relatively larger than in adults.

Remarks. – Though the Uzbek material is poorly preserved its features are diagnostic of *B. anomala*. It differs from other smooth species of *Bolbozoe* by its rounded shape (*B. psittaca* is elongated; Perrier *et al.*, 2019a), its tiny rostrum (*B. beccata* has a prominent beak-like rostrum; Perrier *et al.*, 2014c) and



**Fig. 2.** Lateral views of myodocopes from the upper member of the Aburtkan beds, Khotynbulak Formation, Ludlow Series, of Kanda, North Nuratau Ridge, Uzbekistan. A–C: *Richtereria migrans*: A: left valve (OUMNH CY.00066); B: right valve (OUMNH CY.00067); C: left valve (OUMNH CY.00068). D, H, I: *Bolbozoe anomala*: D: open carapace in butterfly position (OUMNH CY.00069); H: right valve (OUMNH CY.00070); I: anterior part of right valve showing the bulb and rostrum (OUMNH CY.00071). E–G: *Parabolbozoe bohémica*: E: anterior part of left valve showing the bulb, rostrum and adductorial muscle scar (OUMNH CY.00072); F: detail of the anteroventral projection of left valve (OUMNH CY.00073); G: left valve showing remnants of the reticulate ornament (OUMNH CY.00074). J, K: *Silurocypridina calva*: J: anterior part of left valve showing rostrum and the adductorial muscle scar (OUMNH CY.00075); K: open carapace in butterfly position (OUMNH CY.00076). All images are photographs; A–C, E: silicone casts of external moulds; D, F–K: internal moulds. Scale 500 µm: specimens A–K.

the lack of a well-developed caudal process (present in *B. acuta*; Perrier *et al.*, 2011, 2019a).

**Stratigraphic and geographic range.**—Ludlow Series, North Nuratau Ridge, Uzbekistan. Also known from the upper part of the Wenlock to at least the middle part of the Pridoli Series. Occurs in the Czech Republic, France, Sardinia (Perrier *et al.*, 2011), Wales and England (Perrier *et al.*, 2019a), and Poland (Perrier *et al.*, 2019b). If *B. jonesi* is conspecific with *B. anomala* the range of the species would extend into the Lochovian Series, Lower Devonian (see Perrier *et al.*, 2011).

#### Genus *Parabolbozoe* Přibyl, 1988

**Type species.**—*Bolbozoe bohémica* Barrande, 1872; by monotypy. Ludlow Series, Silurian, Prague, Czech Republic.

**Other species.**—*Parabolbozoe armoricana* Perrier *et al.*, 2011 and *Parabolbozoe britannica* Perrier *et al.*, 2019a.

**Stratigraphic and geographic range.**—Upper part of the Wenlock to Ludlow or Pridoli Series. Known from the Czech Republic (Perrier *et al.*, 2011), France (Perrier *et al.*, 2011), Sardinia (Gnoli *et al.*, 2009), Wales and England (Perrier *et al.*, 2019a), and Poland (Perrier *et al.*, 2019b).

*Parabolbozoe bohémica* (Barrande, 1872) (Figs. 2E–2G, 3B, 3F, 3J, 3N and 3R)

2019a *Parabolbozoe bohémica* (Barrande, 1872); Perrier *et al.*: pl. 6, figs. 1–13; pl.7, figs. 1–10 (see p. 31 for full synonymy).

2019b *Parabolbozoe bohémica* (Barrande, 1872); Perrier *et al.*: figs. 2D and 2E.

2019c *Parabolbozoe bohémica* (Barrande, 1872); Perrier *et al.*: fig. 7J.

**Type material.**—Lectotype (designated Bouček, 1936: 63). A left valve, NM-L 23658 (ex. CE1193). Barrande, 1872: pl. 27, fig. 19 (in reverse); Perrier *et al.*, 2011: pl. 3, fig. 1.

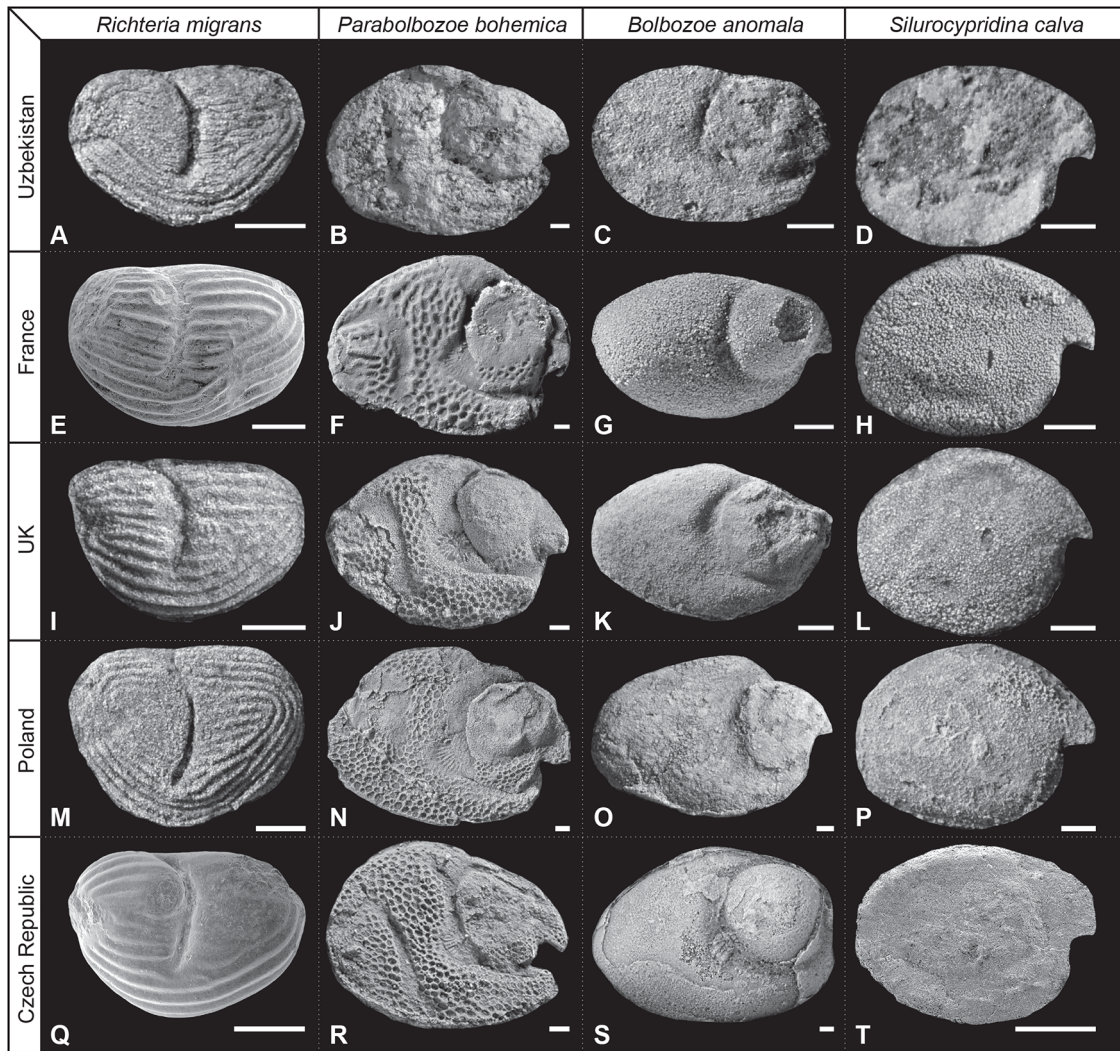
**Type locality.**—Praha-Malá Chuchle, Výskočilka, Czech Republic.

**Type horizon.**—Kopanina Formation, Ludlow Series (stratigraphical division e2 of Barrande, 1872; horizon with the trilobite “*Cromus*” beaumonti).

**Material.**—Eight valves from the outcrop at Kanda.

**Description.**—Adult valve is sub-ovoid in lateral outline, gently curved dorsally and ventrally, posteriorly tapering





**Fig. 3.** Lateral views of four species of Silurian myodocopes from the North Nuratau Ridge, Uzbekistan (A–D), France (E–H), the UK (I–L), Poland (M–P) and the Czech Republic (Q–T). A, E, I, M, Q: *Richtereria migrans*: A: left valve (OUMNH CY.00066); E: left valve (FSL 705029a); I: right valve, image reversed (OUMNH 35481); M: left valve (ZPAL O.63/6); Q: left valve (FSL 705002a). B, F, J, N, R: *Parabolbozoe bohémica*: B: left valve, image reversed (OUMNH CY.00074); F: right valve (FSL 710420); J: left valve, image reversed (OUMNH 35087); N: right valve (ZPAL O.63/5); R: left valve, image reversed (FSL 710759). C, G, K, O, S: *Bolbozoe anomala*: C: right valve (OUMNH CY.00070); G: right valve (FSL 710595); K: right valve (OUMNH 35467); O: left valve, image reversed (ZPAL O.63/24); S: right valve (NM-L 23572, lectotype). D, H, L, P, T: *Silurocypridina calva*: D: right valve of a carapace (OUMNH CY.00076); H: left valve, image reversed (FSL 710652); L: right valve (OUMNH 35382); P: right valve (ZPAL O.63/11); T: left valve, image reversed (FSL 710772). All images are photographs except E and Q which are SEM images. A, F–N, R, T: silicone casts; B–E, O–Q, S: internal moulds. All scale bars: 500  $\mu$ m.

slightly. Bulb is large, anterodorsal, has centre above valve mid-height, extends posteriorly to almost line of maximum valve height and ventrally to below valve mid-height; outline is sub-circular, with a slight indentation opposite the rostrum. Rostrum is large, hook-like, generally with a pointed end. Rostral incisure is well developed, below which the valve has a forward pointing projection. Caudal process is not preserved in the Uzbek material. Maximum valve length is at about the level of end of rostrum; maximum valve height is at about valve mid-length; maximum valve width is at the crest of the bulb. A narrow, fairly deep sulcus flanks the bulb posteriorly and ventrally, is widest dorsally and at its mid-length is the site of

the adductor muscle scar. In posterior one-third of valve a narrow S-shaped sulcus skirts around dorsal and anterior base of caudal process and projects forward near valve ventral margin. Adductor muscle scar prominent, consisting sub-parallel, radiating and alternating ridges and furrows arranged in a double series feather-like pattern. In the Uzbek specimens, faint remains of reticulation covers external valve surface. During ontogeny, size of bulb becomes relatively smaller and valve shape changes from almost circular to ovoid and density of reticulation decreases.

**Remarks.** – Though poorly preserved the Uzbek specimens show the reticulation characteristic of *P. bohémica*.

*P. armoricana* has corrugate ornament (Perrier *et al.*, 2011, 2019a) and *P. britannica* is corrugated and pitted (see Perrier *et al.*, 2019a).

Stratigraphic and geographic range.—Ludlow Series, North Nuratau Ridge, Uzbekistan. Also known from the upper part of the Wenlock and lower part of the Ludlow Series. Occurs in the Czech Republic, France, Sardinia (Perrier *et al.*, 2011), England and Wales (Perrier *et al.*, 2019a) and Poland (Perrier *et al.*, 2019b).

Suborder ENTOMOZOCOPINA Gründel, 1969

Superfamily ENTOMOZOIDEA *sensu* ENTOMOZOA-CEA Přibyl, 1950

Family ENTOMOZOIDAE Přibyl, 1950

Genus *Richteria* Jones, 1874

Type species.—*Cypridina serrato-striata* Sandberger, 1845; subsequent designation by Kegel, 1934: 413. Lower Famennian, Upper Devonian of Germany.

Stratigraphic and geographic range.—*Richteria* is known from the Silurian and Devonian. Supposed records of its occurrence in younger and older strata (all the unrevised “*Entomis*” species, see Bassler and Kellett, 1934) lie outside the scope of the present study and have not been confirmed by the present authors. The genus is known from Europe (Czech Republic, Germany, Poland, Belgium, France, Italy, U.K.; Perrier *et al.*, 2007, 2019a–c), Arctic Russia (Perrier *et al.*, 2014a), Central Asia, and China (Perrier *et al.*, 2007).

*Richteria migrans* (Barrande, 1872) (Figs. 2A–2C, 3A, 3E, 3I, 3M and 3Q)

1981 *Entomozoe*; Mikhailova, p. 130, fig. 3.

2019a *Richteria migrans* (Barrande, 1872); Perrier *et al.*: pl. 12, figs. 1–3, 11 and 12 (see p. 39 for full synonymy).

2019b *Richteria migrans* (Barrande, 1872); Perrier *et al.*: fig. 2F.

2019c *Richteria migrans* (Barrande, 1872); Perrier *et al.*: fig. 7L.

Type material.—Lectotype (subsequently designated by Přibyl, 1950: 11). An incomplete right valve; Národní Museum, Prague, on slab NM-L 22944. Barrande, 1872: pl. 24, figs. 12–14; Bouček, 1936: text-fig. 2a; Perrier *et al.*, 2007: text-figs. 6a–6b.

Type locality.—Former Dvorce quarry (today Podolí swimming pool), Podolí district of Prague.

Type horizon.—Kopanina Formation, Ludlow Series. Material.—Forty-two valves from Kanda.

Description.—Valve large, bean-shaped in lateral outline. Greatest length is slightly above mid height; greatest height is at the adductor sulcus. Dorsal margin shorter than valve length. Preadductor and postadductor areas very slightly curved dorsally; ventral, anterior and posterior margins convex. Anterior valve margin shows a faint notch in some large specimens. Adductor sulcus long, deep, crescent shaped, extends two-thirds of valve height from in front of mid length near dorsal margin to below the preadductor node. A simple elliptical adductor muscle scar is present at the slightly widened ventral extremity of the sulcus. Preadductor node is generally unornamented but can be weakly ribbed and less developed in some specimens. External valve surface has up to 25 longitudinal ribs, including in some specimens short,

intercalated and bifurcated ribs. The alignment of ribs is not disturbed by the adductor sulcus. Ribs merge posteriorly, converge on a triangular smooth area anteriorly and curve slightly away from the valve margin ventrally. Conjoined open valves are consistently connected along dorsal margin, but there is no evidence for presence of hinge structure.

Remarks.—The specimens of *R. migrans* are the best preserved among the Uzbek myodocopes, notably showing the typical entomozoid ribbed ornament. Morphological comparison with material from other regions (see Figs. 3A, 3E, 3I, 3M and 3Q), resolves the specimens recorded as *Entomozoe* (*Richteria*) cf. *migrans* (Barrande, 1872) by Mikhailova (1972, 2000) as conspecific with *R. migrans*.

Stratigraphic and geographic range.—Ludlow Series, North Nuratau Ridge, Uzbekistan. Also known from the upper part of the Ludlow Series in the Czech Republic, France, Sardinia, Poland, Central Asia, Arctic Russia, England, Wales and possibly Germany and Sweden (Perrier *et al.*, 2007, 2014a, 2019a–c).

Superfamily CYPRIDINOIDEA *sensu* CYPRIDINACEA Baird, 1850

Family CYPRIDINIDAE Baird, 1850

Genus *Silurocypridina* Perrier *et al.*, 2011

Type species.—*Silurocypridina retroreticulata* Perrier *et al.*, 2011 from the Silurian of France.

Other species.—*Silurocypridina variostrata* Perrier *et al.*, 2011 and *Silurocypridina calva* Perrier *et al.*, 2011.

Stratigraphic and geographic range.—Silurian (upper Ludlow or Pridoli Series); France, Czech Republic, England, Wales, Poland and possibly Sardinia (Perrier *et al.*, 2011, 2019a–c).

*Silurocypridina calva* Perrier *et al.*, 2011 (Figs. 2J, 2K, 3D, 3H, 3L, 3P and 3T)

2019a *Silurocypridina calva* Perrier *et al.*, 2011; Perrier *et al.*: pl. 17, figs. 1–5 and 8–11 (see p. 49 for full synonymy).

2019b *Silurocypridina calva* Perrier *et al.*, 2011; Perrier *et al.*: fig. 2L.

2019c *Silurocypridina calva* Perrier *et al.*, 2011; Perrier *et al.*: fig. 7T.

Type material.—Holotype, a three-dimensionally preserved left valve (LPB 18926). Perrier *et al.*, 2011: pl. 5, figs. 8 and 9.

Type locality.—Les Chevrolières, near St Denis-d’Orques, Sarthe, France.

Type horizon.—Le Val Formation is in the upper part of the Ludlow Series or lower part of the Pridoli Series, and currently cannot be further resolved.

Material.—Nine valves from the outcrop at Kanda.

Description.—Valve dome-like, with sub-ovoid lateral outline; hinge short. Rostrum well developed, is about 10–20% of valve length, protrudes distinctly forward beyond anteroventral margin of valve. Rostral incisure well developed, rounded to angular in lateral outline. Adductor muscle scar is small, subcentral, crescent-shaped and convex anteriorly. Valves smooth. During ontogeny valve shape changes from almost circular to sub-ovoid.

Remarks.—*S. calva* is known to display considerable variation in valve outline and shape of the rostrum. The morphology of the rostrum, the crescent-shaped muscle scar and



lack of ornament assign the Uzbek material to *S. clava*. Other species of *Silurocypridina* are reticulate (*S. retroreticulata*) or corrugate (*S. variostrata*; Perrier *et al.*, 2011, 2019a).

Stratigraphic and geographic range.—Ludlow Series, North Nuratau Ridge, Uzbekistan. Also known from the Silurian of the Czech Republic, France, Poland, England, Wales and possibly Sardinia (Perrier *et al.*, 2011, 2019a–c).

## 5 Discussion

### 5.1 Palaeogeographical position and significance

Central Asia in general contains a collage of structurally complex terranes whose relationships and geological history are intricate and controversial (McCann *et al.*, 2013; Kröner, 2015). The assignment of the region of Uzbekistan in question to a particular terrane/palaeocontinental area and its palaeogeographic position during the Silurian is very conjectural and has elicited a wide range of opinions. Several studies have treated the area of the North Nuratau Ridge of Uzbekistan as part of an “Alai Terrane Group”, whose position during the Silurian is considered problematic but which is generally accepted to have accreted with a “Kazakh” (micro) continent during the Carboniferous. Biske and Seltmann’s (2010) tectonic synthesis and palaeogeographic reconstruction of pertinent areas of central Asia during Devonian times placed Kyzylkum-Alai, Merishkor-Ulan and several other “microcontinents” within a “Turkestan Ocean” positioned in subtropical latitudes between the Baltica plate and the Kazakh continent. Heubeck’s (2001) reconstruction shows a broadly similar plate configuration. McCann *et al.*’s (2013) synthesis of the Ordovician–Carboniferous tectono-sedimentary evolution of the North Nuratau region allies its position in the Silurian to a carbonate (–clastic) dominated Alai microcontinent positioned astride the equator in the Turkestan Ocean and opposite the Kazakh continent some 20 degrees to the north.

Interestingly, various Upper Silurian non-myodocope benthic ostracod associations are similar in shelf facies over a large area of Uzbekistan, from the Turkestan–Nuratau mountain region to the Kyzyl–Kum hills (Mikhailova, 1981, 2000 and unpublished analyses). Such occurrences would link the supposed palaeogeographically close Kyzylkum–Alai and Merishkor–Ulan microplates of various authors. Furthermore, such ostracod faunas are compositionally closest to faunas of the western and eastern slopes of the northern and central Urals, as well as the western slope of the southern Urals (Abramova, 1976; Mikhailova, 1981).

Fossils have not yet proved decisive in determining the palaeogeographical positioning of the many central Asian terranes (see Cocks and Torsvik, 2002, 2013; Fortey and Cocks, 2003; Torsvik and Cocks, 2013). On balance of the available evidence we tentatively regard the Uzbek region/terrane in question as a small microcontinent placed between the North and South China plates (Fig. 4). This position, in all palaeogeographical reconstructions, lies many tens of degrees longitudinally distant from the Baltica, Laurentia and Avalonia palaeocontinents, and in general also accords with the palaeogeographical location of the Alai (–Tarim) terrane as resolved by Yakubchuk (2017), who regards it in close proximity to the North China plate in northerly subtropical latitudes.

### 5.2 Biostratigraphical significance

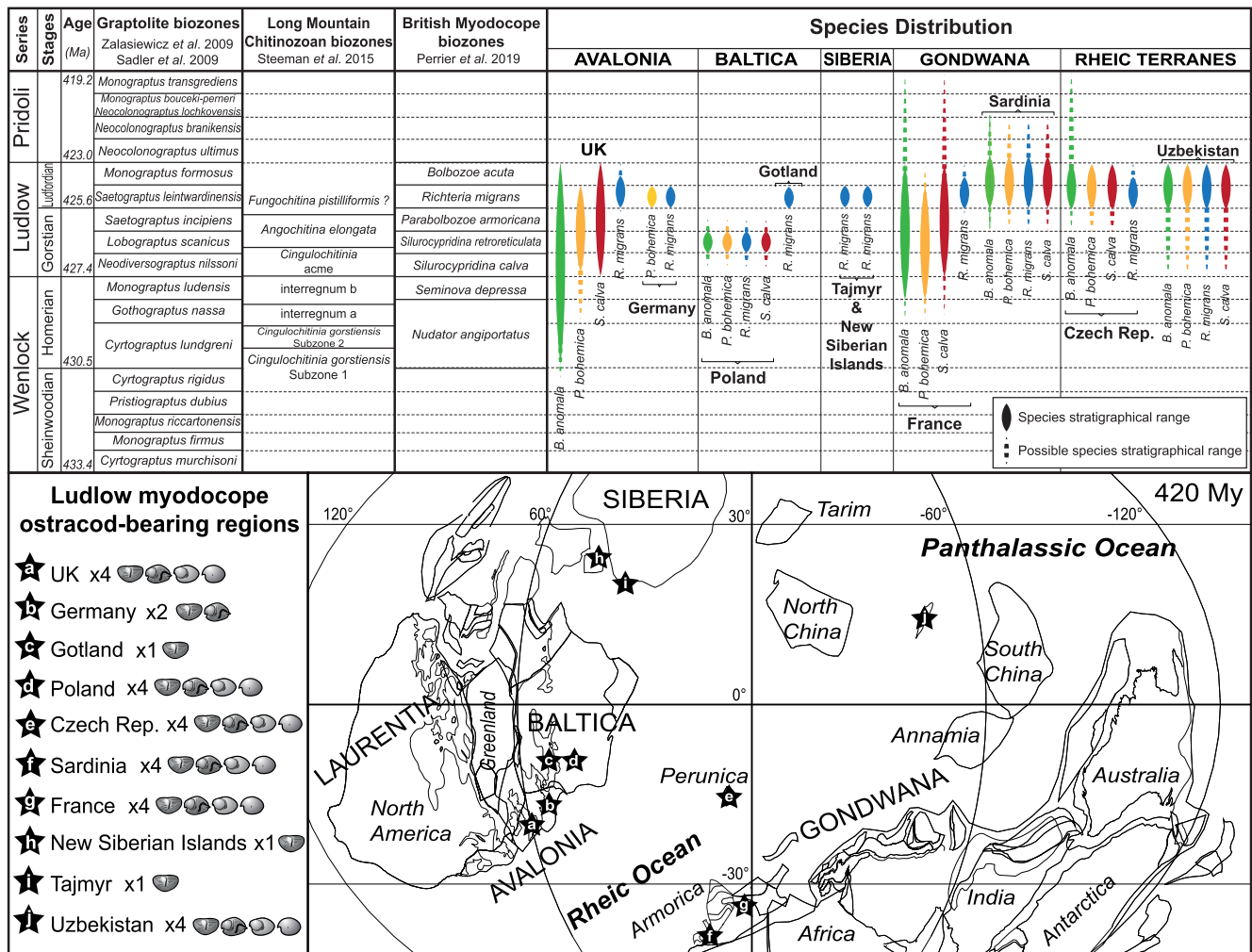
The biostratigraphic control using graptolites recorded by T.N. Koren (unpublished written information given to Uzbek geologist S. Piven; typed records stored in the Uzbekistan Geological Survey, Tashkent) from various outcrops and stratigraphic levels of the upper member of the Aburtkan beds narrows down the biostratigraphical age of the present Uzbek ostracod material to the *nilssoni* to *formosus* graptolite biozones of the Ludlow Series (Fig. 4). Based on inter-regional correlation of the myodocope ostracods (see Perrier *et al.*, 2019a, c) that we identify from the locality at Kanda, the Silurian rocks there are most likely of the upper Gorstian (*scanicus/incipiens* Biozone) to upper Ludfordian (*leintwardinensis* and *formosus* biozones). One myodocope species, *R. migrans*, is particularly informative as it is restricted to the Ludfordian in the UK, Germany, Gotland, Arctic Russia, France, Sardinia and Bohemia (Perrier *et al.*, 2014a, 2019a, c). However, its presence in the mid-Gorstian *scanicus* Biozone of Poland (Perrier *et al.*, 2019b) may imply that this species originated earlier. The other three myodocope species found in Kanda are all long-ranging species and thus do not provide additional biostratigraphic control. *B. anomala* is known from strata of the lower Homerian to the upper Pridoli, *P. bohémica* from strata of the upper Homerian to the uppermost Ludfordian, and *S. calva* from the upper Homerian to the upper Pridoli (Perrier *et al.*, 2019a, c; Fig. 4). The coincidence of the four Uzbek myodocope species corresponds to the assemblage present in the *R. migrans* myodocope biozone of the UK (Perrier *et al.*, 2019a, c), coeval to the *leintwardinensis* graptolite biozone and the *Fungochitina pistilliformis*? chitinozoan biozone (Steeman *et al.*, 2015; Fig. 4). The *Richteria migrans* Biozone is also recognized in Germany (Perrier *et al.*, 2014a), Gotland (Perrier *et al.*, 2014a), Arctic Russia (Perrier *et al.*, 2014a), France (Perrier *et al.*, 2007), Sardinia (Perrier *et al.*, 2007) and Bohemia (Perrier *et al.*, 2007).

### 5.3 Palaeoecological significance

The widespread palaeogeographic distribution of *R. migrans*, *B. anomala*, *P. bohémica* and *S. calva* in southerly tropical to mid latitudes on both sides of the early Palaeozoic Rheic Ocean, was noted by Siveter *et al.* (1991) and Perrier *et al.* (2007, 2011, 2019a). Perrier *et al.* (2014a) expanded the distribution of *R. migrans* to the subtropical region of the palaeo-northern hemisphere on, or next to, the Siberia palaeocontinent (Fig. 4). These new Uzbek records at tropical latitude in the palaeo-northern hemisphere, thousands of kilometres east of the previous ones, therefore reinforce the idea that *R. migrans*, *B. anomala*, *P. bohémica* and *S. calva* had wide dispersal capacities (Fig. 4).

Our new observations also confirm that, as noted by Siveter *et al.* (1991) and Perrier *et al.* (2007, 2011, 2019a), the occurrences of bolbozoids, entomozoids and cyprinidids are characteristically associated with either dark micritic limestones (e.g., Arctic Russia, Sardinia, Montagne Noire) or shales (e.g., Bohemia, Armorican Massif, Poland, Central Asia). In addition to myodocopes, these lithologies typically contain, *inter alia*, orthoconic nautiloid, graptolite, phyllocarid





**Fig. 4.** Stratigraphic and palaeogeographic distribution of selected Silurian myodocope species in Uzbekistan, UK, Germany, Poland, Gotland, Arctic Russia, France, Sardinia and the Czech Republic. Map for the Ludlow (420 Ma) after Torsvik and Cocks (2013).

and bivalve dominated associates, as in the case of the occurrence in Uzbekistan. The myodocope-bearing facies typify possible deep shelf environments or topographic lows on the shelf (Siveter *et al.*, 1991; Perrier *et al.*, 2011) and are characterised by the lack of bioturbation, the presence of lamination and by a low diversity mostly pelagic fauna. These facies data, added to the newly extended cosmopolitan distribution suggest that at least these four myodocope species probably possessed a pelagic lifestyle, and this is consistent with the timing of a proposed ecological shift in pioneer pelagic (myodocope) ostracods from benthic to pelagic during the mid-Silurian (see Siveter, 1984; Siveter *et al.*, 1987, 1991; Siveter and Vannier, 1990; Vannier and Abe, 1992; Perrier *et al.*, 2007, 2011, 2015, 2019a, b).

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