The myodocope ostracod *Entomozoe* from the Early Silurian of Severnaya Zemlya, Russian Arctic

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The myodocope ostracod *Entomozoe* aff. *Entomozoe tuberosa* (Jones 1861) has been identified from the Silurian Telychian Stage, Llandovery Series of Severnaya Zemlya, Russia. *Entomozoe* was previously known only from Scotland (*E. tuberosa*), Greenland (*E.* aff. *E. tuberosa*) and South China (*E.* cf. *E. tuberosa*). The new find signifies that *Entomozoe* has biostratigraphical and palaeogeographical significance: all occurrences are from Upper Llandovery sediments of tropical/subtropical palaeolatitudes. It represents a rare and early species link between the 'Baltic-British' Silurian ostracod faunal province and ostracod assemblages of the Russian Eurasian Arctic, and supports the notion that the North Kara Terrane and Laurentia were once palaeogeographically close. The palaeoenvironmental setting of the Russian material is consistent with the idea that this Early Silurian myodocope was probably benthonic.

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Introduction

Specimens of a myodocope ostracod, *Entomozoe* aff. *Entomozoe tuberosa* (Jones, 1861), have been identified from a Silurian Llandovery Series fauna collected from the Severnaya Zemlya Archipelago (formerly Nicholas II Land) in the central Siberian part of the Russian Arctic (Fig. 1). This material represents a rare Early Silurian myodocope and the fourth confirmed occurrence of the genus *Entomozoe* s.s. The Russian material occurs in a relatively shallow-water terrigenous-carbonate sequence that accumulated on what is now identified as the North Kara Terrane. This paper addresses the biostratigraphical, palaeogeographical, palaeozoogeographical and palaeoecological significance of the new find and *Entomozoe* s.s. in general.

Material and Methods

The myodocope described here is part of faunal collections made by one of us (O.K.B.) and A.P. Gubanov (Uppsala University) on an expedition to the Severnaya Zemlya Archipelago in 1999 (Gee et al. 1999). The myodocope-bearing fauna comes from Lower Silurian Section BG99-13 (Bogolepova et al. 2000), located at approximately 79°40´28˝N, 96°31´10˝E, in the middle reaches of the Ushakova River in the central part of October Revolution Island.

The myodocope material consists of specimens on rock slabs, now housed in the Museum of Evolution, Uppsala University, numbers SIB 1025-35. We have used the morphological terminology of the myodocope valve of Siveter et al. (1987). Rock matrix was prepared from the specimens mechanically, using a vibrotool. The photographs were taken using an Aristophot mounted with a Leica camera, following the methods outlined in Siveter (1990).

Geological setting and stratigraphy

The geology of Severnaya Zemlya has been investigated only since the 1930's and is still relatively little known (for a history of studies see Bogolepova et al. 2000; Männik et al. 2002). Ice covers approximately 50% of the surface area of the archipelago. The ice-free regions expose sedimentary sequences of mostly Precambrian (Neoproterozoic) to Palaeozoic age. The Silurian of Severnaya Zemlya is known from Komsomolets, Pioneer, Dlinnyi and October Revolution islands and the Sedov Archipelago (Fig. 1). It consists of up to 2,400 m of mostly richly fossiliferous and diverse sequences, divided in ascending order into the Vodopadnaya, Golomyannaya, Sredninskaya, Samojlovichskaya, Ust's-pokojninskaya and Krasnobukhinskaya formations, and ranges from Early Llandovery to Prídolí age (see Krasnov et al. 1983 with revisions in Matukhin et al. 1999; Mannik et al. 2002).

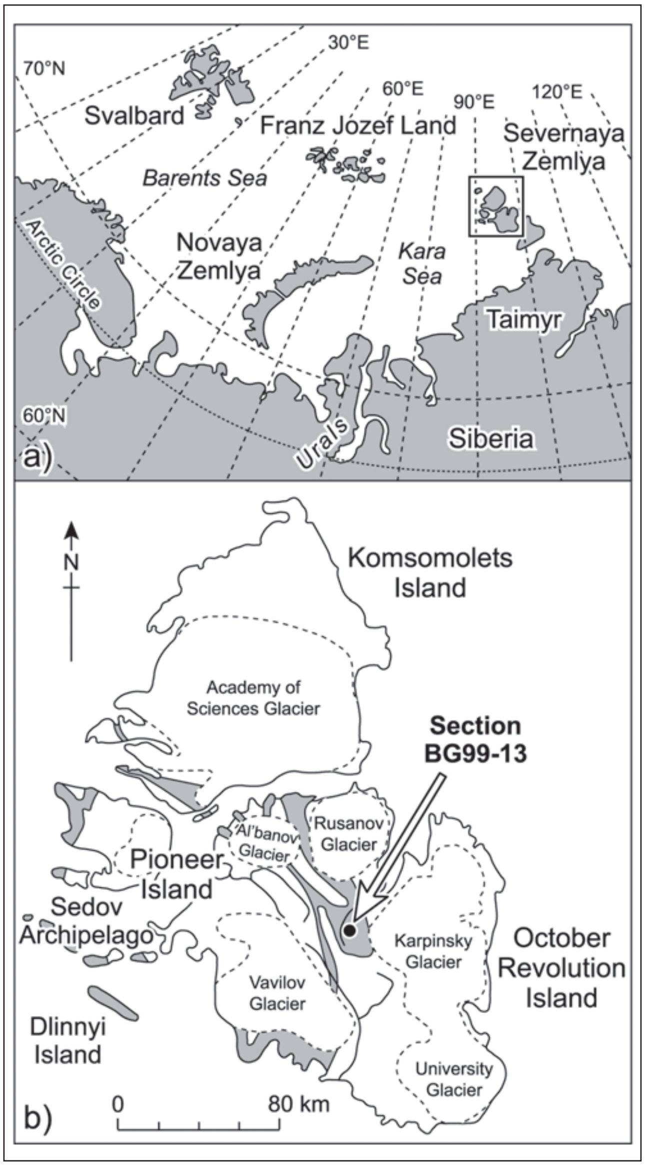

Fig. 1. a) Eurasian Arctic area; b) Severnaya Zemlya, with Silurian outcrops (shaded) and the location of the section yielding Entomozoe *aff.* E. tuberosa *on the Ushakova River, October Revolution Island.*

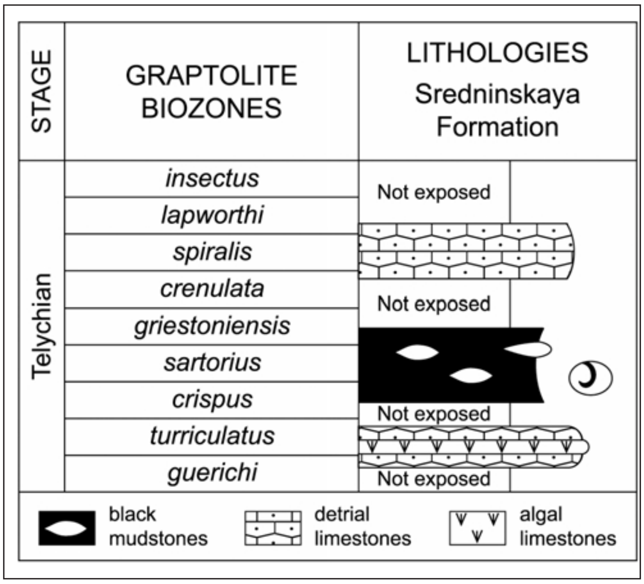

Fig. 2. Stratigraphy and lithologies of Section BG99-13, Sredninskaya Formation, Silurian, October Revolution Island. The ikon indicates the stratigraphic position of Entomozoe *aff.* E. tuberosa.

Section BG99-13 (Bogolepova et al. 2000) of October Revolution Island is a sequence of algal and detrital limestones together with black mudstones containing dark micritic carbonate nodules (Fig. 2). The mudstones and associated concretions contain graptolites, brachiopods and cephalopods. The concretions also yield gastropods, bivalves, conodonts, algae and the myodocope ostracod *Entomozoe* aff. *Entomozoe tuberosa*. Faunal and lithological evidence indicates that the rocks in Section BG99-13 belong to the Sredninskaya Formation, the type section of which lies on the Matusevicha River about 25 km to the west. Evidence from graptolites and other fossils indicates a mid Telychian, Late Llandovery age for Section BG99-13 (Fig. 2), at a level between the upper part of the *M. crispus* Biozone to the *M. griestoniensis* Biozone (Bogolepova et al. 2000). It should be noted that these rocks were previously referred to (Menner et al. 1979; Bogolepova et al. 2000) as being part of the Golomyannaya Formation.

Palaeoecological sigificance

In the carbonate nodules with the myodocope ostracods there are common graptolites (*Stimulograptus clintonensis*, *Stimulograptus* sp. *Streptogratus loydelli*), brachiopods (*Alispira* sp., *Dalejina* sp., *Howelella* sp., *Nalivkinia* sp., *Zygospiraella* sp. and lingulids), cephalopods (*Kionoceras* sp., *Phragmoceras* sp., *Pentameroceras* sp. A), gastropods (*Holopea* sp., *Loxonema* sp.) and rare bivalves (*Ctenodonta* sp., *Dualina* sp., *Sibirinka* sp.), machaeridians (*Plumulites* sp.) and algae. Notwithstanding the occurrence of graptolites and probable pelagic cephalopods, the lithofacies and fauna imply a relatively shallow shelf setting dominated by epibenthonic forms. Similar, low diversity graptolite faunas dominated by *Stimulograptus*, with subordinate *Streptograptus*, have been described from shelf environments in Wales (Loydell & Cave 1993). The shallow shelf occurrence of the Russian material is consistent with all previous interpreted palaeoenvironmental settings of *Entomozoe*, in records from Scotland (Siveter & Vannier 1990), China (Siveter et al. 1991) and Greenland (Siveter & Lane 1999).

The shelf setting is also consistent with the idea that this Early Silurian myodocope was probably benthonic

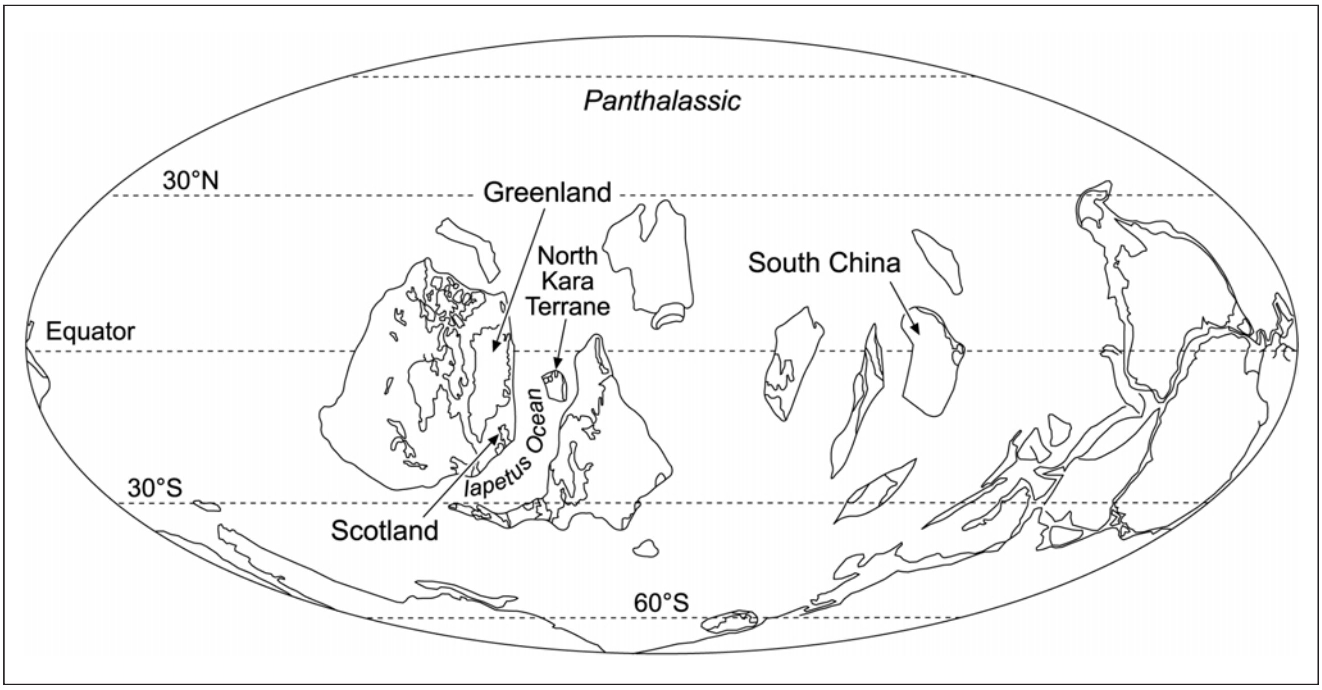

Fig. 3. Known occurrences of Entomozoe*: the Late Llandovery of Scotland (*E. tuberosa; *Siveter & Vannier, 1990), north Greenland (*E. *aff.* E. tuberosa; *Siveter & Lane 1999), south China (*E. *cf.* E. tuberosa; *Siveter et al. 1991) and the North Kara Terrane (*E. *aff.* E. tuberosa; *herein). Global reconstruction for latest Ordovician-earliest Silurian times (simplified from Cocks & Torsvik 2002).*

(Siveter & Vannier 1990; Siveter & Lane 1999), and thereby supports the notion of a Late Silurian ecological shift for the origin of pelagic (myodocope) ostracods (Siveter & Vannier 1990; Siveter et al. 1991). Early, Llandovery-Wenlock myodocopes were benthic, living with dominantly benthic associates on well oxygenated shelves. Myodocope ostracods appear to have undergone an ecological shift by the Ludlow-Prídolí, an event that provides the best evidence for the earliest occurrence of pelagic ostracods in the fossil record (see Siveter 1984; Siveter et al. 1987, 1991; Siveter & Vannier 1990; Vannier & Abe 1992; Siveter & Lane 1999; Gabbott et al. 2003; Siveter et al. 2003).

Biostratigraphical significance

Entomozoe is an early and rare Llandovery myodocope ostracod (see Siveter et al. 1991; Vannier & Abe 1992). The only known earlier myodocope is from the Late Ordovician, Ashgill Series, Soom Shale of South Africa (Gabbott et al. 2003). As in Severnaya Zemlya the occurrence of *Entomozoe* elsewhere, in Scotland, South China and North Greenland, is confined to the Late Llandovery Telychian Stage and therefore the genus can be used as an indicator of that stratigraphic level. It is possible (see below) that all of this *Entomozoe* material represents a single species, though confirmation of this is currently prevented by consideration of preservational and other factors.

Palaeogeographical significance

The known global distribution of *Entomozoe* reflects low palaeolatitudes and the new occurrence reported herein supports current palaeogeographic reconstructions for the Silurian (Fig. 3). The Severnaya Zemlya Archipelago together with the northern part of Taimyr represent the North Kara Terrane, a microplate that collided with central Taimyr (today part of the Siberian plate) during Late Palaeozoic times (Vernikovsky 1996). During the Early Silurian, the North Kara Terrane was located in tropical to subtropical latitudes, in the northern part of a remnant Iapetus Ocean (Pickering & Smith 1995 argue that this ocean was essentially closed at this time) and between the nearby palaeocontinents of Baltica to the east and Laurentia to the west. Scotland and Greenland formed part of the eastern margin of Laurentia; south China was at similar latitudes but distant. This palaeogeography is based on a range of geological data such as facies patterns and faunal distributions, and is supported by palaeomagnetic data (Metelkin et al. 2000; Li & Powell 2001; Cocks & Torsvik 2002).

As pelagic larvae are unknown in ostracods the occurrence of *Entomozoe* in Severnaya Zemlya provides additional evidence of perhaps close proximity between the North Kara Terrane and Laurentia (and Baltica?). The south China plate was at about 100 degrees palaeolongitude to the east, across an ocean, and that occurrence of *Entomozoe* is not easily explained by the disper-

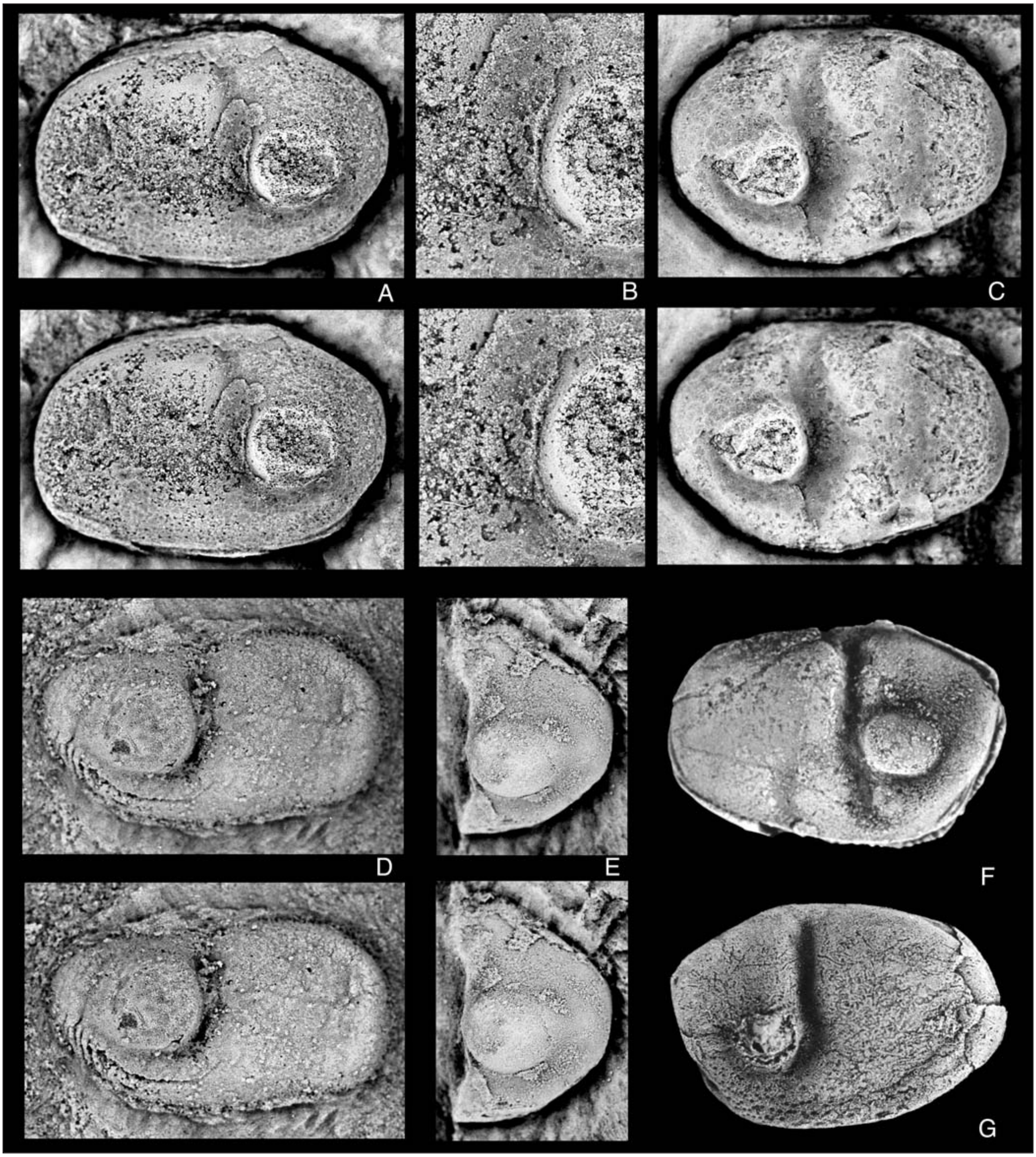

Fig. 4. A-E . Entomozoe *aff.* E. tuberosa, *from Section BG99-13, October Revolution Island, Severnaya Zemlya; Sredninskaya Formation, Telychian, Llandovery Series.*

A, B, internal mould of right valve (remnants of shell are present only along ventral and dorsal margins and in the adductorial sulcus), SIB 1026: A, lateral stereo-pair, x4.7; B, stereo-pair detail of adductor muscle scar, x11. C, internal mould of left valve (remnants of shell are present only along ventral and dorsal margins), SIB 1025; lateral stereo-pair, x5.2. D, poorly preserved left valve (internal mould?), SIB 1028; lateral stereo-pair, x7.2. E, incomplete (anterior part of) right valve, SIB 1027; lateral stereo-pair, x6.1.

F, Entomozoe *aff.* E. tuberosa, *from Centrum Sø, Kronprins Christian Land, eastern North Greenland; Telychian, Llandovery Series. Right lateral view of carapace, Geological Museum, University of Copenhagen, Denmark, MGUH 24385, x4.4.*

G, Entomozoe tuberosa *(Jones, 1861), from bank of River North Esk, upstream from junction with Wether Law Linn, North Esk Inlier, Pentland Hills, near Edinburgh, Scotland; Wether Law Linn Formation, Telychian, Llandovery Series. Cast of external mould of left valve, Geological Survey, Edinburgh, UK, GSE 10812, x5.7.*

sal factors known for supposed benthonic ostracodes. However, 'island hopping' (e.g. see Cocks & Fortey 1982), via the North Kara microplate, is a possible migratory mechanism to account for such a distribution.

Palaeozoogeographical significance

There is only one previous record of a myodocope ostracod from the Silurian of the Eurasian Arctic. The ‘entomozoacean’ (see Siveter & Vannier 1990 regarding the use of this name) ‘*Entomis*’ aff. *lamarmorai* Canavari, 1900 was reported from Ludlow Series cephalopod limestone biofacies of the Taimyr Peninsula of central Siberia (Kríz & Bogolepova 1995). Similar forms are known from several locations in the upper Silurian of Europe, including Sardinia.

The new occurrence of *E.* aff. *Entomozoe tuberosa* represents a rare and early species link between the ‘Baltic-British’ Silurian ostracod faunal province and ostracod assemblages of the Russian Eurasian Arctic. Most biostratigraphical studies of Silurian ostracods lie within an ostracod biogeographical region centred on the North Atlantic. This, in essence, is a ‘Baltic-British Province’ (detailed in Siveter 1989), drawn east of the Appalachians, north of Bohemia, and extending to southern Britain, Scandinavia, the east Baltic, Belorussia, the Ukraine and towards the Urals. It includes the time restricted (Late Silurian) ostracod assemblages of the ‘Fundy’/’Arisaig-Eastport’ belt of north-eastern North America, and is recognised particularly using beyrichiacaean palaeocope associations.

To the east, in the Urals (Abushik 1962, 1980b, 1986, 1997; Zenkova 1970, 1975, 1988; Abushik et al. 1983) and the associated Arctic Vaigach-Dolgy-Novaya Zemlya islands (Abushik 1970, 1980a, 1981) there are Silurian ostracods (genera) with Baltic affinities but none of the index species known from elsewhere in the faunal province (Siveter 1989; see also Abushik & Evdokimova 1999). Baltic influence is also present but not strong, at least as far as key palaeocope species are concerned, in both the Severnaya Zemlya Archipeligo (Abushik 1982a, 1982b, 1999, in press; Abushik & Evdokimova 1999) and the often leperditiid-prolific assemblages elsewhere in Siberia (Abushik 1960, 1975, 1977, 1990; Abushik et al. 1960; Bazarova 1982). In the Late Silurian-Early Devonian of the Altai-Sayan region ostracod faunas of a different, essentially non-palaeocope aspect dominate (Polenova 1970).

Systematic Palaeontology

Subclass Ostracoda Latreille, 1802 (*nom. correct.* Latreille 1806)
Superorder Myodocopa Sars, 1866
Order Myodocopida Sars, 1866 (*nom. correct.* Pokorny 1953)
Suborder Myodocopina Sars, 1866
Superfamily Bolbozoacea Boucek, 1936
1936 Bolbozoacea, Boucek, p. 62.
1950 Entomozoacea nov. nom.; Pribyl, p. 3.
Family Bolbozoidae Boucek, 1936
1936 Bolbozoidae n. f., Boucek, p. 62.
1950 Entomozoidae nov. nom.; Pribyl, p. 4 (= Entomidae Jones 1873).

Type genus. Bolbozoe Barrande, 1872, from the Silurian of Bohemia, Czech Republic.

Other genera. Entomozoe Pribyl, 1950 (*pro Entomis* Jones, 1861; *non* Herrich-Schaeffer, 1856); *Sulcuna* Jones & Kikby, 1884.

Diagnosis (modified from Siveter & Vannier 1990). Myodocopids with a generally well-developed adductorial sulcus extended ventrally and forward around a node or bulb to reach or almost reach the anteroventral to anterior valve margin. Weak posterior sulcus sometimes present. Incisure (= gape) and notch (= indentation) present at anterior margin, usually below a rostrum or above an anteroventral projection. Adductor muscle scar consists of a series of subparallel, radiating, alternating ridges and furrows, typically forming a feather-like pattern overall. Valves reticulate, corrugate, tuberculate, punctate or smooth.

Remarks. Based on the type genera *Entomozoe* and *Bolbozoe*, Siveter & Vannier (1990) concluded that the families Entomozoidae and Bolbozoidae are synonymous and they tentatively assigned the Bolbozoacea to the myodocope Order Myodocopida. In contrast, Vannier & Abe (1992, p. 498) considered that the type-species of *Entomozoe*, "probably belongs to the Entomoconchacea", an extinct middle Palaeozoic superfamily which they included within the other myodocope Order, the Halocyprida.

The first description of the full compliment of soft-parts of a Palaeozoic ostracod has recently been made based on a Silurian cylidroleberidid myodocope (Siveter et al. 2003), but its shell morphology is not similar to that of *Entomozoe*.

Genus *Entomozoe* Pribyl, 1950

1990 *Entomozoe* Pribyl, 1950; Siveter & Vannier, p. 51 (q.v. for full synonomy).

1999 *Entomozoe* Pribyl, 1950; Siveter & Lane, p. 9.
Type-species. Subsequently designated by Miller, 1892, p. 707; *Entomis tuberosa* Jones, 1861, p. 137. Lectotype designated by Siveter & Vannier, 1990, p. 53.

Other species. *Entomozoe* is currently regarded as monotypic. Other published 'Entomis' or entomozoacean species may be congeneric with *E. tuberosa* but such judgements must await examination of the material (Siveter & Vannier 1990).

Diagnosis. Large bolbozoid having a vertical adductorial sulcus, curved forward below a moderately sized anteroventral node. Slight anterior indentation in shell outline and rostral incisure present. Adductor muscle scar consists of series of alternating ridges and furrows forming biserial-radial, feather-like pattern. Surface smooth to weakly punctate-reticulate (modified from Siveter & Vannier 1990).

Entomozoe aff. *Entomozoe tuberosa* (Jones, 1861)
Fig. 4A-E.

1999 *Entomozoe* aff. *Entomozoe tuberosa* (Jones 1861); Siveter & Lane, p. 9, fig. 4a-e, g.

Material. At least 11 specimens on rock slabs; Museum of Evolution, Uppsala University, numbers SIB 1025-35. Some valves have the shell preserved; others occur as mostly exfoliated, internal moulds.

Description. Valves approximately almond shaped, weakly inflated overall; maximum height at about the site of adductorial sulcus, maximum length at about mid-height. Lateral valve outline gently curved ventrally, more strongly curved dorsally about a point just in front of the adductorial sulcus, evenly rounded posteriorly, and is rounded anteriorly. Anteroventral valve outline inclined forward, is very gently indented along site of presumed weakly developed rostral incisure (this area lacks shell in all of the best, large specimens).

Adductorial sulcus long, narrow, occurs just in front of mid-length; continues ventrally and becomes obsolete close to ventral part of valve in lateral view, and also branches and curves gently forward around dome-like node. Latter is sited mostly below mid-height and projects laterally well beyond rest of valve. Faint posterior sulcus developed in some specimens, particularly in ventral part of valve. Adductor muscle scar occurs at height of node (Fig. 4A-C); manifest by several, faint, alternating ridges and furrows arranged into forwardly curved biserial-radial pattern. No external ornament recognised.

Measurements. Maximum valve length - valve height of two well preserved internal mould specimens: 11.1-7.7mm (SIB 1025), 13.05-8.8mm (SIB 1026).

Discussion. The Russian material is indistinguishable from *E.* aff. *Entomozoe tuberosa* described (Siveter & Lane 1999) from Greenland. The Russian and Greenland specimens differ from the coeval *Entomozoe tuberosa* from Scotland (Siveter & Vannier 1990) by having a slightly longer adductorial sulcus, a less obviously developed rostral incisure, a lack of punctae and by having a (weak) posterior sulcus. Such differences possibly represent a separate species or, simply, intraspecific variation. Because of the relatively small amount of available material from Russia (and Greenland), compared to the hundreds of valves known from Scotland, cautiously an 'aff.' assignment is preferred herein.

Occurrence. Sredninskaya Formation, Telychian, Llandovery Series; Section BG99-13 (Bogolepova et al. 2000), middle reaches of the Ushakova River, October Revolution Island, Severnaya Zemlya.

Conclusions

- The ostracod *Entomozoe* aff. *Entomozoe tuberosa* (Jones, 1861) occurs in the Telychian Stage, Llandovery Series of Severnaya Zemlya.
- Like its coeval, congeneric Scottish, Greenland and Chinese counterparts, this Russian *Entomozoe* species lived on a shallow water shelf dominated by epibenthonic fauna and probably had a benthonic lifestyle. This would be consistent with the notion of a Late Silurian ecological shift for the origin of pelagic (myodocope) ostracods.
- *Entomozoe* can be used as an indicator for rocks of Telychian age.
- The Russian *E.* aff. *Entomozoe tuberosa* represents a rare and early species link between the 'Baltic-British' Silurian ostracod faunal province and ostracod assemblages of the Eurasian Arctic.
- *Entomozoe* distribution reflects low palaeolatitudes and the Russian occurrence is consistent with the North Kara Terrane being close to Laurentia in the Early Silurian.

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