

The myodocope ostracode *Entomozoe* from an early Silurian (Telychian, Llandovery) carbonate mound of the Samuelsen Høj Formation, North Greenland

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Entomozoe aff. *Entomozoe tuberosa* (Jones 1861), from carbonate mounds of the Samuelsen Høj Formation, represents one of the few ostracodes documented from the Silurian of Greenland and a rare occurrence of *Entomozoe* from outside Scotland. Like its coeval, congeneric Scottish counterparts, the Greenland *Entomozoe* lived on a shallow-water shelf dominated by epibenthonic fauna and probably had a benthonic, swimming(?) lifestyle. Its environmental, ecological and geographical setting is consistent with the idea that these earliest, Lower Silurian myodocopes were benthonic and, therefore, that Upper Silurian pelagic representatives must have resulted from an ecological shift in the group.

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A Silurian Llandovery Series fauna collected from eastern North Greenland contains scarce specimens of a myodocope ostracode, *Entomozoe* aff. *Entomozoe tuberosa* (Jones 1861). The find represents a rare Llandovery age myodocope and only the second occurrence of *Entomozoe* known outside the Llandovery of Scotland. The environmental, ecological and geographical setting of the Greenland material, in shallow-water carbonates on the palaeo-continent of Laurentia, is consistent with the notion (Siveter & Vannier 1990; Siveter *et al.* 1991) that the earliest, Lower Silurian (Llandovery–Wenlock) myodocopes were benthic, living on well-oxygenated shelves. Myodocope ostracodes appear to have undergone a benthic to pelagic ecological shift by the Upper Silurian, an event which provides the best evidence for the earliest occurrence of pelagic ostracodes in the fossil record (Siveter 1984; Siveter *et al.* 1987, 1991; Siveter & Vannier 1990; Vannier & Abe 1992).

Material and methods

The myodocope-bearing fauna was obtained by J.W. Cowie (University of Bristol, UK) and P.J. Adams on a

Danish state-aided expedition to North Greenland in 1956. The most detailed maps then available were 1:1 000 000 scale aeronautical charts. The fossils are from collections made at “2 km from the north shore of Centrum Sø, at a height of about 300 metres, at approximately 22°20′W, 80°13′N, in Kronprins Christian Land, west of Dijnphna Sund” (Fig. 1; J.W. Cowie, personal communication, as reported in Lane 1972, p. 336). Contrary to Lane 1972 (p. 337, text-fig. 1a) both these collections were made in the Samuelsen Høj Formation (Fig. 2), a unit erected to encompass the isolated carbonate mounds found in several areas of North Greenland, such as Peary Land, Valdemar Glückstadt Land and Kronprins Christian Land (Hurst 1984, p. 52; see Fig. 1 for locations). The locality yields a Llandovery, Telychian Stage, *Pterospirifer celloni* Biozone conodont assemblage (Armstrong & Aldridge 1982; Armstrong 1983, 1990; Hurst 1984, p. 59).

The material consists of two myodocope specimens, housed in the Geological Museum, University of Copenhagen (MGUH), Denmark. Photographs were made using an Aristophot mounted with a Leica camera (methods outlined in Siveter 1990). Morphological terminology of the myodocope shell follows Siveter *et al.* (1987).

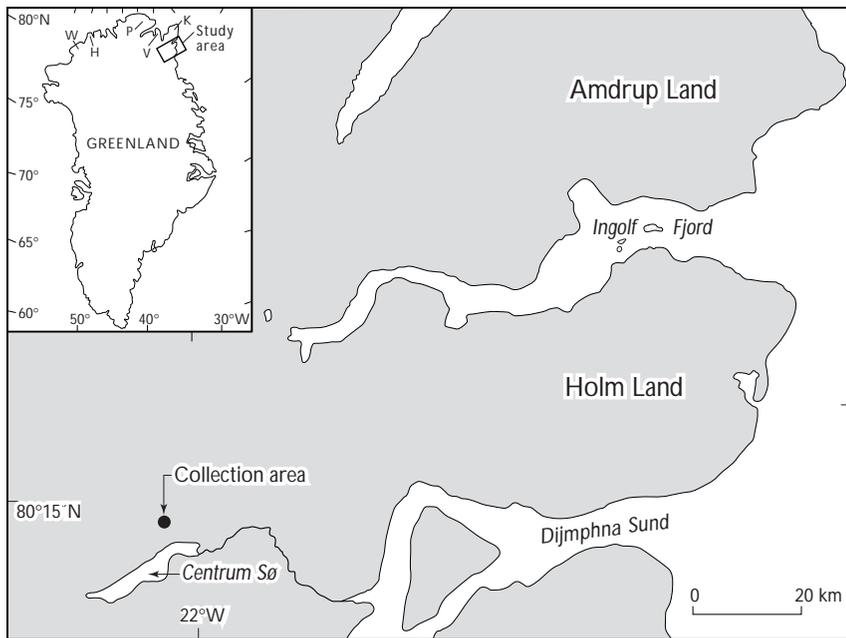


Fig. 1. Locality yielding *Entomozoe* aff. *E. tuberosa*: north side of Centrum Sø, Kronprins Christian Land, eastern North Greenland. **H**: Hall Land, **K**: Kronprins Christian Land, **P**: Peary Land, **V**: Valdemar Glückstadt Land, **W**: Washington Land.

Ostracodes from the Silurian of Greenland

Entomozoe aff. *E. tuberosa* is one of the few ostracode taxa documented from the Silurian of Greenland, though some forms are often common locally. Predominantly smooth-shelled ('non-palaeocope') species are often encountered in the platform carbonates of the Samuelsen Høj Formation from Kronprins Christian Land, Valdemar Glückstadt Land and Peary Land and from correlative formations in Washington Land and Hall Land in western North Greenland (see Fig. 1 for locations). 'Smooth ostracods' (possibly leperditiiids) were reported from the probable Rhuddanian of the Turesø Formation (= the 'un-named Silurian(?) dolomite formation') and from the Aeronian of the Ymers Gletscher Formation (= the 'un-named Silurian limestone formation') of Børglum Elv, central Peary Land (Armstrong & Lane 1981, pp. 31–32). Hurst (1984, p. 37) documented abundant ostracodes from probable Aeronian strata in the lower half of the Odins Fjord Formation of Peary Land. From later collections made in the same area (GGU 184145), a beyrichiacean and abundant smooth ostracodes were recorded from the *P. celloni* Biozone near the top of the Odins Fjord Formation (Lane 1988, p. 93). The latter, largely unstudied ostracode fauna, includes smooth *Conbathella*-like thlipsuraceans and the beyrichiacean *?Apatobolbina* ('*Platybolbina*' of Lane); both genera occur in the late

Llandovery – early Wenlock of Anticosti Island, Canada (Copeland 1974).

Poulsen (1934, p. 37) described the unrevised *Ceratomypris symmetrica* gen. et sp. nov. and *Euprimitia?* sp. from the Aeronian – early Telychian Cape Schuchert Formation of Washington Land, western North Greenland. *Monoceratella mazos* Lane 1980, was established from a Telychian – ?earliest Wenlock boulder within a Silurian conglomerate of Kap Schuchert, Washington Land.

Lifestyle of *Entomozoe* aff. *E. tuberosa*

Interpretation of mode of life of fossils depends on evidence from their functional morphology and design, and from independent geological data such as the nature of their faunal associates and their patterns of facies and palaeogeographical distribution (e.g. see Fortey 1985 for trilobites; Siveter 1984 and Siveter *et al.* 1991 for Silurian ostracodes). Interpretation of the mode of life of Silurian ostracodes is not helped by the fact that none range to the Recent. There are also the potential pitfalls inherent in reconstructing the palaeoecology of vagile organisms, such as adopting circular reasoning in allowing notions on probable lifestyle to unduly influence ideas on where the animal was supposedly living.

Morphological evidence

In Recent myodocopes the rostral incisure facilitates protrusion of the first and second antennae for use in locomotion, particularly swimming. The faintly developed rostral incisure in *E. aff. E. tuberosa* may imply that its frontal appendages were not especially well developed and that, like *E. tuberosa* from the late Llandovery of the Pentland Hills, Scotland (see Siveter & Vannier 1990), it may not have been an accomplished swimmer. Moreover, intuitively the reasonably thick, relatively heavy(?) shell of *E. aff. E. tuberosa* is not a character readily associated with a pelagic lifestyle.

Depositional environment: facies and faunal associates

The carbonate mounds of the Samuelsen Høj Formation have elongate to circular outcrops, of 50 m to 5 km widths or circumferences of 200 m to 10 km, though none of their many lithologies have great lateral extent (Mayr 1976; Hurst 1980, 1984). The mounds accumulated in a relatively shallow, mid- to outer-shelf setting; as such, they are typical of many others in the Palaeozoic and Mesozoic, which often occur as products of rapid subsidence of a mature shelf. Though difficult to estimate accurately the distance from shoreline and the water depth in which the mounds formed, a fairly high-energy environment, well within the euphotic zone, is indicated; moreover, frequent sub-aerial exposure due to local changes in shelf-subsidence rate can be imagined.

The ostracodes occur in a coquina which is dominated by trilobites constituting the relatively high diversity 'styginid-cheirurid-harpetid trilobite Assemblage' (Lane 1972; Thomas & Lane 1999), all of which probably had a benthonic mode of life; e.g. *Meroperix ataphrus*, *Chiozoon cowei*, *Hyrokybe pharanx*, *Scotoharpes loma*, *Stenopareia* and *Calymene*. Equivalent trilobite faunas occur in similar carbonate mound facies of early Ordovician Arenig (cheirurid-illaenid community of Fortey 1975) to early Devonian Pragian (Chlupáč 1983) age and taxonomically different but homoeomorphic similar trilobite assemblages occur up to the latest Palaeozoic (for example, see Lane & Owens 1982; Owens 1983); however, no myodocopes have been recorded from these other trilobite associations. Rare, undetermined bryozoans and small numbers of brachiopods (e.g. *Lissocoelina*, *Streptis* and a delthyrid; Boucot *in* Thomas & Lane 1999) and rugose and tabu-

late corals (*Microplasma lovenianum*, *Favosites gothlandicus*, *Dinophyllum*, *Tryplasma* and ?*Tabularia*; Scrutton 1975) represent the sessile epibenthonic components of the myodocope-bearing fauna. Vagile epibenthonic associates are rare gastropods (e.g. *Subulites*, *Gyronema*, *Liospira*, *Megalomphala* and platycerids) and undetermined bivalves and rostroconchs. Rare, undetermined cephalopods are the only possible pelagic associates. Thus, the animals co-occurring with *E. aff. E. tuberosa* are almost all epibenthonic forms (Fig. 3). An assignment to Benthic Association 3 of Boucot (1975) is likely (Hurst & Surlyk 1984).

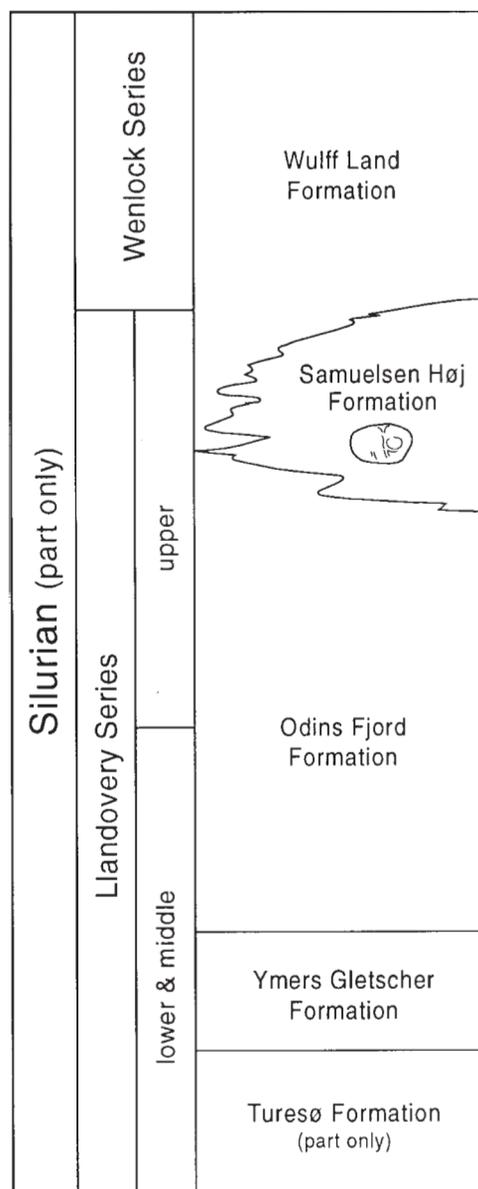


Fig. 2. Stratigraphic position of *Entomozoe* aff. *E. tuberosa*, in the late Llandovery Series, Samuelsen Høj Formation, eastern North Greenland.

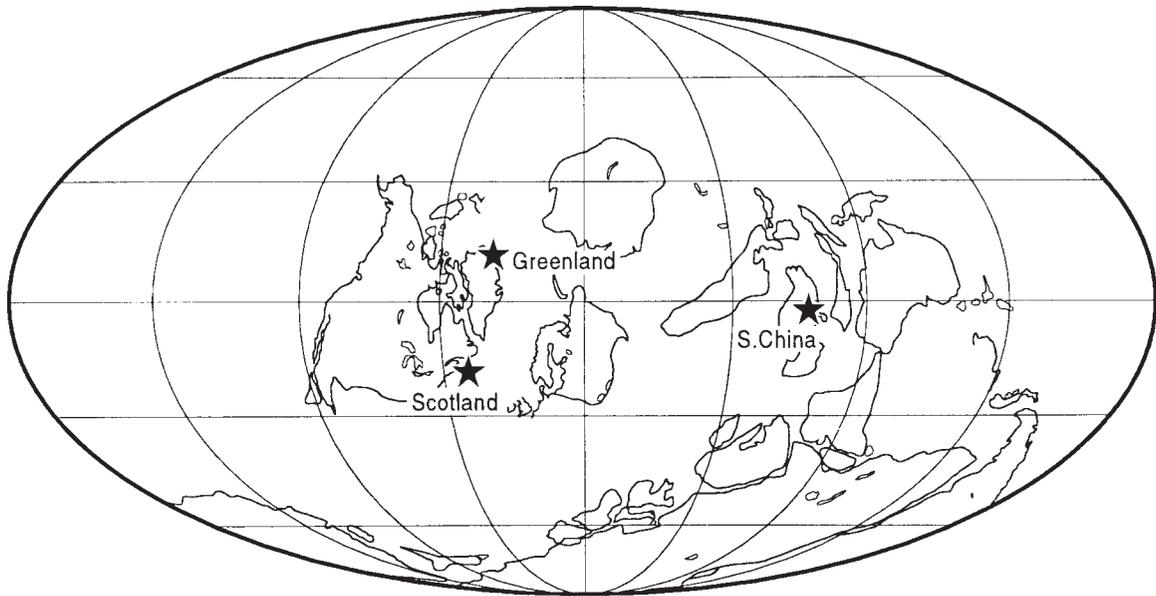


Fig. 3. Known occurrences of *Entomozoe*: the late Llandovery of Scotland (*E. tuberosa*; Siveter & Vannier 1990), eastern North Greenland (*E. aff. E. tuberosa*; herein) and south China (*E. cf. E. tuberosa*; Siveter *et al.* 1991). Base map for the Llandovery is after Scotese & McKerrow (1990).

Palaeogeographical distribution

Entomozoe is known only from Scotland (*E. tuberosa*; Siveter & Vannier 1990), Greenland (*E. aff. E. tuberosa*; herein) and South China (*E. cf. E. tuberosa*, Siveter *et al.* 1991, pp. 152, 161, fig. 4), all in late Llandovery strata deposited in tropical latitudes (Fig. 3). Greenland and Scotland were relatively close then, forming part of the eastern margin of the continent of Laurentia (equivalent to mostly present-day North America), but the south China plate was at about 100° palaeo-longitude distant across an ocean. This distributional pattern is not easily explained by the dispersal factors known for supposed benthonic ostracodes (pelagic larvae are unknown in extant members of the group) but 'island hopping' is a possible migratory mechanism (e.g. see Cocks & Fortey 1982).

The evidence suggests that *E. aff. E. tuberosa* from Greenland lived on a relatively shallow-water, carbonate shelf with a concomitant fauna of almost exclusively epibenthonic taxa and including photosynthesising organisms (Hurst 1984, p. 53). The palaeogeographical distribution of *Entomozoe* does not necessarily imply a pelagic dispersal capacity. The ostracode was probably benthonic and perhaps had some swimming capabilities.

Palaeoecological significance of *E. aff. E. tuberosa*

Certain Silurian myodocopes are good candidates for pioneer pelagic ostracodes (Siveter 1984; Siveter *et al.* 1987, 1991; Siveter & Vannier 1990). Characteristically Upper Silurian Ludlow and Pridoli myodocopes lived with low diversity pelagic faunas, in outer shelf topographic lows or off-shelf basin slopes, and are often associated with deposits which imply anoxic or lowered oxygen conditions. In contrast, Lower Silurian Llandovery and Wenlock myodocopes lived with dominantly benthic associates on well-oxygenated shelves. Evidence from Britain, France, the Czech Republic, Sardinia, Australia and China underpins the idea that myodocope ostracodes may have undergone a benthic to pelagic ecological shift in mid-Silurian times (Siveter & Vannier 1990; Siveter *et al.* 1991).

E. tuberosa from Scotland appears preferentially to have inhabited shallow, nearshore, shelf environments and, like most of its associates, is considered to be part of the habitually vagile (swimming?) benthos (Siveter & Vannier 1990). That the coeval *Entomozoe* from Greenland had a similar general habitat and possible lifestyle is consistent with the notion and timing of an ecological shift affecting myodocopes during the Silurian.

Systematic palaeontology

Subclass Ostracoda Latreille 1802 (*nom. correct.*
Latreille 1806)

Superorder Myodocopa Sars 1866

Order Myodocopida Sars 1866 (*nom. correct.*
Pokorný 1953)

Suborder Myodocopina Sars 1866

Superfamily Bolbozoacea Bouček 1936

1936 Bolbozoacea, Bouček, p. 62

1950 Entomozoacea nov. nom. Příbyl, p. 3

Family Bolbozoidae Bouček 1936

1936 Bolbozoidae n. f., Bouček, p. 62

1950 Entomozoidae nov. nom. Příbyl, p. 4

(= Entomidae Jones 1873)

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

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

Diagnosis. Myodocopids with a generally well-developed adductor sulcus extended forward and ventrally around a node or bulb to reach or almost reach the anteroventral to anterior valve margin. 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. (Modified from Siveter & Vannier 1990.)

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.

Genus *Entomozoe* Příbyl 1950

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

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

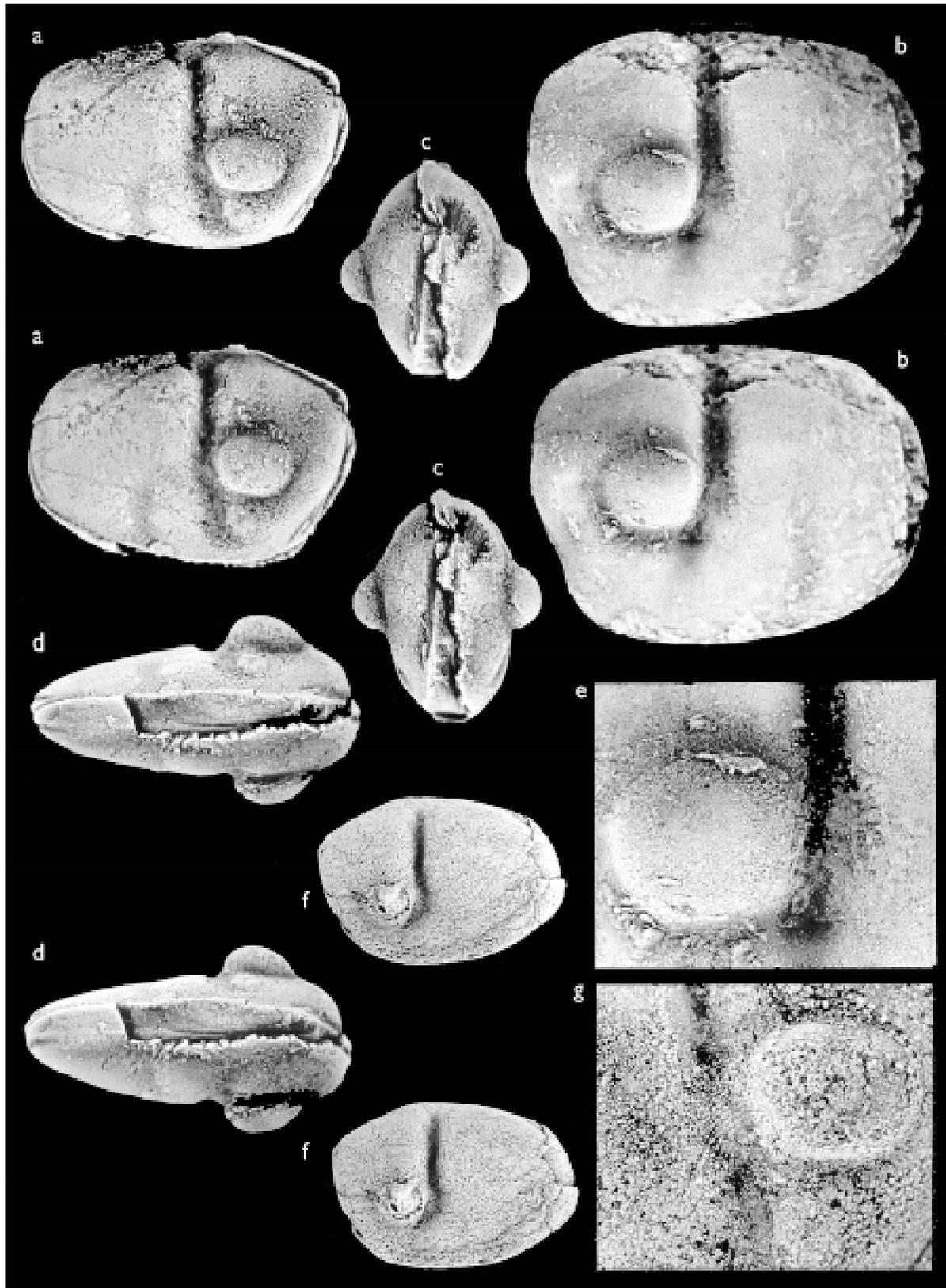
Diagnosis. Large bolbozoid having a vertical adductor sulcus, curved forward below a moderately sized anteroventral node. Anterior indentation in shell outline and rostral incisure present. Adductor muscle scar consists of series of alternating ridges and furrows forming biserial-radial, feather-like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

***Entomozoe* aff. *Entomozoe tuberosa* (Jones 1861)**
Fig. 4a–e, g

Material. Two specimens, both with shell preserved: a left valve on a small rock piece (MGUH 24384) and an isolated carapace (MGUH 24385).

Description. Valves approximately almond shaped, weakly inflated overall; maximum height at anterior part of adductor sulcus, maximum length just above mid-height. Lateral valve outline gently curved ventrally, more strongly curved dorsally about a point just in front of the adductor sulcus, evenly rounded posteriorly, and is sharply rounded anteriorly at point above mid-height. Anteroventral valve outline inclined forwards is very gently indented along site of presumed weakly developed rostral incisure (this area is damaged and lacks shell in both specimens). Valve bends – at site along lateral outline of valve – to form wide, flattish, ventral admarginal surface which narrows anteroventrally and posteroventrally. Left valve overlaps across to fine ridge at site of valve bend along right valve.

Adductor sulcus long, narrow, occurs just in front of mid-length, widens to form V-shape area adjacent to hinge line. Faint posterior sulcus, developed just behind adductor sulcus, in ventral one-third of valve. Both sulci curve gently forward ventrally to become obsolete close to ventral part of valve in lateral view. Dome-like node sited immediately in front of adductor sulcus and mostly below mid-height, projects



laterally well beyond rest of valve. Adductor muscle scar occurs at height of node, mani-fest externally by at least nine, faint, alternating ridges and furrows arranged into forwardly curved biserial-radial pattern. No external ornament recognised.

Measurements. Maximum valve length–height: 17.1–12 mm (MGUH 24384), 13.5–9.1 mm (MGUH 24385).

Discussion. These two Greenland specimens differ from the smaller, coeval *Entomozoe tuberosa*, from the Wether Law Linn Formation in Scotland (Siveter & Vannier 1990), by having a slightly longer adductor sulcus, a less obviously developed rostral incisure, a lack of punctae and especially by having a posterior sulcus (compare Fig. 4a–e, g and 4f). Such differences probably represent a separate species but, because of the small amount of available material, a new taxon is not proposed.

Occurrence. Samuelsen Høj Formation, *Pterospathodus celloni* conodont Biozone, Telychian, Llandovery Series; at a height of about 300 m, two kilometres from the northern shore of Centrum Sø (approximately 22°20'W, 80°13'N), Kronprins Christian Land, eastern North Greenland.

Conclusions

1. *Entomozoe* aff. *E. tuberosa* represents only the fourth formally documented ostracode from the Silurian of Greenland and only the second record of *Entomozoe* from outside its Scottish type area.

Fig. 4. **a–e, g:** *Entomozoe* aff. *E. tuberosa* from Cowie's collection localities 1510 (MGUH 24384) and 1511 (MGUH 24385), near Centrum Sø, Kronprins Christian Land, eastern North Greenland, Telychian, Llandovery Series, Silurian.

a, c, d, g, carapace, MGUH 24385; a, c, d: Right lateral, anterior and ventral stereo-pairs, × 4. g: Detail of muscle scar, near base of adductor sulcus, × 8. b, e: Left valve, MGUH 24384; b: Lateral stereo-pair, × 4. e: Detail of muscle scar, near base of adductor sulcus, × 9.

f: *Entomozoe tuberosa* (Jones 1861), stereo-pair of cast of external mould of left valve, Geological Survey (Edinburgh, United Kingdom) GSE 10812, × 4. From the right bank of River North Esk, upstream from junction with Wether Law Linn, North Esk Inlier, Pentland Hills, near Edinburgh, Scotland; Wether Law Linn Formation, late Llandovery Series, Silurian.

2. Like its coeval, congeneric Scottish counterparts, the Greenland *Entomozoe* lived on a shallow-water shelf dominated by epibenthonic fauna and probably had a benthonic, swimming(?) lifestyle.
3. The Greenland *Entomozoe* endorses the opinion that the earliest, Lower Silurian myodocopes were benthonic and as such is consistent with the model that myodocopes experienced an ecological shift during the Silurian.

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