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NON-MINERALISED DISCOIDAL FOSSILS FROM THE ORDOVICIAN BARDAHESSIAGH FORMATION, CO. TYRONE, IRELAND

BREANDÁN ANRAOI MACGABHANN AND JOHN MURRAY

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Abstract

Four non-mineralised fossils from the Ordovician Bardahessiagh Formation, near Pomeroy, Co. Tyrone, have been examined for the first time following their recovery from a temporary trench dug in 1992, and are here described as *Seputus pomeroyi* gen. et sp. nov. These are discoidal impressions with up to 120 radial ridges extending from a central ring to a sharply defined margin, and they are tentatively interpreted as rotatiscid eldonids. The fossils are preserved as moulds and casts in a medium-grained quartzose sandstone bed, which is densely packed with corals, trilobites, brachiopods and delicately preserved echinoderms, probably representing an event bed on an outer shelf or upper slope setting. The non-mineralised fossils are likely to represent a para-autochthonous assemblage of benthic organisms, preserved by early diagenic mineralisation in anaerobic conditions produced by the decay of organic matter entrained within the bed, a mode of preservation broadly similar to that of non-mineralised fossils from the Ediacaran System. The preserved discs are believed to represent a tough exterior more resistant to decay than the (unknown) remainder of the organism.

Introduction

Non-mineralised organisms represent the most common component of modern marine ecosystems; however this predominance is not matched in the fossil record. Descriptions of non-mineralised fossils are thus of some considerable importance, firstly to increase our knowledge of the cryptic component of extinct ecosystems represented by such organisms, and secondly to increase our understanding of the taphonomic conditions that allowed for their preservation. This in turn facilitates a better assessment of exactly how representative such fossils are of extinct unmineralised biotas in general. Here we report an occurrence of non-mineralised fossils in a shallow marine sandstone from the Ordovician of Co. Tyrone, and discuss the implications of this unusual find.

Age and geological setting

The material in question was recovered from a temporary trench (located at 54° 36' 16" N, 6° 52' 41" W) dug by the Ulster Museum in September 1992 near Pomeroy, Co. Tyrone, Ireland. The trench was situated some 10m south of an infilled quarry (Fig. 1), approximately 650m SSW of Craigbardahessiagh summit, and it exposed the top of the Bardahessiagh Formation (Scrutton *et al.* 1998). This unit forms part of an Ordovician transgressive sedimentary sequence on the Laurentian margin of Iapetus, which unconformably overlies the Tyrone Ophiolite, obducted in the Grampian Orogeny (Hutton *et al.* 1985; Candela 2006; Graham 2009). Biostratigraphic control indicates that the top (Member III cited in Candela 2002, 2006) of the formation straddles the boundary of the Burrellian Stage (Longvillian Substage) and Cheney Stage (Woolstonian Substage) of the Caradoc Series (Candela

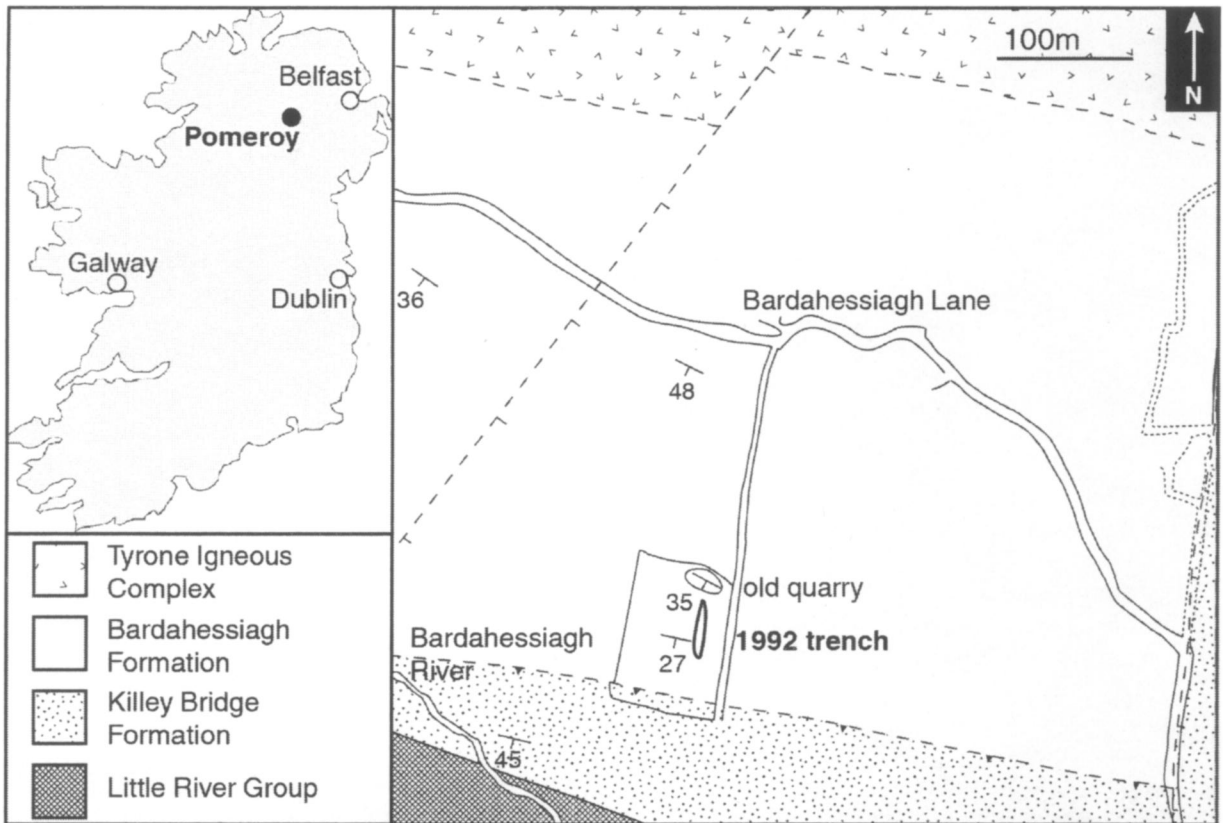


Fig. 1—Map showing the location of the temporary trench and local lithologies, with the location of Pomeroy noted on the inset. Redrawn from Scrutton *et al.* (1998).

2002, 2006) according to the 'old' European Ordovician time-scale (Fortey *et al.* 1995). This corresponds with the uppermost Sandbian and lowermost Katian (Sa2 and Ka1 stage slices) according to the new standard global Ordovician time-scale (Gradstein *et al.* 2004; Bergström *et al.* 2009). Whilst cephalopods (Evans 1994), corals (Scrutton *et al.* 1998) and brachiopods (Candela 2001, 2002, 2006) have subsequently been described from the material recovered, the fossils discussed herein were simply stored in the Ulster Museum until being brought to our attention in early 2005.

Sedimentological setting

Four specimens, of what appear to be a single fossil taxon, are preserved in a 50 × 40cm block of medium-grained sandstone, on a fracture surface sub-parallel to bedding. The bed, a micaceous quartz arenite with minor chlorite and abundant iron oxides (haematite), is densely packed with skeletal remains, and several delicate fossils (e.g. asteroids and carpoids) in the bed are preserved largely intact (Fig. 2), although the original calcite or aragonite is often significantly or completely degraded, leaving excellent mouldic preservation. Articulation of shells is common; however, orientation

is random and no sorting is evident. No trace fossils or evidence of bioturbation have been observed in the material, nor have any sedimentary structures. The way up of the material was not recorded, and is unknown.

Due to the nature of the material, being loose and out of context, only a limited interpretation of the sedimentology is possible. Scrutton *et al.* (1998) and Candela (2006) reported that trilobite and brachiopod assemblages indicated a mid-shelf shallow water setting for most of the Bardahessiagh Formation, with differing brachiopod faunal associations and the sequential appearance of particular trilobite taxa indicating deposition in progressively deeper water. Assemblages from the top of the formation were regarded as indicative of an upper-slope setting. The articulated nature of the bivalved fossils, the lack of sorting of skeletal remains and the undamaged detailed preservation of some extremely delicate mineralised fossils, as well as the soft-bodied remains, is indicative of fairly minimal transport distances and relatively rapid burial, and is consistent with a storm deposit interpretation, although Scrutton *et al.* (1998) favoured a turbiditic origin. The orientation of the discs subparallel to the bedding surfaces suggests that the transporting current was of low density, and that some degree of settling occurred.

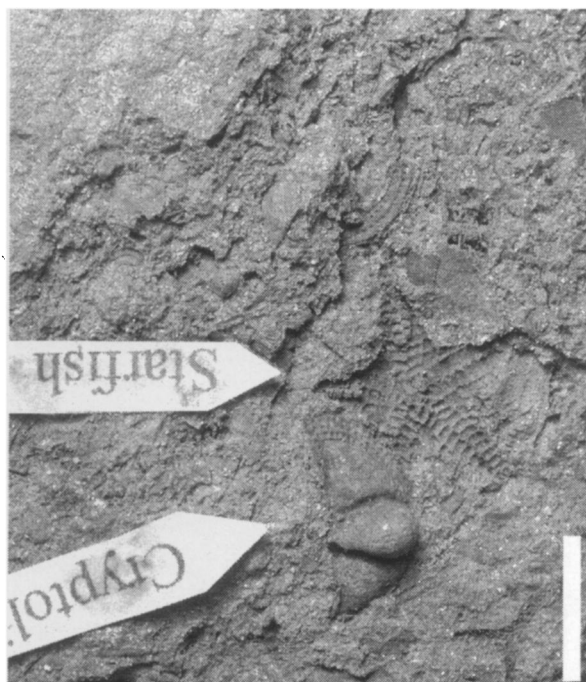


Fig. 2—Well-preserved asteroid and trilobite fragments, with part of one discoidal specimen visible on the upper left. Scale-bar 10mm

Systematic palaeontology

? Unranked stem group CAMBROERNIDS Caron *et al.* 2010

? Family ROTADISCIDAE Dzik 1991

Genus *SEPUTUS* gen. nov.

Type species

Seputus pomeroii sp. nov. (by monotypy).

Etymology

For the Latin word *seputus*, meaning ‘buried, sunk or immersed’, which seems appropriate, given the style of preservation.

Generic diagnosis

As specific diagnosis.

SEPUTUS POMEROII sp. nov.

Figs 3–6

Holotype

Fig. 5, Ulster Museum, Belfast, UM K29807.

Etymology

For the nearby town of Pomeroy.

Material

Four specimens (Figs 3–5; the fourth specimen is unfigured, as the preservation of morphological detail

is so poor as to render it indistinguishable from the enclosing sediment in a grey scale image), all with both part and counterpart preserved, in differing degrees of preservation. All are curated in the Ulster Museum, Belfast: UM K29807.

Specific diagnosis

Ovoid disc, characterised by up to 120 radial lines extending from a central ring of diameter 2–3mm. The radial features extend out towards the margin, which is sharp and lacks any form of protrusion or extensions. A concentric ornament, of a more irregular and coarse nature, may also be present; however, this is not thought to necessarily represent the original morphology (of the living organism). The rest of the organism is unknown.

Description

The specimens of *Seputus pomeroii* are discoidal impressions up to 70mm in diameter and are noticeably darker in colour than the surrounding sediment. Not all specimens preserve a full disc, nor are the specimens truly circular; long axes are not aligned parallel. The uneven nature of the part impression surfaces (due to natural irregularities) appear to be exactly mirrored by their counterparts. While preservation quality varies, some distinguishing features are visible. The disc surfaces are adorned by radial and approximately concentric features; two or three irregular approximately concentric rings are superimposed by fine unbranched straight radial lines, all of which appear to extend from the centre to the outermost sharply defined margin. The width of the radial lines is close to the grain size of the sediment, and this (in combination with variation in the quality of preservation both within and between the specimens) makes it difficult to ascertain their number with any degree of certainty; however, this is estimated at 120. A centralised structure is also present on two specimens (Figs 4–5), 2–3mm in diameter. Importantly, the relief of the radial lines on the specimens is not the same sense on all four specimens: on the ‘part’ block, the radial lines are grooves on three specimens, and ridges on the fourth (Fig. 5, the holotype), which appears to be of exactly opposite relief to the other three. An elongate area, approximately 70mm long and 30mm wide, beside the specimen in Fig. 3 (indicated on Fig. 6), is rich in mica and darkened, similar to (but not as dark as) the specimens themselves. This feature (taken in conjunction with the associated disc) may provide more of an indication of the original shape of the entire organism, which may suggest against a truly discoidal form. However, closely packed tentacles or similar appendages (such as would occur on a scyphomedusa)

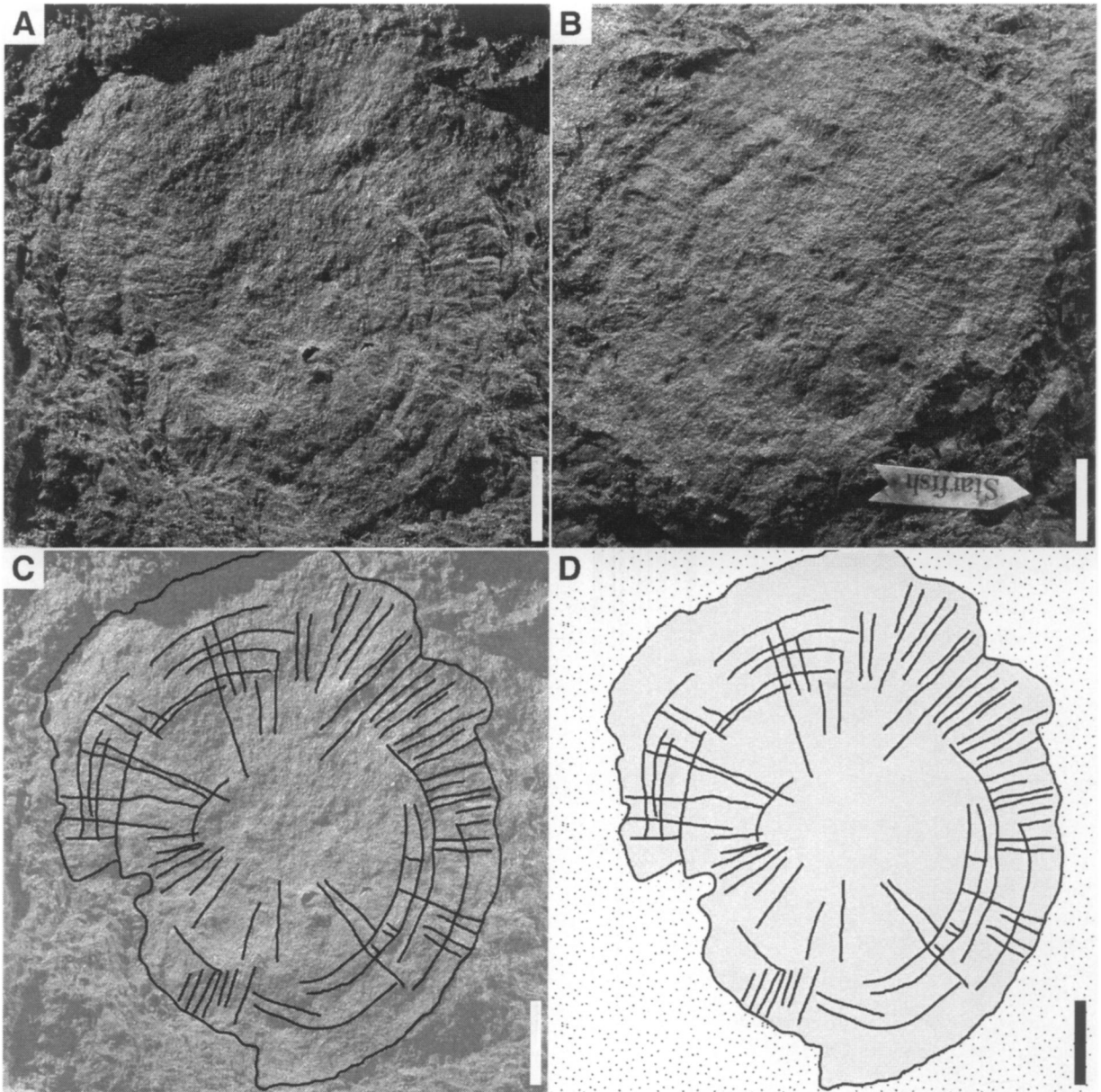


Fig. 3—*Seputus pomeri* n. gen., n. sp., first specimen; all scale-bars 10mm. A, part; B, counterpart; C, part with line drawing superimposed; D, line drawing of part.

may also have caused this feature, or alternatively it may be completely unrelated to the discs.

Deviation of the discs from a truly circular shape may be a result of the deformation of the soft body, or may be due to an original non-circular shape; tectonic deformation is ruled out as a cause by the observation that the long axes of the fossils are not aligned, and the undeformed nature of other associated fossils in the bed.

The regular and consistent nature of the radial lines is probably a reflection of the original morphology of the organism, while the irregular nature of the concentric features probably indicates that they are unrelated to

morphological construction, but are more likely to be a result of deformation of the soft body by compaction, perhaps indicating an originally convex morphology.

Interpretation

We believe that these fossils represent the transported remains of four examples of a non-mineralised organism with a decay-resistant discoidal structure. Without the entire organism, of course, the fossils cannot be assigned to any particular taxonomic group with any degree of confidence. However, we believe that *S. pomeri* is best interpreted as a rotadiscid eldonid.

The eldonids are a clade of Palaeozoic discoidal

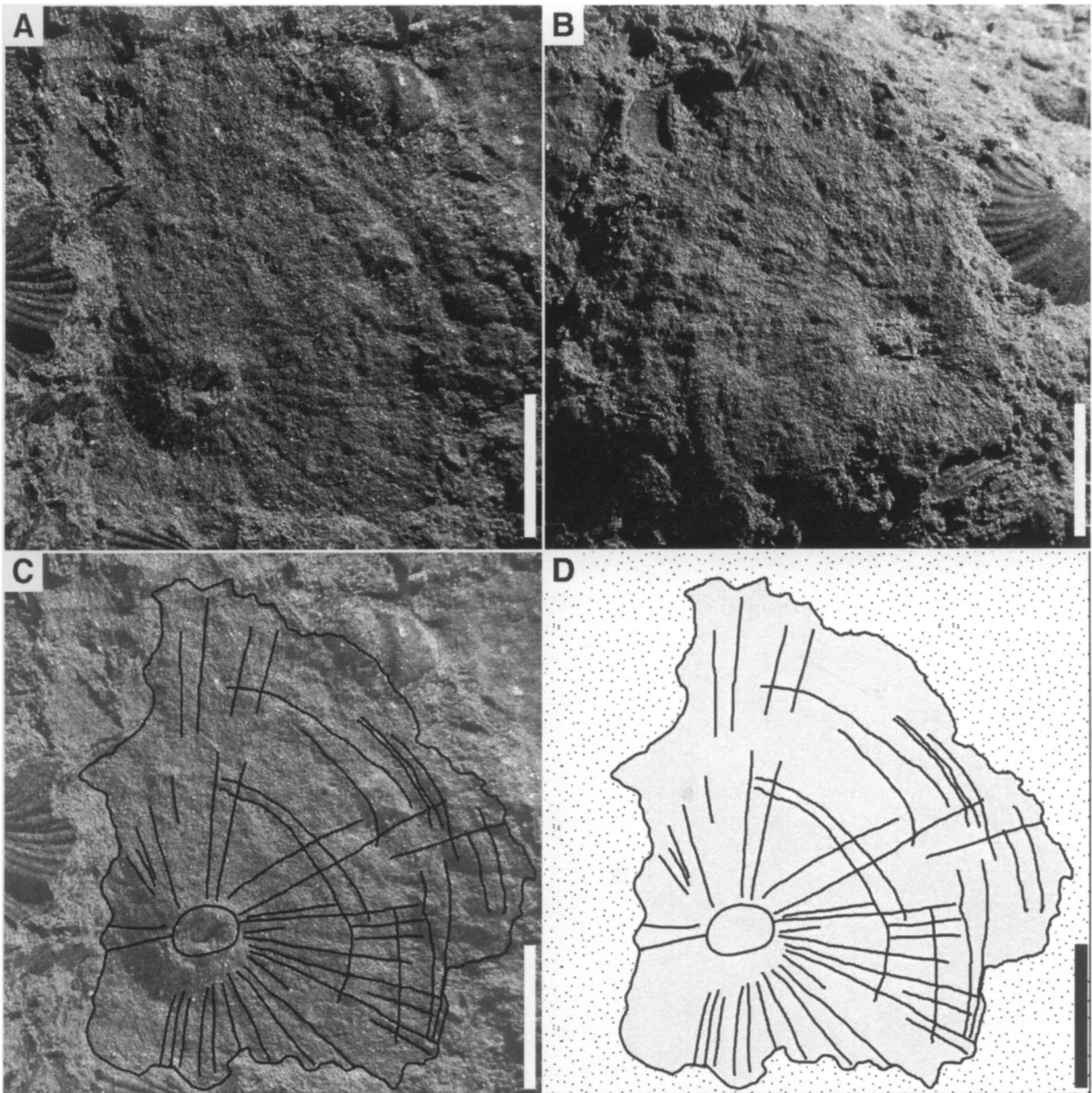


Fig. 4—*Seputus pomeroii* n. gen., n. sp., second specimen; all scale-bars 10mm. A, part; note the central structure; B, counterpart; C, part with line drawing superimposed; D, line drawing of part.

benthic organisms (Walcott 1911; Friend 1995; Zhu *et al.* 2002), characterised by a coiled gut in the central part of the disc. While their systematic position is controversial, with specimens having previously been described as holothurians, scyphozoans, porpitud hydrozoans, lophophorates and stem-group echinoderms, they were shown to be triploblastic (ruling out any interpretation as a cnidarian) by Friend (1995), who believed that a stem-group echinoderm interpretation was by far the most plausible. The eldonids were recently included by Caron *et al.* (2010) in the unranked stem-group Cambroernids, which they considered to be primitive deuterostomes. Interpretation of *S. pomeroii* as an eldonid is supported

by the extremely similar preservation of the eldonid *Velumbrella czarnockii* as variably oriented discs with radial ornamentation within pebbly sandstone beds in the Middle Cambrian of Poland (Stasinska 1960; Dzik 1991; Masiak and Zylinska 1993). Other eldonid fossils are also known to be preserved as moulds and casts in siliciclastic sediments (e.g. Friend 1995; Fryer and Stanley 2004).

Three informal groups can be recognised within the eldonids—the eldoniids, paropsonemids and rotadiscids (Fig. 7). The eldoniids (e.g. Fig. 7a), typified by *Eldonia ludwigi* from the Burgess Shale (Cambrian, Canada; Walcott 1911; Friend 1995), have a simply ornamented

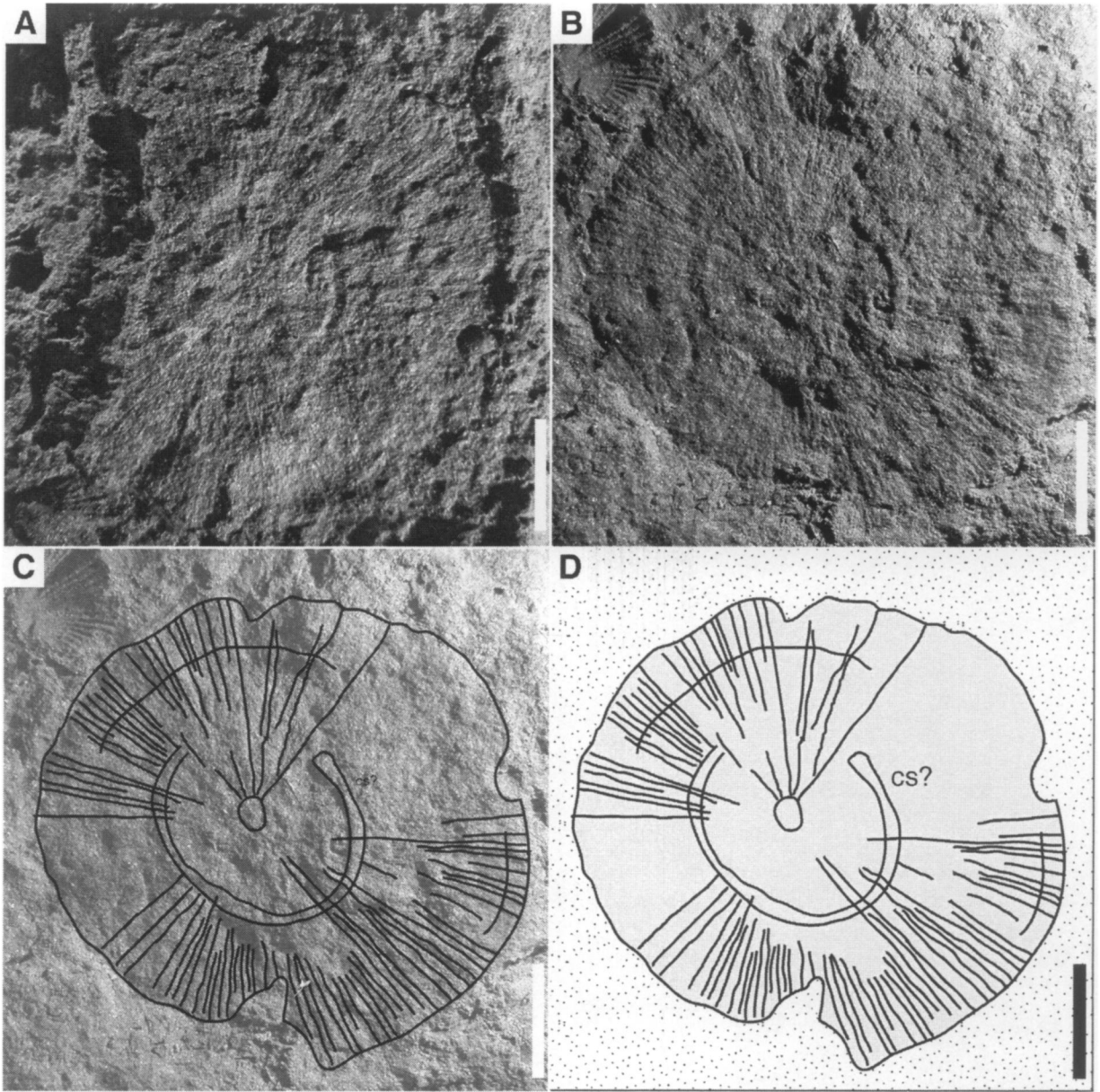


Fig. 5—*Seputus pomeri* n. gen., n. sp., holotype; note the central structure, and the subcircular coiled structure near the centre of the disc. All scale-bars 10mm. A, part; B, counterpart; C, counterpart with line drawing superimposed; D, line drawing of counterpart (cs?—subcircular coiled structure potentially representing a coiled sac).

outer integument showing up to 30 primary radial lobes, which bifurcate towards the margin, while the paropsonemids (e.g. Fig. 7b, typified by *Paropsonema cryptophya* from the Devonian of New York; Clarke 1900) have a much more complex radial ornamentation consisting of two or three series of primary radially arranged ridges, with secondary ridges perpendicular to the primary set. Both of these morphologies are quite unlike that expressed in *S. pomeri*. The rotadiscids (e.g. Fig. 7c), however, show numerous radial lines extending from a central ring, superimposing fine concentric lines. Only two rotadiscid species are known:

Rotadiscus grandis and *Pararotadiscus guizhouensis*, both from the Lower Cambrian of China (Dzik 1991; Dzik *et al.* 1997; Zhu *et al.* 2002).

While *S. pomeri* differs from the previously described rotadiscids in both the number of radial lines (generally around 40) and in lacking a fine concentric ornament (which may represent growth rings), the similarity is striking (compare to Zhu *et al.* 2002, Fig. 7a, reproduced here as a line drawing in Fig. 7c). Moreover, it is entirely possible that the lack of fine concentric structures in *S. pomeri* may be a taphonomic artefact due to the much coarser grain size



Fig. 6—Collected block of sandstone from the Bardahessiagh Formation, including the specimen in Fig. 3b (counterpart), with an elongated micaceous darkened area (labelled 'el') visible leading away from the specimen, the origin of which is unknown. Scale 50mm with 10mm subdivisions. Photograph by Mike Simms (Ulster Museum)

of the containing sediment, which would likely have been unable to faithfully replicate such minute details, if present.

Although the available evidence is admittedly equivocal; based on the similarity to *Pararotadiscus* and the unlikelihood of most other potential interpretations, we tentatively assign *S. pomeroii* to the eldonids as the first known post-Cambrian rotadiscid. However, a relationship with other, enigmatic discoidal fossils cannot be unequivocally discounted, and it is worth exploring some alternative potential interpretations.

1. Scyphozoan medusa

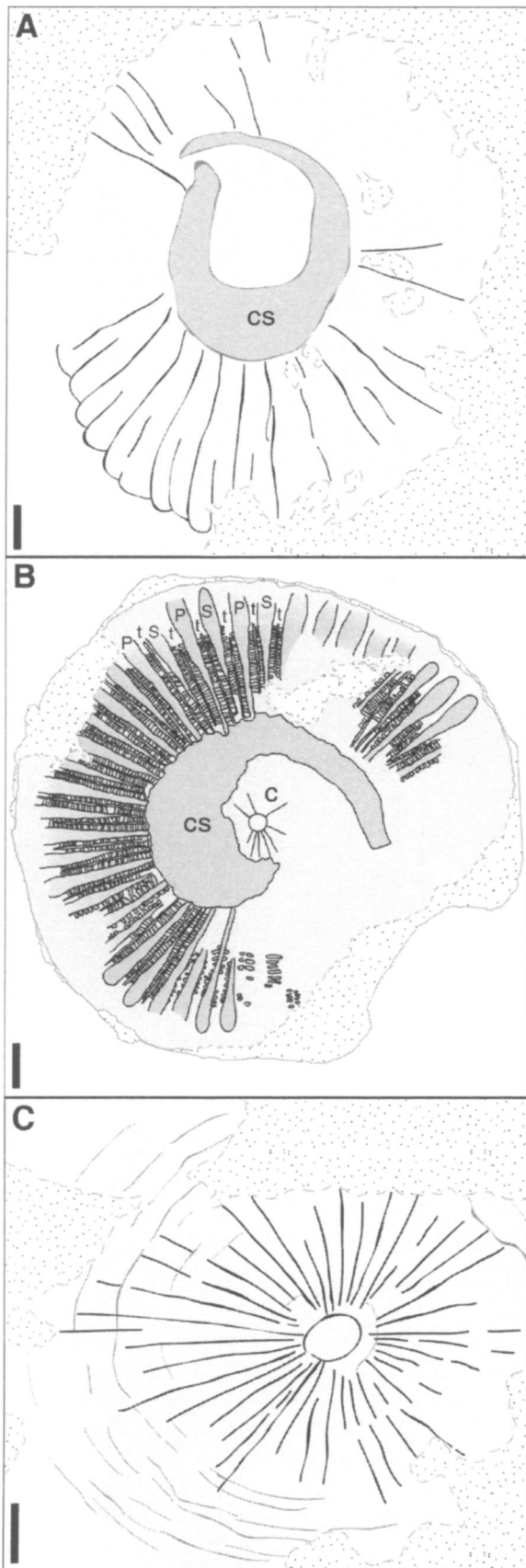
The discoidal shape of *S. pomeroii* is typical of cnidarians, however, the lack of tetradial symmetry does not favour a scyphomedusan interpretation, nor are such densely packed radial lines characteristic of scyphozoans. Furthermore, entrapment in a storm deposit or mass flow would perhaps suggest that the

organisms were originally benthic: while pelagic organisms may be preserved in this style if they sink to the bottom immediately upon death and are caught up in event sedimentation prior to the onset of decay, it is difficult to envisage four pelagic organisms simultaneously suffering such similar chance fates. A scyphozoan interpretation is thus not considered likely.

2. Benthic cnidarian

Actinians (e.g. anemones) may be radially ornamented as a reflection of the internal subdivision of the body cavity into mesenteries; however, this interpretation can probably be rejected as there are far too many radial lines in *S. pomeroii* for this to be the case.

Any suggestion of a relationship to mineralised, flat to shallow-conical cnidarians (kilbuchophyllid corals) from the locality (Scrutton *et al.* 1998) is ruled out not only by the lack of mineralisation, but also by clear



examples of septal insertion in the latter. Further, as noted above, although the kilbuchophyllid corals are known to occur as flat compressions and composite moulds within the Bardahessiagh Formation, Scrutton *et al.* (1998) specifically noted that this was limited to stratigraphically lower parts of the formation.

3. Porpitud hydrozoan

Several Phanerozoic non-mineralised discoidal structures preserved as moulds and casts have been described as porpitud hydrozoans (often referred to in the literature as ‘chondrophorines’), a pelagic group of hydrozoans with a concentricly chambered chitinous float (Stanley and Kanie 1985; Stanley 1986; Stanley and Yancey 1986; Yochelson and Mason 1986; Fryer and Stanley 2004). While the presence of a decay-resistant disc would be consistent with the interpreted morphology of *S. pomerii*, it has no regular concentric annuli similar to those of other porpitud hydrozoans to suggest that the disc acted as a float. The pelagic habit of the porpitud hydrozoans would also make it extremely difficult for the organisms to become entrained within sediments such as these, and be subsequently preserved (see discussion of a scyphomedusan affinity above). Such an interpretation is therefore not consistent with the taphonomy of these fossils. It should also be noted that many specimens described as fossil porpitud hydrozoans are now known to in fact represent swing marks (Jensen *et al.* 2002).

4. Enigmatic benthic discoidal organism

A few other non-mineralised discoidal fossils, preserved as moulds and casts, are also known, most of which are enigmatic (e.g. Lenz 1980; Cherns 1994). These are only superficially similar to *S. pomerii*, although of course any relationship at a higher taxonomic level cannot be ruled out.

5. Holdfast of benthic stalked form

Several Ediacaran organisms, for example *Charniodiscus* (Laflamme and Narbonne 2008), were stalked forms with a discoidal attachment disc or holdfast. It has been previously suggested that many simple discoidal fossils represent examples of such organisms where

Fig. 7—Line drawings of representative examples from the three informal eldonid groups. A, an eldoniid: *Eldonia ludwigi* (Cambrian, Burgess Shale, Canada; Royal Ontario Museum specimen ROM 95-1000-1), cs-coiled sac; B, a paropsonemid: *Paropsonema mirabile* (Silurian, Brunswick, Australia; Museum Victoria MV 30713a). P-primary radial structures, S-secondary radial structures, t-tertiary radial structures, c-central ring, cs-coiled sac; note also the concentrically-arranged ridges between the radial structures; C, a rotadiscid: *Pararotadiscus guizhouensis* (Cambrian, Kaili, China; Guizhou University of Technology, Institute of Paleontology GTB-24-2-104; Fig. 7a of Zhu *et al.* 2002).

the stalk and upper parts of the body are not preserved (Gehling *et al.* 2000; MacGabhann 2007). While the morphological simplicity and similarity of Ediacaran discs often makes it difficult to confirm whether or not individual fossils are holdfasts (MacGabhann 2007), unequivocal examples generally have an inner boss comprising roughly one-quarter to one-third of the overall radius, which represents the zone of attachment of the stalk to the disc. No such feature is observed on *S. pomeroii*. It should also be noted that although some Cambrian fossils have been compared to Ediacaran fronds (e.g. *Thaumaptilon* from the Middle Cambrian Burgess Shale of Canada; see Conway Morris 1993), no such fossils have been reported to date from the Ordovician. Furthermore, such holdfasts are thought to represent an adaptation to microbially bound sea-floors, which are generally believed to have virtually disappeared from open shallow marine environments at the base of the Cambrian following the evolution of efficient bioturbating lifestyles (Gehling 1999; Seilacher 1999; Bottjer *et al.* 2000; Narbonne 2005; Gehling *et al.* 2005). While absence of evidence is not evidence of absence, interpretation as an Ediacaran-like holdfast thus seems unlikely.

6. Microbial or fungal colonies

It has been proposed that many discoidal Ediacaran fossils may represent bacterial or fungal colonies (Peterson *et al.* 2003; Grazhdankin and Gerdes 2007; MacGabhann 2007). These are again thought to be a particular adaptation to Ediacaran environments believed to have disappeared in the earliest Cambrian, making such an interpretation unlikely. The transported nature of the assemblage also precludes such an interpretation, as it is extremely difficult to envisage how such a microbial colony would either be detached from the sea-floor, intact and undamaged but with no remnant of its original substrate, or be capable of maintaining integrity in a current of sufficient energy to remove such a structure from the substrate.

7. Compressed spherical organisms

Certain Ediacaran discoidal fossils have been interpreted as the compressed remains of originally spherical organisms, for example *Beltanelliformis*, which has been interpreted as a compressed spherical alga similar to the modern green alga *Derbesia* (Xiao *et al.* 2002). However, the regular and straight nature of the radial structures rules out a similar interpretation for *S. pomeroii*: even if radial structures were present on a spherical alga or similarly shaped organism, the effects of compression would necessarily distort these. It is also highly unlikely that in the case of transported remains,

the origin of the radial structure would be consistently preserved at the centre of the compressed disc.

There is therefore no readily apparent alternative to the tentative interpretation of *S. pomeroii* as a rotadiscid eldonid.

The tenacity of this assignment, as well as the clear differences between *S. pomeroii* and the previously described rotadiscids are sufficient to warrant their separation at a generic level. It should also be noted that while MacGabhann (2007) cautioned against the erection of new genera for discoidal fossils preserved as moulds and casts in siliciclastic sediments, such caution was specifically limited to Ediacaran specimens preserved on bedding plane surfaces and therefore does not apply in this case.

Taphonomy

The preservation of the fossils, within what is essentially a sedimentary event horizon, with different orientations and demonstrably at slightly different levels within the bed, indicates that the organisms are not preserved *in situ*, but have been transported. This is confirmed by reversal of the sense of relief on one of the four specimens, indicating that this specimen was preserved upside down relative to the other three. The absence of associated and clearly defined biomineralisation indicates an entirely soft-bodied nature for *S. pomeroii*. The precise matching of surface irregularities between part and counterpart indicates that these are true natural moulds and counterpart casts, rather than compressions of soft-bodied discoidal organisms. It also suggests that the integument of the organisms was not rigid, but was flexible and deformable (to a degree); an interpretation that is supported by the deviation from circularity with randomly oriented long axes.

Two factors in particular are required to explain the highly unusual preservation of fossils with these particular properties in this bed:

1. Rapid lithification of sediment

Experimental studies of cnidarian taphonomy (Norris 1989) have demonstrated that once decay has started, fine details of truly soft-bodied organisms cannot be preserved. In laboratory experiments, subtle features, analogous to the radial lines preserved in *S. pomeroii*, could only be preserved by the rapid application of plaster immediately following the death of the organism (Norris 1989). The sediment which moulded *S. pomeroii* must therefore have been coherent enough to retain these subtle features prior to the onset of decay of this part of the organism. However, given that most of the organism

appears not to have been preserved at all, decay of the more labile tissues must have been underway prior to lithification. Whilst it may be possible that some labile tissues were simply too insubstantial to be preserved as moulds and casts by siliciclastic sediments (irrespective of how rapidly lithification occurred), in this instance, the entire internal anatomy (including any potential feeding structures: mouth, oesophagus, stomach, intestine, anus, musculature or internal body structure, etc.) of the animal is clearly not evident (assuming, of course, that an animal interpretation is correct and that these structures were originally present). It is unlikely that all of these features were sufficiently insubstantial as to leave absolutely no trace, indicating that these must have been in an advanced state of decay upon lithification. This produces a definitive time-scale for the lithification of the sediment, which thus appears to have been extremely rapid.

2. Lack of bioturbation

This would otherwise have mixed the sediment, destroyed the impressions and prevented rapid lithification from occurring.

No bioturbation or trace fossils have been observed in the material, nor has there been any mention of such structures by previous authors (e.g. Scrutton *et al.* 1998; Candela 2001, 2002, 2006), thus the second condition was certainly met. Close examination of the shelly fossils also supports rapid lithification: Scrutton *et al.* (1998) noted that while calcitic fossils were always preserved undistorted, aragonite-shelled organisms, including the kilbuchophyllid corals, were often preserved flattened or as composite moulds within the formation, but not in the richly fossiliferous beds at the top (including the horizon hosting *S. pomerioi*) where 'all material, whether originally of aragonitic or calcitic composition, is preserved undistorted' (Scrutton *et al.* 1998, 122). This clearly supports the suggestion that the *S. pomerioi* bed was more rapidly lithified than most other beds within the formation. As noted above, preservation in this style requires lithification of the moulding sediment prior to the decay of the preserved part of the organisms, and lithification of the casting sediment after decay. The fact that the same surface of *S. pomerioi* is preserved in all four specimens, irrespective of their orientation, seems to suggest that rapid lithification occurred preferentially on one side of the organism only. This may have been controlled by the original morphology of the animal, with softer and more labile tissues interfering with the lithification process on the opposite side of the disc. Decay of the softer parts must therefore have been underway during the rapid lithification of the casting sediment.

One potential explanation for the rapid lithification is early diagenetic mineralisation in anoxic conditions. An analogous taphonomic process has been shown to be responsible for the preservation of Ediacaran fossils in the Flinders Ranges of South Australia (Gehling 1999; Gehling *et al.* 2005; Narbonne 2005; Droser *et al.* 2006), where decay of microbial mats, buried by event sedimentation (and therefore quickly encased in an oxygen-restricted environment), is thought to have caused anoxic conditions to develop as they decomposed. The lack of (vertically orientated) bioturbation further hindered the possibility for oxygen exchange between the buried sediments and the sea-water above. The bacterially mediated reaction of sea-water sulphate with sedimentary iron in these anoxic conditions produced early diagenetic iron sulphide minerals (iron monosulphides and pyrite), which rapidly lithified the event bed soles, preserving the soft-bodied organisms as negative hyporelief impressions. These minerals oxidise extremely easily and are, therefore, rarely preserved, but are usually expressed in the rusty colour of bed-sole surfaces and the presence of diagenetic haematite (Gehling 1999, Gehling *et al.* 2005). In the case of *S. pomerioi*, the preservation of the fossils within an event bed, rather than on a bed sole, rules against microbial mats as a factor in preservation. In any case, there is no clear evidence to suggest the presence of any kind of microbial mats in the succession, and widespread development of these structures is generally believed to have been absent after the Cambrian (Gehling 1999; Seilacher 1999). However, Allison (1990) noted that due to the vast amounts of oxygen required for aerobic decay, if the supply of oxygen is in any way limited or compromised, decay of large amounts of organic matter will very quickly proceed to anaerobic decay. As noted above, there is no evidence of bioturbation or any kind of post-depositional disturbance of the sediment in the uppermost Bardahessiagh Formation, and it is likely that, internally, this event bed had a more restricted flow of oxygen (certainly relative to conditions at the sea-floor a short distance above). It is therefore plausible that decay of the soft parts of the numerous organisms inside this horizon may have been responsible for the development of anoxic conditions, which could then have facilitated the reaction of sedimentary iron with sea-water sulphate to produce early diagenetic mineralisation. The reddish (rusty) colour of the bed and the presence of abundant haematite supports this as a potential taphonomic model for *S. pomerioi*, as does the partial dissolution of calcite, as sulphuric acid is a by-product of the weathering of pyrite to iron oxides. The darkened surfaces of both the parts and counterparts of the fossils is also thought to reflect the distribution

of iron oxides, the production of which must therefore have been controlled by the organic matter (analogous darkening has been observed in fossil leaves preserved in a similar way, e.g. Spicer 1977; Grimes 2001). This is entirely consistent with the idea, expressed above, that the preserved disc of *S. pomeroyi* may represent only a part of the organism, which was more resistant to decay, as the model requires the decay of labile tissues to produce the anoxic conditions necessary for such early diagenic mineralisation.

The taphonomy of these fossils thus appears to be analogous to that of the terminal Neoproterozoic Ediacaran fossils, at least in terms of the chemical and diagenic processes and reactions involved in their preservation. It may also be noted that while most Ediacaran fossils are preserved on bedding surfaces, a minority component including *Pteridinium* and some rangeomorphs (Grazhdankin and Seilacher 2002; Narbonne 2005) are preserved, like *S. pomeroyi*, within siliciclastic beds, a taphonomic mode termed as 'Nama-style preservation' by Narbonne (2005). It should also be noted that there has been some debate over whether organisms preserved in this particular style were originally fully infaunal and are preserved *in situ*, or were instead benthic and entrained within event-bed depositional flows prior to their preservation (e.g. Grazhdankin and Seilacher 2002). While the evidence in Ediacaran cases remains equivocal, the unequivocal evidence that specimens of *S. pomeroyi* were transported indicates that the latter process is certainly possible.

Conclusions

Four discoidal fossils recovered from a 1992 trench through the top of the Ordovician Bardahessiagh Formation near Pomeroy, Co. Tyrone, have been examined for the first time and described as *Seputus pomeroyi* gen. et sp. nov. These are preserved within a medium-grained sandstone bed, which is interpreted as a low-density mass flow or storm deposit. The fossils are here interpreted as moulds and casts of radially ornamented tough, decay-resistant discoidal parts of entirely non-mineralised organisms, the majority of which are not preserved. Early diagenic precipitation of iron sulphide minerals within the bed in an anaerobic environment produced by the decay of the truly soft parts is thought to be responsible for the preservation of these specimens. This concept is supported by the presence of abundant iron oxides in the vicinity of the specimens. *S. pomeroyi* is very tentatively interpreted as a rotadiscid eldonid, although a relationship with a number of other enigmatic discoidal organisms cannot

be ruled out at this stage. The nature of the occurrence of *S. pomeroyi* and problems associated with confidently interpreting both its morphology and affinities illustrate just how little is known about the non-mineralised components of Palaeozoic ecosystems.

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