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Bryozoa from the Ordovician (Caradoc) of Courtown, County Wexford, Ireland

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Abstract

The Ordovician Courtown Limestone Formation (Aurelucian, Caradoc) of County Wexford, south east Ireland comprises a sequence of blue to white fossiliferous limestones, calcareous sandstones and siltstones, with a basal conglomerate developed in places. A moderately rich brachiopod - trilobite fauna has been described from the Formation. Bryozoans were reported from the Formation when it was first mapped but were not systematically described. This study has revealed that the bryozoan fauna is moderately diverse containing 10 species of trepostomes and cryptostomes. All specimens are abraded and broken. The fauna compares biogeographically with others from Wales, Sweden and Estonia.

Introduction

Bryozoans have been reported from the Courtown Limestone Formation, but have remained undescribed to modern taxonomic standards. The bryozoans *Stenopora fribrosa* var. *ramosa* and var. *lycoperdon* were noted by Baily (1887) from 12 localities in the immediate Courtown area. These two bryozoans were widely reported from localities in the Ordovician of the British Isles in the nineteenth century, where the name was applied to dome-shaped and ramose colonies, respectively. It has subsequently become clear that "*S. fibrosa*" contains more than two taxa. Brenchley and Treagus (1970) stated that "bryozoa occur in most exposures" when they examined the Courtown Limestone Formation. This study systematically describes and illustrates the bryozoan fauna from Courtown.

Geological Setting of the Courtown Limestone Formation

The Lower Palaeozoic rocks of south Waterford (Fig. 1) consist of shallow and deep water carbonates and shales overlain by volcanic material (Tietzsch-Tyler and Sleeman 1994a; Sleeman and McConnell 1995). It has been suggested that this succession represents a submarine volcanic island arc formed at the margins of the Avalonian continental plate margin above subducting Iapetus oceanic plate (Sleeman and McConnell 1995).

The Duncannon Group (Gardiner 1974) occurs in a band trending northeast to southwest from its southern extremity near Dungarvan, Co. Waterford northeastwards to south Co. Wicklow (Fig. 1B) and is part of the Leinster Terrane. It comprises a Middle to Upper Ordovician suite (Upper Llanvirn to

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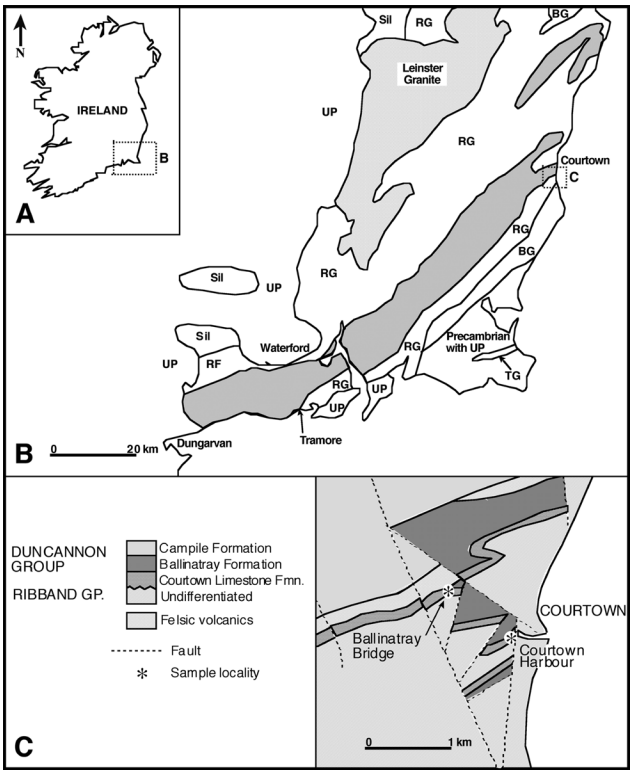

Figure 1. Geological Map of southeast Ireland: (A) General location. (B) Diagonal ornament = Duncannon Group; RG = Ribband Group; BG = Bray Group (Cambrian); RF = Ross Group (probably part of the Duncannon Group); Sil = Silurian; TG = Tagoat Group; UP = Upper Palaeozoic. (C) Courtown showing local stratigraphical succession (left) and geology (right). (Modified from Key et al. 2005, fig. 1).

Caradoc) of limestones, black shales and basaltic, andesitic and rhyolitic arc volcanics (Owen and Parkes 2000) of which the Courtown Limestone Formation and the Tramore Limestone Formation locally form basal units.

The Courtown Limestone Formation of the Duncannon Group (Gardiner 1974) comprises a sequence 50 m thick of blue to white fossiliferous limestones, calcareous sandstones and siltstones, with a basal conglomerate developed in places. It has been strongly deformed which resulted in a well-developed cleavage. It has also been extensively diagenetically altered by hydrothermal fluids (Key et al. 2005). It crops out at various localities close to the village of Courtown, County Wexford. The type locality is in a quarry at Courtown Harbour which is now flooded and inaccessible. In the nineteenth century the area was mapped by the Geological Survey of Ireland which reported the occurrence of fossils at various localities (Hardman 1887); many of these are now difficult to locate precisely (Parkes 1994). Recent collecting from the 1960s onwards has concentrated on coastal exposures particularly at Duffcarrick Rocks 4 km north of Courtown (Brenchley and Treagus 1970; Mitchell et al. 1972) and at an inland locality at Ballintray Bridge 1 km northwest of Courtown (Parkes 1994). A moderately rich brachiopod-trilobite fauna has been described from the Courtown Limestone Formation (Brenchley and Treagus 1970; Mitchell et al. 1972).

The Courtown Limestone Formation lies unconformably on reddish-purple mudstones and siltstones of the Riverchapel Formation—the youngest part of the Ribband Group (Tremadoc-Arenig). This has been dated as Lower Arenig on the basis of graptolites (Skevington 1970).

The age of the Courtown Limestone Formation has been debated by various authors. On paleontological and stratigraphical evidence Carlisle (1979) argues that it ranges from Middle Llandelio to the Costonian Stage of the Caradoc, while Brück et al. (1979) give a Llandeilo age. However, in a review of the geology of the region, Tietzsch-Tyler and Sleeman (1994a,b) give an older age range of Upper Llanvirn to Middle Llandeilo for the formation. Succeeding the Courtown Limesone Formation is the Ballinatray Formation from which shales have yielded graptolites of the *gracilis* Biozone (Longvilian Stage), which indicates a Caradoc age. Most recently, Harper and Parkes (2000) considered the formation to be within the Aurelucian Stage of the Caradoc.

Local Correlation: The Courtown Limestone Formation and the Tramore Limestone Formation crop out some 75 km apart. The Tramore Limestone Formation has been dated at Llandeilian to Aurelucian in age (Harper and Parkes 2000). Nevertheless, on the basis of their faunal similarities and stratigraphic position, they have been closely correlated, initially on the basis of the common occurrence of the rare trilobite *Eirelithus* (Crimes and Crossley 1968), but subsequently on the basis of additional faunal elements (Mitchell et al. 1972; Carlisle 1979). Twelve brachiopod genera and four trilobite genera are common to both formations with the presence of the stratigraphically restricted brachiopod *Glyptorthis crispa* (M'Coy) being particularly important for their correlation. Bryozoans have been described from the Tramore Limestone, including *Diplotrypa petropolitana* (Wyse Jackson et al. 2002), but they have not been systematically described.

Biogeographical comparison

Shelly faunas described from south-eastern Ireland south of the Iapetus suture zone have been variously attributed to the Avalonian, Baltic, Scoto-Appalachian, and Celtic faunal provinces (Williams 1969a, b; Williams et al. 1972; Harper et al. 1996; Parkes and Harper 1996). The Tramore Limestone Formation fauna (especially the brachiopods) has mixed affinities to the Scoto-Appalachian and Anglo-Welsh faunas (Neuman 1984; Harper and Parkes 1989; Murphy et al. 1991; Parkes 1992).

The bryozoans of the Courtown Limestone Formation have affinities to faunas from Wales (Buttler 1991, 1997) and links with Sweden and Estonia (Bassler 1911). Southeast Ireland and Wales both formed part of the micro-continent of Avalonia during the Caradoc. Avalonia has very close faunal links with the continent of Baltica and by the Ashgill the two had joined.

Material

This paper is based on specimens contained in the Geological Survey of Ireland, Dublin [GSI]:

GSI:F08024; Ballintray Bridge, Ballintray Lower, Co. Wexford; Courtown Limestone Formation, Ordovician. GSI 19th century collection.

GSI:F11391; GSI:F11397; Courtown Harbour, Courtown, Co. Wexford; Courtown Limestone Formation, Ordovician. GSI 19th century collection.

Specimens are heterogeneously orientated in petrological thin sections; they are all abraded and fragmented. The terminology in all descriptions is that of Boardman et al. (1983) and Boardman and Buttler (2005). Taxa that could not be conclusively identified to species level are referred to as "cf." and "sp.", based on the recommendations of Bengston (1988).

The trepostome genera are placed in families based on Astrova (1978). A total of 10 species, eight trepostomes and two cryptostomes, are formally described; the fauna is, however, more diverse than this but the specimens are in fragments too small to identify.

Systematic Paleontology
Phylum Bryozoa Ehrenberg, 1831
Class Stenolaemata Borg, 1926
Order Trepostomata Ulrich, 1882
Family Heterotrypidae Ulrich, 1890
Genus *Hemiphragma* Ulrich, 1893
Hemiphragma pygmaeum Bassler, 1911
Fig 2.1-2

Hemiphragma pygmaeum Bassler, 1911: 289. fig. 176; Buttler, 1997: 121; figs 4-5.

non *Hemiphragma pygmaeum* Bassler, Nekhorosheva, 1970: 84; pl. vii, figs. 5-6.

Material: F08024(3)i, F11397(1)i, F11397(1)ii, F11391(1) i, F11397(A)i

Description: Zoaria erect with thick cylindrical branches, on average 4.55 mm in diameter. Autozooecia bud interzooidally throughout the endozone, where they are irregular-rounded in transverse section; mean maximum diameter 0.26 mm. Endozonal walls are thick and curve smoothly outwards to meet the zoarial surface at 90°. Large endozonal styles, with thick cores (0.08 mm mean diameter) and thin sheaths are present.

The exozone is recognized by a gradual thickening of the zooecial walls. Autozooecial wall thickness is slightly irregular. Both merged and serrated autozooecial boundaries are recognized across the cortex in longitudinal sections. Autozooecial cross-sectional apertures are rounded in tangential section. Autozooecial diameters average 0.23 mm by 0.17 mm within the exozone. Basal diaphragms are found throughout the colony. Hemiphragms are present throughout the colony and alternate on both sides of the living chamber, spaced on average 0.15 mm apart.

Mesopores are present and originate in the outer parts of the endozone. They are rounded in tangential section, average 0.07 mm in diameter, and contain thick closely spaced, basal diaphragms. Some mesopores are infilled with stereom in the distal parts of the exozones. Large exozonal styles are common.

Discussion: This species from Courtown is very similar to *Hemiphragma pygmaeum* described from the middle Ordovician of south Wales (Buttler 1997). They both differ from the type species, from Sweden, described by Bassler (1911) by not having the distinctive 'mushroom-shaped' colony form that characterizes the holotype.

Distribution: Chasmops Limestone (upper Caradoc) Oland, Sweden; Llandelio Limestone (lower Caradoc), south Wales, UK.

Hemiphragma sp.
Fig 2.3-5

Material: F08024(3)ii, F08024(5)i, F08024(6)i

Description: Zoaria erect with thick cylindrical branches, on average 4.4 mm in diameter. Autozooecia bud interzooidally throughout the endozone. Endozonal walls are thick and curve smoothly outwards towards the exozones.

The exozone is wide, on average 1.7 mm thick, and is recognized by a gradual thickening of the zooecial walls which meet the zoarial surface at 90°. Autozooecial wall thickness averages 0.08 mm in the exozones and the cortex thickness is slightly irregular. Autozooecial boundaries are merged across the cortex in longitudinal sections. Autozooecial cross-sectional apertures are circular in tangential section, in the outer exozone. Autozooecial diameters average 0.18 mm by 0.12 mm within the exozone. Basal diaphragms are present but not common. Short (on average 0.05 mm), thick hemiphragms are located on alternating sides of the living chamber in the exozone.

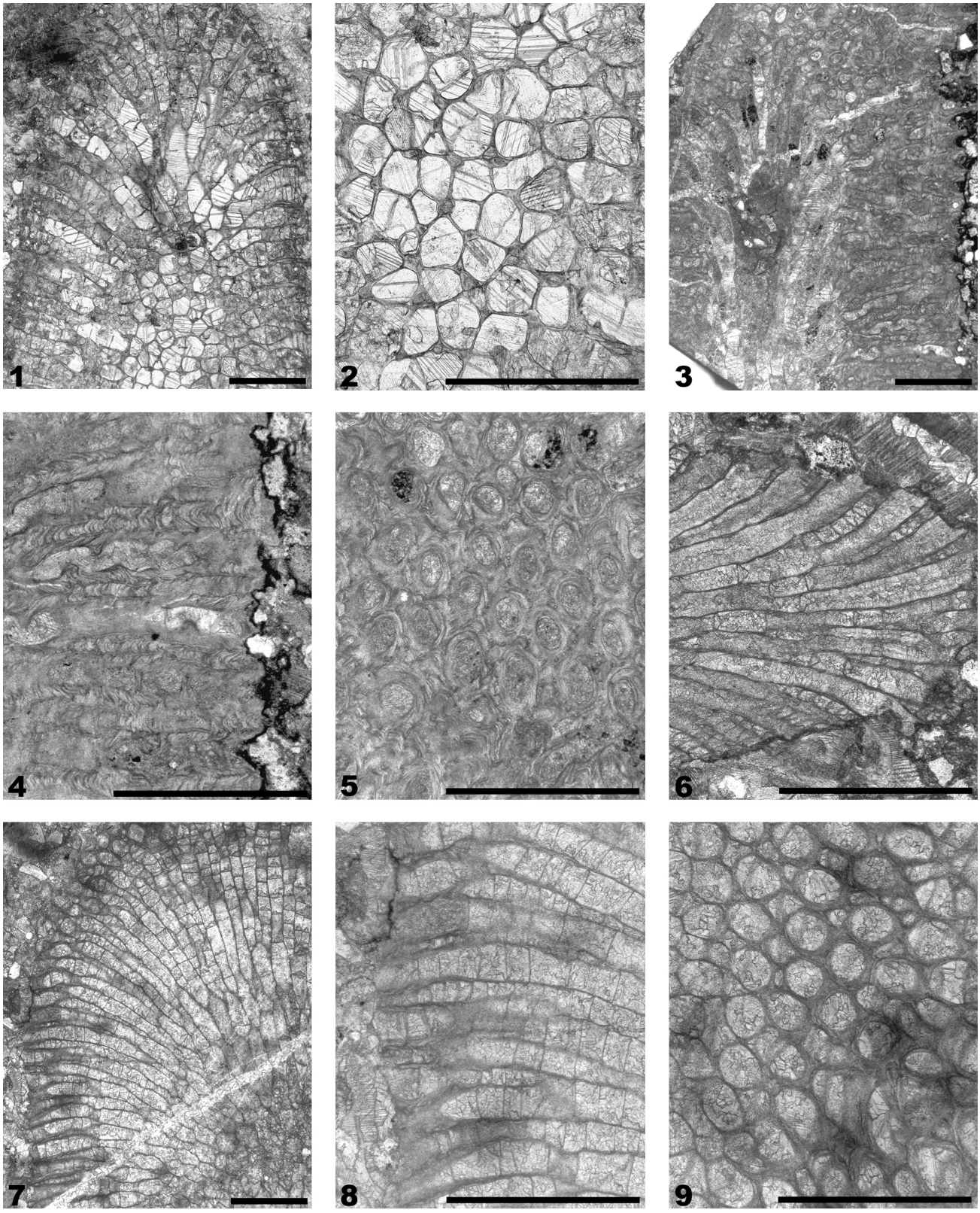

Figure 2. (1-2). *Hemiphragma pygmaeum* GSI:F11397(A)i. 1. Oblique longitudinal section showing long thin alternating hemiphragms. 2. Tangential section with large styles located between autozooecia. (3-5). *Hemiphragma* sp. GSA:F08024(5)i. 3. longitudinal section showing thick exozones. 4. Longitudinal section showing thick short hemiphragms and abundant long exozonal styles. 5. Tangential section showing small exozonal styles and rounded autozooecial apertures. (6). *Hallopora* cf. *tolli* GSI:F11397(1)iii. Longitudinal section showing mesopores with abundant diaphragms. (7-9). *Hallopora* sp. GSI:F11397(1a)i. 7. Longitudinal section showing diaphragms throughout the autozooecia. 8. Longitudinal section. 9. Deep tangential section showing circular zooecial apertures. All scale bars = 1 mm.

Mesopores are present but few. They are rounded in tangential section and may be infilled with stereom in the distal parts of the exozones. Long, thin exozonal styles, with slightly sinuous calcite cores are common throughout the exozone.

Discussion: *Hemiphragma* sp. differs from *H. pygmaeum*, also from the Courtown Formation, by possessing thicker, shorter, hemiphragms which are confined to the exozones, and by having smaller styles than the latter species. This species has similarities with *Hemiphragma panderi* described by Bassler (1911) from the Kuckers Shale in Estonia which also has rare mesopores and small styles. The diaphragms in the Estonian species appear to be longer and more abundant.

Suborder Halloporoidea Astrova, 1965
Family Halloporidae Bassler, 1911
Genus *Hallopora* Bassler, 1911
Hallopora cf. *tolli* Bassler, 1911
Fig 2.6

Hallopora cf. *tolli* Bassler: Buttler, 1991: 160-2; fig. 10

Material: F11391(2)i, F11397(1)iii

Description: Zoaria erect with cylindrical branches, at least 1.7 mm in diameter, the exozones are highly abraded.

In the endozone autozooecia bud interzooidally. Autozooecia walls are thin, roughly parallel to branch axis in center of endozone, then smoothly curving out obliquely to zoarial surface. Scattered diaphragms are present in autozooecia in the endozone; they are rare in the exozone.

Autozooecial walls thicken gradually in the exozone. Mesopores are present, originating in the outer endozone. The mesopores contain abundant orally deflected basal diaphragms, spaced, on average, 0.05 mm apart.

Discussion: The specimens are highly abraded and no tangential sections have been observed. However it has a similar arrangement of mesopores and diaphragms to that of *Hallopora* cf. *tolli* Bassler 1911 described from the Caradoc of north Wales (Buttler 1991).

Distribution: Llanbedrog Mudstones (Caradoc) near Llanbedrog, Gwynedd, north Wales, UK.

Hallopora sp.
Fig 2.7-9

Material: F08024(2)i, F08024(3)iii, F11391(1a)i

Description: Zoaria erect with cylindrical branches, on average 10 mm in diameter. Only fragments of this species were found, and they are abraded.

In the wide endozone autozooecia bud interzooidally. Autozooecia walls are roughly parallel to the branch axis within the endozone and curve outwards to the outer endozone to meet the zoarial surface at approximately 90°. Thin diaphragms are present in autozooecia throughout the endozone, spaced, on average, 0.26 mm apart.

Autozooecial walls thicken gradually in the exozone, and autozooecial boundaries are serrated in longitudinal sections. Exozone thickness is, on average, at least 0.1 mm in these abraded branch fragments. Diaphragms in the exozone spaced on average 0.16 mm apart. Mesopores are present but not common, originating in the outer endozone, and are irregularly circular in cross section. They contain orally deflected basal diaphragms, spaced, on average, 0.06 mm apart.

Discussion: *Hallopora* sp. differs from *Hallopora* cf. *tolli*, also described from the Courtown by having abundant diaphragms throughout the colony and less common mesopores. This species has a similar diaphragm arrangement to that of *Hallopora* aff. *wesenbergiana*, described from the Llandeilo limestone in south Wales (Buttler 1997).

Family Trematoporidae Miller, 1889
Genus *Batostoma* Ulrich, 1882
Batostoma sp. A
Fig 3.1-2

Material: F08024(3)iv, F08024(4)i

Description: Zoaria erect with cylindrical branches, on average, over 5 mm in diameter. The endozone is wide and autozooecia bud interzooidally throughout. Diaphragms are present. Endozonal walls are thin and curve smoothly outwards to meet the zoarial surface at 80°.

The narrow exozone is recognized by a gradual thickening of the zooecial walls. Autozooecial wall thickness averages 0.1 mm in the outer exozone; the cortex thickness is slightly irregular. Autozooecial boundaries are merged in longitudinal

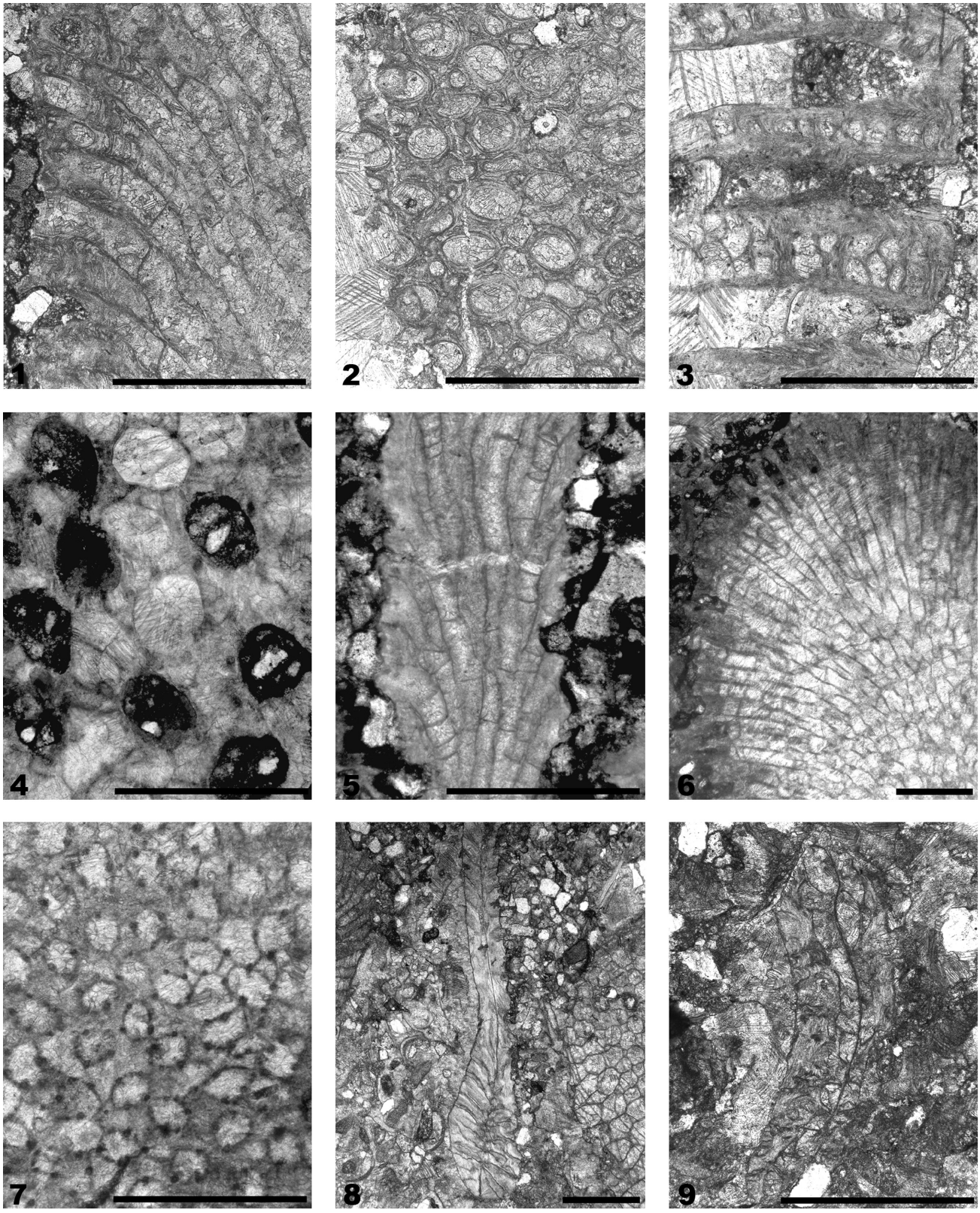

Figure 3. (1-2). *Batostoma* sp. A. GSI:F08024(3)iv. 1. Longitudinal section. 2. Tangential section showing mesopores and exozonal styles. (3-4). *Batostoma* sp. B. GSI:F08024(8)ii. 3. Longitudinal section showing mesopores containing cystiphragms and diaphragms. 4. Tangential section showing circular autozooecial apertures and styles. (5). *Eridotrypa* sp. GSI:F08024(7)ii. Longitudinal section. (6-7). *Nicholsonella* sp. GSI:F08024(7)i. 6. Longitudinal section showing indistinct granular nature of the colony walls. 7. Tangential section showing abundant styles surrounding autozooecial apertures. (8). *Graptodictya* sp. GSI:F11397(1)iv. Longitudinal section. (9). *Stictoporellina* sp GSI:F11397(1)v. Longitudinal section showing pustules in the exozones. All scale bars = 1 mm.

sections. Autozooecial cross-sectional apertures are circular to oval in tangential section and diameters average 0.23 mm by 0.15 mm within the exozone. Basal diaphragms are found in the outer endozone and exozone. Mesopores are present and originate in the outer parts of the endozone. They are small, circular in tangential section, on average, 0.09 mm in diameter, and contain orally deflected, closely spaced basal diaphragms. Some mesopores are infilled with stereom in the distal parts of the exozones. Small exozonal styles are common.

Discussion: This is one of two species of *Batostoma* recognized from the Courtown Limestone. It is distinctive because of the very narrow exozone. The endozone is poorly preserved preventing species identification.

Batostoma sp. B
Fig 3.3-4

Material: F08024(1)i, F08024(6)iii, F08024(7)iii, F08024(8) ii

Description: Zoarium, large and massive. Only fragments of this species are found and they are much abraded. Diameter of F08024(1)ii is at least 18 mm.

Autozooecial walls are thick and slightly irregular; they curve smoothly to meet the zoarial surface. Exozone is recognized by a thickening of the autozooecial wall. Autozooecial cross-sectional apertures are circular-oval to polygonal in tangential section, with average diameters of 0.38 mm by 0.33 mm. Diaphragms are rare. The autozooecial boundaries are difficult to distinguish but appear merged in longitudinal section.

Mesopores are common, originating in the outer endozone. They are irregularly polygonal in cross-sectional shape and can isolate the autozooecia. The mesopores contain abundant, thick, orally deflected basal diaphragms spaced on average 0.13 mm in the exozones; some develop cystiphrams at the distal end. The mesopores are slightly constricted at the proximal end at the position of the diaphragms. Styles are abundant in the exozones, on average, diameter 0.06 mm. They are composed of a large core with a narrow sheath.

Discussion: This species is distinctive because of the large colony and autozooecial size. It is herein placed in *Batostoma*; however this genus has only previously been characterized as ramose or encrusting (Boardman 1960). It is likely that these specimens are a new species but well preserved tangential sections are required to thoroughly describe it.

Genus *Eridotrypa* Ulrich, 1893
Eridotrypa sp.
Fig. 3.5

Material: F08024(7)ii

Description: Zoarium erect with narrow cylindrical branches, at least 1.4 mm in diameter, however, the colony is abraded. Autozooecia bud interzooidally in the endozone from larger axial zooecia, 0.2 mm in diameter measured in longitudinal section, which are parallel to the branch axis. Irregularly spaced thin diaphragms are common. Endozonal walls are thin and straight.

The exozone is highly abraded but appears narrow and is recognized by a slight thickening of the zooecial walls. Autozooecia extend obliquely to meet the colony surface at low angles. Thin diaphragms are present along the length of the autozooecia. Small exozonal styles are present.

Discussion: The specimen is highly abraded and no tangential sections have been observed, identification to species level is not possible.

Incertae sedis
Nicholsonella sp.
Fig. 3.6-7

Material: F08024(2)ii, F08024(4)ii, F08024(6)ii, F08024(7) i, F08024(8)i

Description: Zoaria erect with thick cylindrical branches, on average 5.75 mm in diameter. Autozooecia bud interzooidally throughout the endozone. Endozonal walls are thin and curve smoothly outwards towards the exozones. Diaphragms are present but not common.

The exozone is wide and is recognized by a gradual thickening of the zooecial walls which meet the zoarial surface at approximately 80°. Autozooecial microstructure cannot be identified due to the preservation of the colonies. Autozooecial cross-sectional apertures are circular to ovate in tangential section, averaging 0.22 mm by 0.15 mm in diameter. Basal diaphragms present in autozooecia in exozone. Mesopores are present, sometimes beaded in longitudinal section; they are irregularly polygonal in tangential section. Styles are common in the outer exozone surrounding the zooecial apertures.

Discussion: The genus *Nicholsonella* is distinguished by the indistinct, granular preservation of the walls. McKinney (1971) did not include it in any of the currently recognized trepostome families because the recrystallized nature of the wall structure.

The specimens from Courtown have a similar morphology to *N. vaupeliformis* Modzalevskaya, 1955, described by Astrova (1965), from northern Russia. The arrangement and size of exozonal styles are alike.

Order Cryptostomata Vine, 1884
Suborder Ptilodictyina Astrova and Morozova, 1956
Family Ptilodictyidae Zittel, 1880
Genus *Graptodictya* Ulrich, 1882
Graptodictya sp.
Fig. 3.8

Material: F11397(1)iv

Description: Zoaria have long, thin, bifoliate branches, maximum length measured is 5.5 mm. The mesotheca is thin and slightly sinuous. The autozooecia curve away from the mesotheca at low angles. Many of the autozooecia are infilled with U-shaped laminar calcite. Longitudinal striae present between autozooecia. Exilapores absent.

Discussion: There are abundant fragments of this genus but they are small and abraded so it is not possible to identify to species level.

Family Stictoporellidae Nickles and Bassler, 1900
Genus *Stictoporellina* Nekhoroshev, 1956
Stictoporellina sp.
Fig. 3.9

Material: F08024(1)ii, F08024(2)ii, F08024(3)v, F08024(4) iii, F11397(1)v, F11391(1)ii

Description: Zoaria bifoliate with thin branches, 0.53 mm width. The mesotheca is thin and straight. Autozooecial diaphragms are absent or rare. Small exilapores present. Pustules, abundant, scattered in the exozone.

Discussion: All specimens of this genus are fragmented so species level identification is not possible; *Stictoporellina* is characterized by its cribrate form but this morphological form has not been observed in this fauna. Exilapores are present in the genus *Stictoporellina*, but due to their fragmentary nature they have only been observed in one of Courtown specimens.

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