Little pieces of mystery from the Silurian of the Dingle Peninsula, Ireland

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ABSTRACT: Three-dimensionally preserved fragments of the enigmatic organism *Sandvikina*, previously reported from the Silurian of Ireland, Scotland and Scandinavia, were recovered from the original Irish material that had revealed the problematic in thin sections. The new specimens derive from conodont residue and document silicified sectors of the distal part of the skeleton. A different pattern characterizes the outer and inner walls, with an external net-like reticulated and an internal continuous and apparently imperforate framework, getting therefore a filter-like feeding system function highly improbable.

Keywords: Problematica; Ludlow; Annascaul inlier; Ballynane Formation; silicification

INTRODUCTION

Problematic microfossils assigned to *Regnellia* and *Sandvikina* were described by Ferretti et al. (1993) from the Silurian of the Dingle Peninsula, County Kerry, Ireland and from a clast of the Old Red Sandstone Greywacke Conglomerate of the Midland Valley of Scotland. The new family Regnellidae was introduced for "conical to cylindrical microfossils with relatively numerous transverse partitions" (Ferretti et al. 1993, p. 774), to include also material described by Lauritzen (1974) from the Silurian of Oslo. In addition, the diagnosis of the genus *Sandvikina* was emended and referred to "microfossil up to about 5 mm in length, in section comprising a basal conical portion … with distally concave transverse partitions and an empty distal portion which widens considerably in comparison with the basal cone" (Ferretti et al. 1993, p. 776). The architecture of the organism designed a basal cone containing up to 40 transversal partitions and a net-like distal part diverging from the base at an angle between 38 and 90 degrees. The calcareous composition prevented to isolate any of the problematic fossils from the surrounding rock-matrix and all the known occurrences are therefore from thin-sections only.

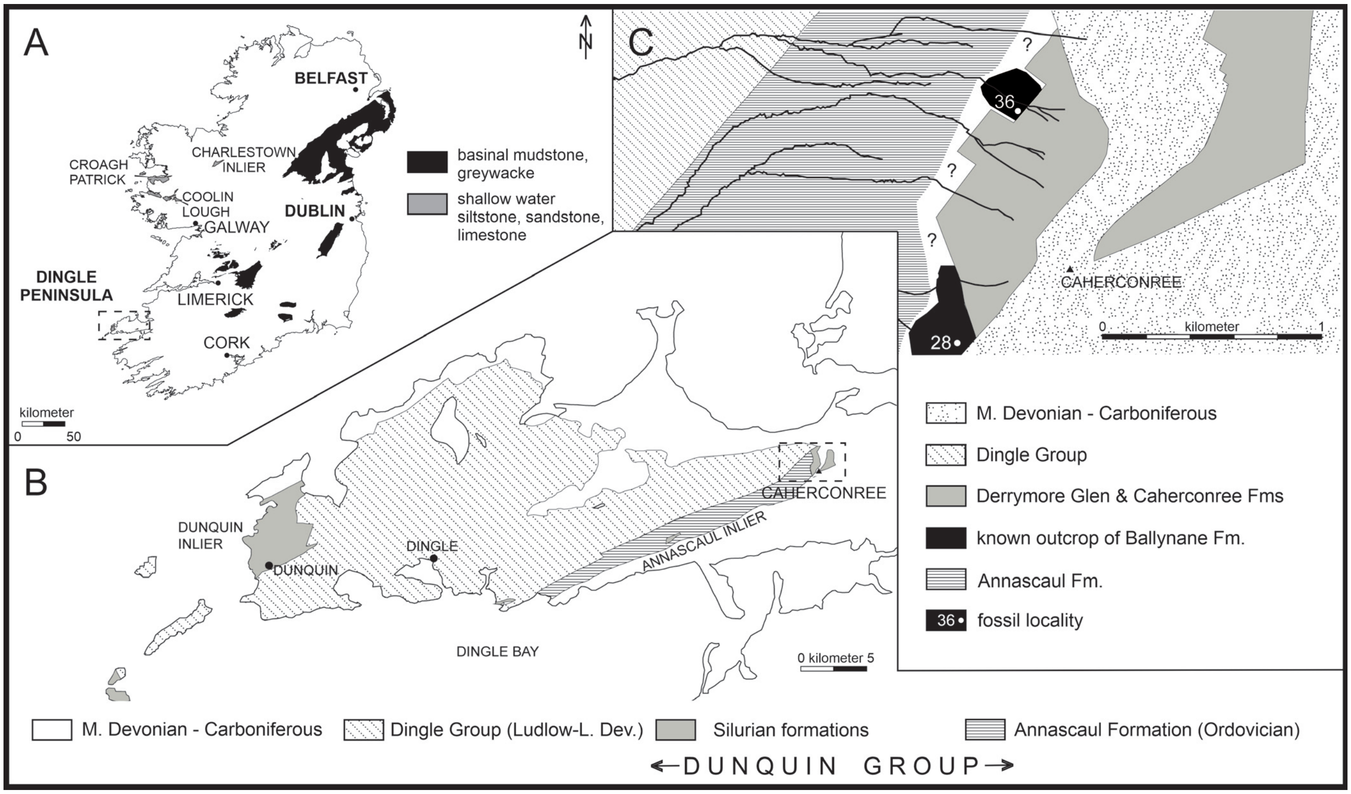
The fauna associated with Regnellidae consisted of trilobites, brachiopods, crinoids and minor bryozoans, conodonts and agglutinated foraminifers (Ferretti and Holland 1994; Kaminski et al. 2016). In addition, two other problematics but of phosphatic composition were reported. Ring-like elements already described in the uppermost Ordovician–Silurian of the Czech Republic and the Carnic Alps by Ferretti et al. (2013) and interpreted as an adhering structure of a benthic organism living on a relatively uniform hard substrate, were reported in the Dingle material by Kaminski et al. (2016) and Ferretti et al. (2021). The same authors indicated also the presence of the enigmatic plates *Eurytholia bohemica* Ferretti et al. 2006. The genus *Eurytholia* had been introduced from the Middle-Upper Ordovician of the Iapetus Ocean (United Kingdom, Sweden, Estonia and Alabama) for a problematic scleritome, ovoid in outline, with protective plates inserted in soft tissue along sub-longitudinal rows (Sutton et al. 2001). Other isolated plates were reported from the Silurian to Middle Devonian of the Czech Republic (Ferretti et al. 2006; Mergl 2019), the Silurian of the Carnic Alps (Ferretti and Serpagli 2008) and the Silurian-lowermost Devonian of Sardinia (Corradini et al. 2009b). Mergl (2019) recently proposed a vertebrate origin for the *Eurytholia* sclerites, remarking the affinity with the conodont *Pseudooneotodus*.

Silicification was a quite common process in Regnellidae, and easily explained at least for the Irish material by the abundant tuffs intercalated with the calcareous nodules. The Scottish specimen of *Sandvikina conica* was entirely silicified and the holotype from the Irish material was partially silicified, having the basal cone calcareous and the distal part completely silicified, with a three-layered organization in specimen IPUM 24223, revealing two calcareous levels and a partially silicified third one (Ferretti et al. 1993).

After almost thirty years from the first report, no new data came out that could finally provide a response on the affinity of this puzzling fossil. A new investigation of the calcareous nodules of the Ballynane Formation, originally focused on conodonts, allowed the recovery of the first three-dimensionally preserved parts of this enigmatic organism. Aim of the present paper is to describe this material and take a step forward in the identification of the problematic organism.

GEOLOGICAL SETTING

Ireland was located in the Silurian at the Iapetus suture zone merging Laurentia, Avalonia and Baltica, and close to Gondwana, deriving the puzzle-like actual configuration due to the fusion of different terranes (Pickering et al. 1988; Soper and Woodcock 2009; Ferretti et al. 2014; Todd 2015). Graptolitic shales and greywackes of basinal facies constitute most of the Silurian (Holland 2009). Shallow-water facies are exposed in limited areas in the western and southwestern parts of the island (text-fig. 1A). A Telychian (Llandovery) transgression occurred to the west as documented by calcareous siltstones and sandstones that have revealed brachiopod faunas. Conodonts were



TEXT-FIGURE 1
Geological setting of the investigated area. A: distribution of Silurian basinal and shallow-water shelf facies in Ireland; B: geological map of the Dingle Peninsula showing the location of Ordovician–Carboniferous rocks and the position of Caherconree; C: exposure of the Ballynane Formation in the Caherconree area with indication of the fossiliferous Localities 28 and 36 (modified from Parkin 1976, Pracht 1996 and Kaminski et al. 2016).

extracted in rare carbonate rocks in the Charlestown inlier, County Roscommon (Aldridge 1980) and, associated with thelodonts, at Coolin Lough, County Galway (Aldridge et al. 1996). Wenlock–Ludlow silty limestones with no conodont record were reported at Croagh Patrick, County Mayo, by Graham et al. (1989). Shelly faunas of mostly brachiopods are there present. Siltstones with thin levels and nodules of limestones and volcaniclastics belonging to the Ballynane Formation are exposed in the Annascaul inlier (Parkin 1976; Prach 1996; Kaminski et al. 2016; text-fig. 1B). No calcareous rocks are present in the younger Caherconree and Derrymore Glenn formations of Ludlow age. The calcareous nodules of the Ballynane Formation are exposed in only two sites, referred as Localities 28 and 36 (Parkin 1976), distant 1 km (text-fig. 1C). Aldridge (1980) and Siveter (1989) described the rich conodont and trilobite faunas respectively from both localities, and provided provisional age assignments (see below).

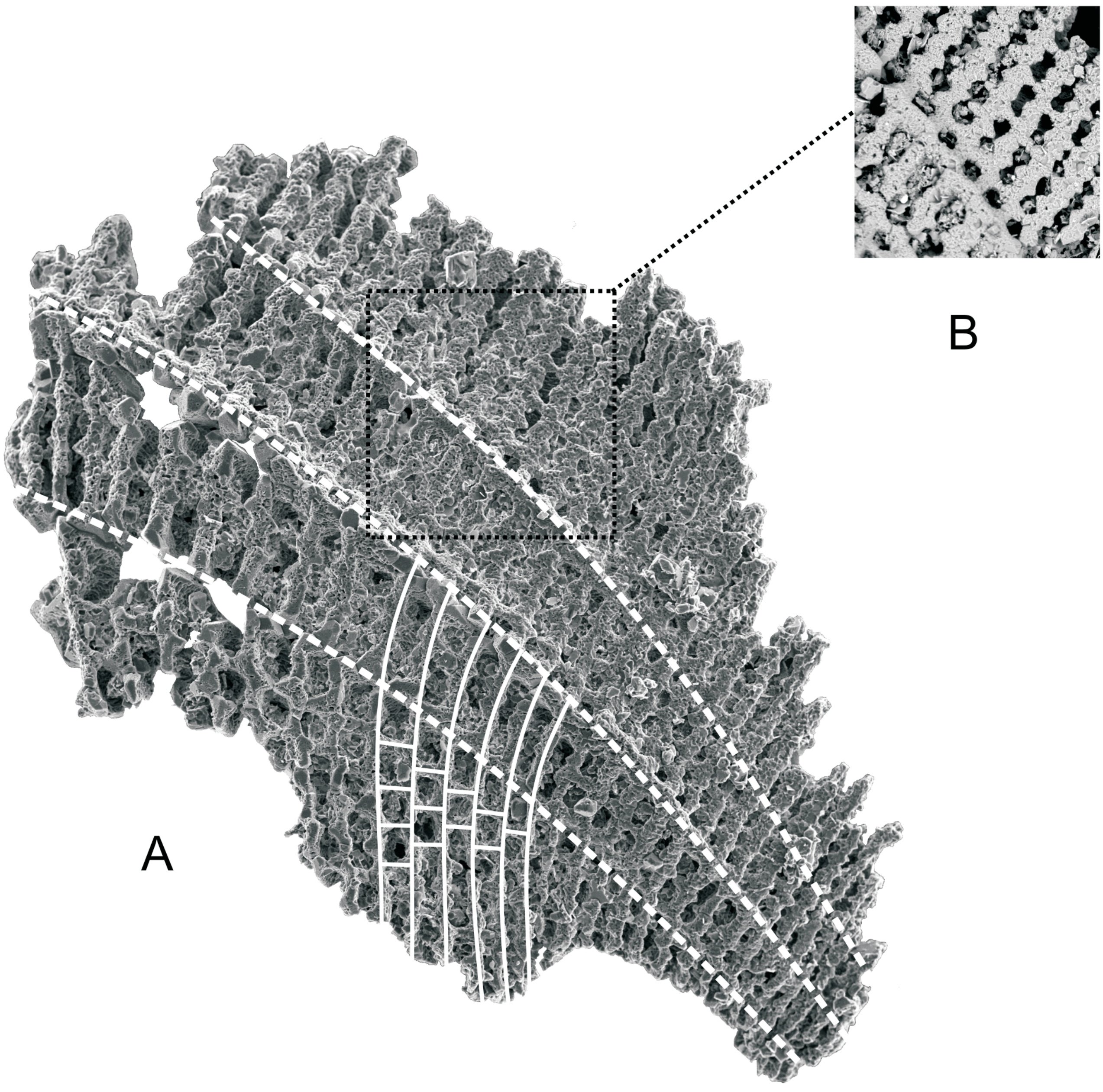
The material under investigation was collected in Locality 36. There, light grey small (5-20 cm) carbonate nodules, embedded in a fine matrix, are exposed for about 3 m. The limestones document a rich thanatocenosis of disarticulated trilobites (Siveter 1989). Crinoidal debris, brachiopods and bryozoans are commonly associated (Ferretti and Holland 1994); agglutinated benthic foraminifers of North American affinity were reported by Kaminski et al. (2016). These agglutinated foraminiferal genera were not present in the Gondwanan Silurian (Llandovery) assemblage recently documented by Kaminski and Perdana (2020). Trilobites and brachiopods occur as well in the silty matrix. A shallow-water environment was inferred, with faunal recolonization episodes punctuated by volcanic events, and redeposition of the fossil material in deeper settings (Ferretti and Holland 1994, fig. 3). Remarkable is the almost complete absence of other Silurian protagonists, notably cephalopods, that dominate coeval deeper-water settings at higher latitudes in the peri-Gondwana region (e.g., Wendt and Aigner 1985; Barca et al. 1992; Ferretti and Serpagli 1996; Ferretti et al. 1998, 2009; Histon 1999; Lubeseder 2008; Corradini et al. 2009a) as well as of specific anoxic organic-rich settings (*sensu* Negri et al. 2009).

The Dunquin inlier provided a rich shelly fauna (Holland 1988) but no conodonts were so far recovered by calcareous rocks.

MATERIAL AND METHODS

Lab processing and analytical microscopy

A sample of some 10 kg of calcareous nodules collected from Locality 36 was etched in formic acid with the standard processing technique in use for conodont preparation. No attempt was made to concentrate a heavy fraction from the >100 µm residue in order to hand-pick under a Zeiss binocular microscope the entire non-calcareous faunal association. Benthic agglutinated foraminifers (Kaminski et al. 2016) and "conodont pearls" (Ferretti et al. 2021) were recovered in this way, together with the problematic organisms herein described.



TEXT-FIGURE 2
Reconstructed architecture of the fragments collected in this work. A, outer view of specimen IPUM 29933 exposing three main longitudinal axes (white dotted lines) intersected by transversal rows (white lines) revealing a definite reticulate pattern. B, backscattered electrons (BSE) image to better display the net-like design. Scale bar in A represents 50 µm.

Specimens were investigated under scanning electron microscopy. Samples were mounted on aluminum stubs previously covered with carbon-conductive adhesive tape. Carbon-coated elements were observed with the Scanning Electron Microscope (SEM) JEOL JSM-6010PLUS/LA InTouchScope, equipped with an Energy Dispersive X-ray (EDX) spectrometer at the Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Italy. SEM-EDX measurements were performed in high vacuum with an accelerating voltage between 5 and 20 keV both for imaging and elemental analyses.

Biostratigraphic assignment of the material

Conodonts and trilobites have been used to refine the age of the calcareous levels exposed in the Annascaul Inlier. Aldridge et al. (1980), by the use of conodonts, proposed a Wenlock age for

Locality 28 and a Ludlow age for Locality 36. Siveter (1989) suggested a mid/late Wenlock–earliest Ludlow age for Locality 36 by the use of trilobites. Our conodont analysis provided a small fauna dominated by *Kockelella ortus absidata* Barrick and Klapper 1976, *Kockelella variabilis variabilis* Walliser 1957, *Panderodus recurvatus* (Rhodes 1953) and *Dapsilodus obliquicostatus* (Branson and Mehl 1933). The presence of *Kockelella variabilis ichnusae* Serpagli and Corradini 1998 allows to fix the age of Locality 36 to the latest Gorstian–early Ludfordian (Ludlow) (Corradini et al. 1998, 2015; Serpagli et al. 1998; Corradini and Ferretti 2009; Corriga et al. 2009; Kaminski et al. 2016; Schönlaub et al. 2017; Gómez et al. 2019; Ferretti et al. 2021).

Repository

Illustrated specimens are deposited in the collections of the Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Italy, under repository numbers IPUM 29933–IPUM 29937.

RESULTS

Nomenclature terms

As the real orientation/positioning of the recovered fragments within the skeletal architecture of the problematic organism is still indefinite, we will refer by convention to the reticulate face as “external” and to the opposed one as “internal”.

Description

Five specimens (pl. 1) collected in this study fit with the features of the problematic organism reported by Ferretti et al. (1993). The most complete specimen (IPUM 29933, pl. 1, fig. 1a-i, and text-fig. 2) is about 1.7 mm long and 1 mm wide and exposes in the external face a peculiar net-like structure of 30 subparallel curved crossbars supported by three major longitudinal curved axes that get more distanced each other (from 50 µm up to 200–250 µm) along the specimen in a sort of “fan”. Transversal partitions are separated each other by about 40 µm. Minor bars, perpendicular to the crossbars, create a net-like pattern with single *fenestrae* about 50 µm wide and 40 µm high (text-fig. 2). These minor bars are not aligned with those of the adjacent rows but appear to grow in alternate positioning. In lateral view, the specimen is slightly excavated (pl. 1, fig. 1f) and its wall framed by 50 µm high “bone-like” *traversae*, distanced each other about 40 µm and possibly representing the terminal ends of the transversal partitions previously described in the external face. It is to be noted that our measurements of the net frame closely match the dimension of the *fenestrae* in the distal portion of the holotype (Ferretti et al. 1993, pl. 1, fig. 1).

Specimen IPUM 29934 (pl. 1, fig. 2a-b), 1.4 mm long and 0.6 mm wide, replicates the reticulate outer pattern with 20 subparallel partitions, separated each other by about 40 µm, intersected by two major and a third faint longitudinal axis. Distance between the axes increases from about 75 µm at one extremity up to 220 µm on the opposite. The three axes get more evident on the internal side of the fragment (pl. 1, fig. 2b), while the reticulate pattern almost disappears. The same happens also for specimen IPUM 29935 (pl. 1, fig. 3a-b), about 1 mm x 1 mm, exposing a reticulate pattern of *fenestrae* about 50 µm wide to 35 µm high (pl. 1, fig. 3a). Bars between transversal crossbars grow not in continuity with bars of adjacent rows, as already remarked for specimen IPUM 29933. The internal view of the same specimen exposes an almost continuous wall with three to four major longitudinal ridges. The reticulate pattern has completely disappeared.

Specimen IPUM 29936 (pl. 1, fig. 4a-b) is about 0.9 mm long x 0.6 mm wide and exposes eight rows that in the upper right part define a clear net pattern of sub-squared 40 x 40 µm *fenestrae*. Again, the reticulate pattern completely fades when observing the opposite side of the fragment (pl. 1, fig. 4b).

Specimen IPUM 29937 (pl. 1, fig. 5a-e), 0.9 mm long and 0.2 mm high, bears three main transversal partitions with secondary bars separating single rows in *fenestrae* about 50 µm wide.

Chemical characterization

Chemical characterization under SEM-EDX analysis revealed that silicon and oxygen are the most abundant elements detected in the spectra run on several spots of the specimens. This was

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PLATE 1

Scanning electron micrographs of the enigmatic specimens recovered from limestones of Locality 36, Ballynane Member, Annascaul Formation, Dingle Peninsula, Ireland
Scale bars represent 100 µm.

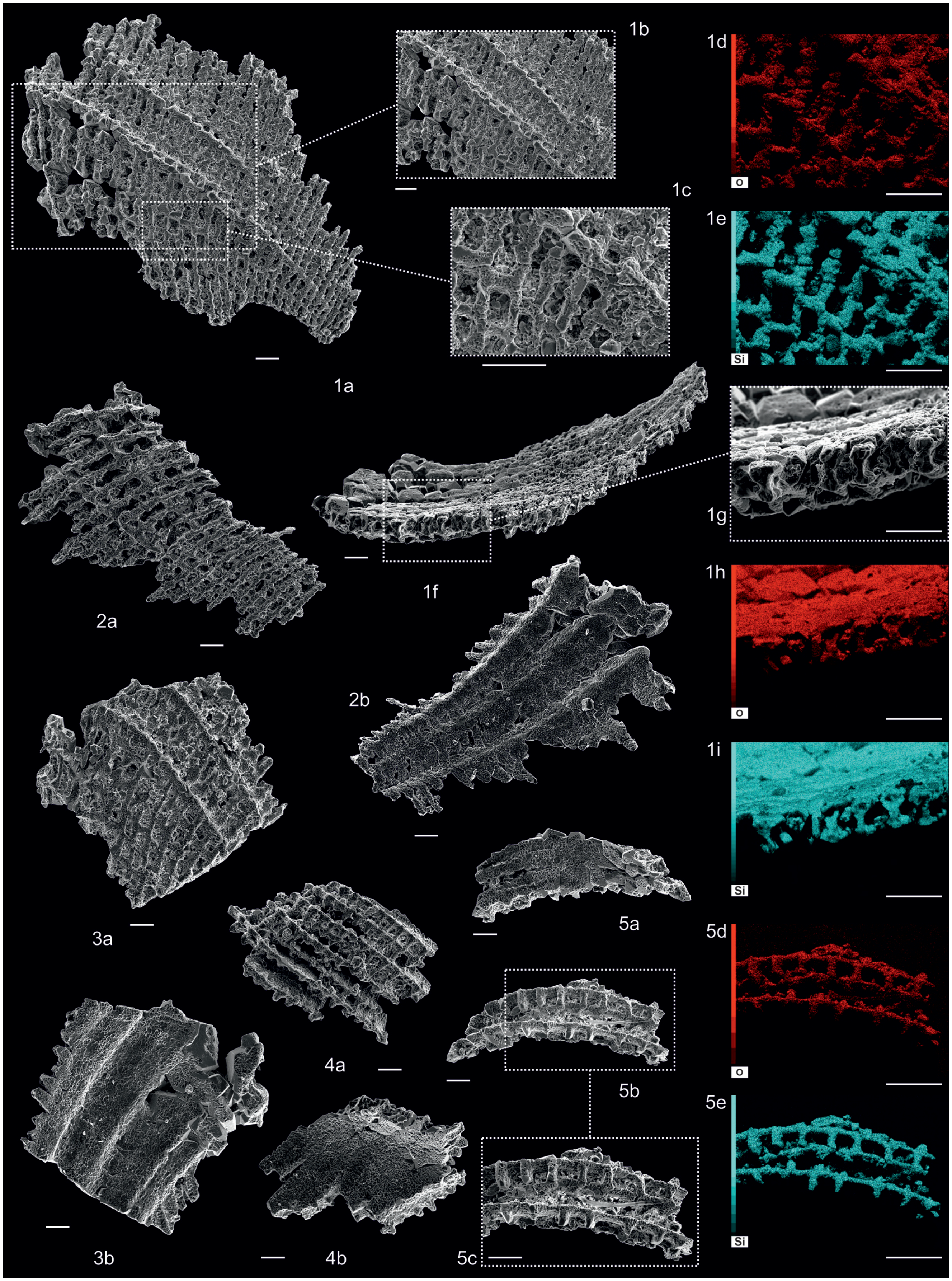
1a-c outer view of specimen IPUM 29933, with the two insets illustrating the presence of longitudinal axes (b) and a reticulate pattern (c); d-e, SEM-EDX elemental maps (O and Si) of the area illustrated in (c); f, lateral view; g, detail of the wall exposing parallel *traversae*; h-i, SEM-EDX elemental maps (O and Si) of the area represented in (g)

2a-b outer and inner views of specimen IPUM 29934

3a-b outer and inner views of specimen IPUM 29935

4a-b outer and inner views of specimen IPUM 29936

5a-c inner (a) and outer (b-c) views of specimen IPUM 29937; d-e, SEM-EDX elemental maps (O and Si) of the area represented in (c). Chemical elemental maps of all analysed specimens reveal a general siliceous compositional uniformity for the enigmatic organism.


1a
1b
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1h
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5a
5b
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confirmed by elemental maps (pl. 1, figs. 1d-e, 1h-i, 5d-e) that document no significant changes in chemical composition from the external to the internal side of the samples, supporting a siliceous compositional homogeneity throughout the entire fragments. Noteworthy to say that calcareous parts eventually present were inevitably removed by formic acid processing.

DISCUSSION AND CONCLUSION

Apart from conodonts, the Dingle association documents a fully benthic community constituted of trilobites, brachiopods, crinoids, bryozoans and agglutinated foraminifers living in well-ventilated shallow water of normal salinity. A similar benthic fauna of brachiopods, echinoderms, ostracods, trilobites, bryozoans, corals, and the blue-green alga *Girvanella* was reported from Scandinavia (Lauritzen 1974). By comparison with associated faunal elements, a benthic mode of life was speculated for Regnellidae, that would have anchored the basal flexible cone to the substrate and exposed the distal network as a filter-like system similarly to sponges (Ferretti et al. 1993).

Thin section observation had revealed that the wall of the distal part was composed of separate layers (Ferretti et al. 1993). This is reinforced by our study, that provides the first three-dimensional preserved pieces of this enigmatic organism. The material has undergone secondary silicification, which however appears not to have obliterated the reticulated pattern of the outer wall. Our material has documented fragments of a slightly curved distal structure, reinforced by longitudinal main axes, made of subparallel transversal partitions, distanced each other of about 40 µm, further subdivided in *fenestrae* about 50 µm wide. The inner wall appears surprisingly avoid of any opening necessary to support a possible filter-function. If observed just on the inner side, in fact, these specimens strongly recall shell fragments.

The other enigmatic organisms recovered in the Irish association, notably the phosphatic rings and plates, do not appear to be related, as indicated by a different chemical composition and stratigraphic distribution, spanning the rings at least from the late Cambrian to the Late Devonian (Müller et al. 1974) and the plates from the Ordovician to the Middle Devonian. The problematic organisms described in this paper has been so far reported only from the Silurian.

Our recoveries provide just a few more clues on this mystery, unluckily not enough to decipher the taxonomic assignment of the problematic fossils. More complete specimens are requested to finally solve the enigma and explain, among other things, the reason of such a small size of these organisms.

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