INSIGHTS INTO THE MORPHOLOGY OF *SPHENOTHALLUS* (CNIDARIA): NEW FEATURES IDENTIFIED IN AN OLD GENUS, FROM THE CARBONIFEROUS (PENNSYLVANIAN, BASHKIRIAN) OF WESTERN IRELAND

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*(Received 3 July 2023. Accepted ** ***** ****)*

Abstract

The recent discovery of well-preserved fragments of *Sphenothallus* in the Central Clare Group (Pennsylvanian) of western Ireland provides new insights into the morphology of this enigmatic, putative cnidarian. The specimens demonstrate a morphological plasticity including features not previously described for *Sphenothallus*, such as the presence of flat sides and angular lateral margins, non-bilateral symmetry in sigmoidal cross-sections suggestive of growth torsion, and a new type of bifurcating branching (new term 'railtrack junction branching' introduced herein), not related to known budding. We propose that these structures were all growth-related features during life, not post-mortem artefacts of collapse or compaction. The flat sides and growth torsion are compared with similar features in conulariids, supporting the previously proposed phylogenetic linkage between the two groups, which may be an example of atavism. However, the bifurcating 'railtrack junction branching' is unknown in conulariids or other similar organisms.

Introduction

The fossil record is replete with many tube-like organisms composed of a variety of substances. Their morphology, ecology and phylogenetic affinity are commonly described as problematic. Nevertheless these 'Problematica' form important components of many marine communities in terms of their abundance and diversity. One such tube, *Sphenothallus* Hall, originally described as *Serpulites longissimus* J. de C. Sowerby from the Silurian of England, and its allies, has been the subject of much discussion, particularly regarding its taxonomic affinities. Only one previous record of *Sphenothallus* is known from Ireland, *S. carbonarius* (M'Coy, 1844) from the Carboniferous of Manorhamilton, County Leitrim. Originally assigned to *Serpulites* the lectotype (NMING:F7357/C) and counterpart (NMING:F7357/B) are in the National Museum Ireland, Natural History, Dublin.

The new Irish material assigned to the genus *Sphenothallus* occurs in the Pennsylvanian (Bashkirian/Regional Substage: Kinderscoutian) rocks of the Clare Basin (Fig. 1). The specimens are relatively abundant and well preserved although fragmentary. All described and illustrated specimens are reposited at the National Museum Ireland, Natural History, Dublin (Accession numbers NG:F35396–NG:F35407).

Phylogenetic affinities and distribution

Sphenothallus is generally described as an enigmatic, flattened tuboid fossil and has been recorded from rocks of Cambrian to Triassic age, although it has not been documented from the Permian System (Bolton 1994; Fatka *et al.* 2012; Chang *et al.* 2018; Van Iten *et al.* 2023). The taxon was first described from the Silurian of England by J. de C. Sowerby (as *Serpulites longissimus*) under the direction of Sir Roderick Murchison during the latter's investigations of the Silurian System (Murchison 1839). James Hall first introduced the generic name *Sphenothallus* in 1847 for what he believed to be plant material. Ruedemann (1896) considered the taxon to be related to the conulariids, although Mason and Yochelson (1985) stated that Ruedemann confused flattened *Sphenothallus* tubes with flattened conulariids. The generic names *Enchostoma*, *Serpulites*, and *Campylites* were also used for similar flattened or tuboid chitinous fossils until the first major revision of the genus *Sphenothallus* by Schmidt and Teichmüller (1956), which covered most European records. The type species of *Sphenothallus* Hall is from the Ordovician of New York; however, it was not until the study by Mason and Yochelson (1985) that the distribution of this genus (which they considered an annelid) throughout the Devonian to Pennsylvanian rocks of North America was documented.

Sphenothallus is remarkably widespread both geographically and stratigraphically. Following the initial interest by 19th Century scientists, based on records predominantly from Europe and the subsequent work of Mason and Yochelson (1985) from the USA, *Sphenothallus* has been recorded from Cambrian to Triassic deposits, except in the Permian, at a wide variety of other locations: South Korea (Choi 1990), Bolivia (Babcock 1993; Hannibal *et al.* 1993), Canada (Bolton 1994), Argentina (Taboada 1997), China (Zhu *et al.* 2000; Wang Yi *et al.* 2003), Estonia (Vinn and Kirsimae 2015), Sweden (Nathorst 1883; Stewart *et al.* 2015), Morocco (Van Iten *et al.* 2016), Ukraine (Dernov 2023), and Slovenia (Van Iten *et al.* 2023).

Radiograph images of specimens from the Lower Devonian Hunsrück Slate of Germany, published by Fauchald *et al.* (1986) were interpreted as showing two tentacles and a spool-like body in the open cavity of *Sphenothallus*. To date, these remain the only putative soft-body parts described for the genus, however they were inconclusive in determining its taxonomic position; but the authors stated that these structures 'would seem to prove beyond question that *Sphenothallus* was indeed wormlike'; they noted, however, that the sleeve of tissue that purportedly supported the two tentacles is similar to the supportive structure at the base of the tentacular crown of extant sabellid polychaetes. Nevertheless, subsequently Fauchald and Yochelson (1990) agreed that *Sphenothallus* was not an annelid based on the lack of segmentation of its soft parts.

Van Iten *et al.* (1992) placed *Sphenothallus* firmly within the Phylum Cnidaria, based on material from the Mississippian Bear Gulch Formation in central Montana, in particular noting the presence of schotts, multilamellar thecae, holdfasts and clonal-branching; all of which are features which can be identified in modern hydrozoans and scyphozoans. Comprehensive reviews by Mason and Yochelson (1985), Van Iten *et al.* (1992) and Neal and Hannibal (2000) have discussed the changing taxonomic position of *Sphenothallus* during the 20th Century, and Zhu *et al.* (2000) provided a very thorough review of the historical nomenclature of the genus. Since then, *Sphenothallus* has generally been accepted as a medusozoan, despite the lack of diagnostic soft-body parts.

More recently, Vinn and Mironenko (2021) have described phosphatic lamellar fibrous 'plywood' layers in *Sphenothallus* from the Mississippian of central Russia. They conclude that this layering could indicate an originally organic layered structure that has been diagenetically phosphatized (similar organic structures are known in cnidarians, polychaete annelids and phoronids) or the phosphatic composition was an original feature (which they consider less likely), indicating a closer affinity with vertebrates. In either case, they acknowledged that while these organic lamellar fibrous 'plywood' layers occur in some cnidarian (anthozoan) tubes (Stampar *et al.* 2015), they are unknown in medusozoans.

Dzik *et al.* (2017) described radial septa and tetraradial symmetry in juvenile *Sphenothallus* and noted a change to a bilateral symmetry in adult specimens. They compared the early ontogenetic growth to coronate scyphozoan polyps and proposed that the ancestor of cnidarians was also a bilaterally symmetrical animal.

Palaeoecology

Sphenothallus has been universally considered a marine animal; it has been recorded from dysoxic, oxic, shallow to deeper-water marine environments, including hardgrounds. The sole exception of an occurrence in non-marine deposits (upper Pennsylvanian lacustrine sediments of New Mexico) has been attributed to allochthonous fragments, carried inshore from a nearby marine environment (Lerner and Lucas 2011). When associated with hardgrounds, the holdfasts of *Sphenothallus* have been reported on presumably dead brachiopods, as well as other *Sphenothallus*. Vinn and Mironenko (2021) linked the appearance of *Sphenothallus* in the Mississippian of Russia to the maximum height of rising relative sea level which coincided with the spread of anoxic conditions in the bottom water layers. Otherwise, it appears to have been an opportunist, usually occurring with few other benthic animals (Bodenbender *et al.* 1989; Van Iten *et al.* 1996; Neal and Hannibal, 2000; Wang *et al.* 2003). The new Irish material similarly occurs with a low number of other benthic organisms (scarce inarticulate brachiopods, unidentified burrowing organisms and demosponges) at the base of a cyclothemic shallowing-upwards unit (Kilkee cyclothem). The specimens are found in grey shale, and there is no evidence of anoxic bottom water conditions as indicated by the presence of infaunal burrowing. Ammonoids (*Anthracoceras* sp. and *Reticuloceras* sp.) also occur rarely in the same horizon but they are generally not considered part of the benthic fauna due to their pelagic, swimming lifestyle; however, a nektobenthic habit has been proposed for some Carboniferous ammonoids (Tanabe *et al.* 1995), so they may have spent some time on the seafloor. Numerous holdfast-like structures embedded in the muddy substrate occur along the same horizon. They are not attached to hard substrates which, apart from the substrates provided by *Sphenothallus* themselves, are almost entirely lacking. Several specimens bear circular or subcircular scars of possible attachments but no specimens of *Sphenothallus* attached to the holdfasts have been found. However, based on the similarity to *Sphenothallus* holdfasts described from elsewhere (Peel, 2021) it is reasonable to assume they are the disconnected holdfasts of *Sphenothallus* which tethered the animals to the seafloor during life.

Systematic palaeontology

Phylum Cnidaria Verrill, 1865
Subphylum Medusozoa Peterson, 1979
Class, Order, Family uncertain
Genus *Sphenothallus* Hall, 1847

Type species. *Sphenothallus angustifolius* Hall, 1847, originally described from the Upper Ordovician of eastern New York State, USA.

Amended diagnosis (after Van Iten et al. 2013). *Sphenothallus* specimens generally consist of a single, slender, gently tapered hollow tube constructed of numerous, very thin (approximately 1–2 µm) lamellae that parallel the exterior surface of the tube (e.g., Van Iten *et al.* 1992, 2002; Muscente and Xiao 2015; Vinn and Kirsimäe 2015). In addition there may be a plywood-style structure with alternating layers of lamellae orientated at high angles (Vinn and Morenenko, 2021). Most specimens contain substantial amounts of the mineral apatite, but others are largely or entirely organic (see Muscente and Xiao 2015 and references cited therein). Tube shape changes during ontogeny from circular in juvenile/immature specimens to ellipsoidal to broadly sigmoidal in some adults. This sigmoidal shape may include the development of flat lateral faces and sharp corners between adjoining faces. The pair of marginal thickenings are asymmetrical and the result of the sigmoidal shape of the adult test. The wide or oral end of the tube is open, and the oral margin of each face is gently curved. The narrow, aboral (apical) end of the tube exhibits a small, sub-conical expansion floored by a thin membrane cemented in life to hard substrates including hardgrounds.

Sphenothallus aff. *carbonarius* M'Coy, 1844

Figs. 2–7

aff. 1844 *Serpulites carbonarius*; M'Coy, p. 170, pl. 23, fig. 32.
aff. 1844 *Serpulites membranaceus*; M'Coy, p. 170, pl. 23, fig. 31.
aff. 1967 *Campylites carbonarius* (McCoy); Wilson, pp. 470–471, pl. 1, figs. 8–16.

Discussion. The specimens described herein are broadly similar to *S. carbonarius,* originally described from the Carboniferous of Ireland by M'Coy (1844). This species was redescribed by Wilson (1967) on the basis of M´Coy´s type material and new material from the Carboniferous of central Scotland, and he concluded that *S. membranaceus* (M'Coy, 1844) should be regarded as a junior synonym of *S. carbonarius*. There is a real difficulty in comparing our new material with previouly described species, as many published species are differentiated purely on width, size and surface structure, with no other differentiating features. Some authors have used the angle of expansion (Peng *et al.* 2005; Fatka *et al.* 2012), however as Neal and Hannibal (2000) pointed out, the rate of expansion varies intraspecifically and cannot be used to distinguish species. The usefulness of the new features described herein to distinguish species is currently unknown as these features have not been described in other species of *Sphenothallus,* and further work on new material is required to understand the levels of intraspecific variation within this genus.

Material and occurrence. 50 incomplete specimens were extracted from a coastal cliff section exposing the uppermost part of the Tullig cyclothem and the base of the Kilkee cyclothem of the Central Clare Group. The Tullig cyclothem is defined as the lithological unit immediately overlying the Gull Island Formation, with the upper boundary defined by the middle of three *Reticuloceras* cf. *stubblefieldi* ammonoid bands (Wignall and Best 2000), which also marks the base of the overlying Kilkee cyclothem. Rider (1974) initially defined the base of each cyclothem as 'the base of the black shale interval at the boundary between the sandy deposition of the cyclothem below and the clay deposition of the cyclothem above'. We favour Rider's initial definition and therefore place the

Sphenothallus horizon at the base of the Kilkee cyclothem, which is 25–~~-~~100cm below the first *Reticuloceras* horizon.

Description and remarks. The new fauna shows examples of typical *Sphenothallus* features as described and illustrated throughout the literature (e.g. Mason and Yochelson 1985; Van Iten *et al.* 1992; Peel 2021) including, gently expanding thecae, clonal budding, transversely ridged and wrinkled surfaces, thickened lateral margins, lamellar layering, diagonal fractures in test and the presence of closely associated holdfasts, although no specimens were found attached to holdfasts (Fig. 2). The Irish specimens show, however, several diagnostic features, notably flat sides and 'angles', sigmoidal cross-sections and 'railtrack junction branching'. These three new characters are described below.

The material provides evidence of the development of flat sides in the adult theca. These flat sides are not immediately obvious in many specimens as they are developed on the lateral margins only and are rarely seen in bedding plane views. In some of the specimens the test is preserved such that it falls out as a separate piece when the specimens are split along bedding planes (Fig. 3). They preserve the organo-phosphatic tube (dark shiny outer layer) with very obvious flat lateral sides as well as the development of diagonally opposed thickened 'angles'. The internal part shows some layering and may have been rigid during life based on the preservation of some sections of test preserved rotated at a very high angle to bedding, such that the flattened part of the test is perpendicular to bedding, indicating they have not been flattened after burial. The thickened lateral margins commonly described in *Sphenothallus* warrant further study, because in the adult specimens displayed here (Figs. 3 and 4) they do not appear as thickened curved margins (see Stewart *et al.* 2015, fig. 3 for an example from a juvenile Cambrian specimen) but clearly form sharp 'angles' on opposite lateral margins of the test. It is also clear that this is not a compactional or collapse feature formed from curved thickened margins but is an original growth feature of the test.

Two specimens of *Sphenothallus* show examples of a new type of branching, termed 'railtrack junction branching' herein. In this type of branching the entire test appears to bifurcate across a transverse midline and diverge at an angle of 25 degrees, duplicating the entire adult test, effectively forming a 'two-headed' test (Figs. 5–7).

Some of the specimens of *Sphenothallus* display distinct flat-sided lateral margins. These flat sides are most clearly seen in transverse cross-sections (Fig. 3). The facets are clearly part of the so-called thickened lateral margins and are only seen in certain examples where the margins are exposed laterally. The facets are often oblique to bedding and may be connected to adjoining flat sides by sharp, acute, obtuse or perpendicular angles or they may be connected to curved sides. The flat sides sometimes show a left/right asymmetry in cross-section, in their connection to other surfaces, with connections to more pronounced curved surfaces on diagonally opposite (upper/lower) sides.

The identification of three new characters in a genus may be considered to require the erection of a new taxon, however we feel that some of the features we describe may have been overlooked in previous studies in other material (beyond the scope of the present study) and they can be best accommodated in an amended diagnosis for the genus.

Discussion

Sphenothallus has generally been described as a 'tube', 'tuboid' or 'flattened tube' with thickened lateral margins and demonstrably tubular forms have been clearly identified in juvenile specimens in the current fauna as well as by previous authors (Dzik *et al.* 2017). Peel (2021) described the main morphological features of *Sphenothallus* as 'the long slender phosphatic tube, originating from a small conical holdfast, and an opposing pair of lateral longitudinal thickenings of the elliptical tube wall'. However, apart from Dzik *et al.* (2017) and a brief comment in Mason and Yochelson (1985) there has been little attention paid to the ontogenetic change in morphology that occurs in *Sphenothallus;* the change from a circular cross-section to a flattened cross-section. It has been assumed by most other authors that this flattening is related to either sedimentary compaction or post-mortem collapse of a thin tubular thallus (Wang *et al.* 2003). Very few photographic images of cross-sections of the adult *Sphenothallus* have been published (Van Iten *et al.* 1992, fig. 1; Wang *et al.* 2003, fig. 8).

The adult Clare specimens display a distinctive, variably thickened test. This central thickened test must have been rigid prior to burial because segments of *Sphenothallus* aff. *carbonarius* preserved at high angles to bedding maintain the same thickened form as those preserved parallel to bedding but rotated at a high angle. This indicates that at least the central part of the test was rigid during life. In addition, two specimens show evidence of brittle fracture prior to burial, again this indicates a rigid thallus during life.

The wrinkled surfaces often described on *Sphenothallus* are well-developed in some of the Clare specimens. In some specimens transverse 'ripples' are present (Fig. 2.D), in others (Fig. 2.C), these are largely replaced by irregular 'wrinkles' with only vestiges of the transverse 'ripples' preserved. While it is easy to ascribe the wrinkling to a collapsed thin membrane, we suggest that the nature of the test is more complex and that these wrinkles or ripples are a primary feature of the *Sphenothallus* test, the function of which is unknown.

The flat-sided margins (Figs. 3 and 4) have not been described in *Sphenothallus* previously. They are only found in adult specimens and are variably developed. The flat margins are not connected to each other to form a rhombus in cross-section but are separated by the irregularly thickened median test. These flat sides bear some slight resemblance to the flat faces of conulariids, long considered to be phylogenetically related to *Sphenothallus* (see Van Iten *et al.* 1992). Conulariids have a tetrahedral (or rarely trihedral or hexahedral test (Sendino *et al.* 2012) composed of (usually) four flat triangular sides which formed an inverted pyramidal test in life. In cross-section they are usually square, however Sandino *et al*. (2012) demonstrated that torsion during growth could produce asymmetrical forms in the Ordovician conulariid *Metaconularia anomala*. Significantly, 56% of their studied specimens showed sinistral torsion when viewed from the apex, producing a twisted rhomboid shape in cross-section. As the apex end is unknown in most of the *Sphenothallus* fragments direct comparison with sinistral or dextral torsion is not possible. However, it is feasible that growth torsion could explain the shape of some of the flat-sided, sigmoidal *Sphenothallus* cross-sections described herein. Both *Sphenothallus* and conulariids have been assigned to the polyps of medusozoan Cnidaria as they both share a similar composition (lamellar, organo-phosphatic test) and the presence of schotts; in addition *Sphenothallus* is known to have reproduced by clonal budding.

It is therefore tempting to suggest that the presence of flat sides in *Sphenothallus* may be another indication of the phylogenetic connection between conulariids and *Sphenothallus*. However, it is difficult to explain how the flat sides are only partially developed, i.e. on lateral margins only and irregularly at that, and the extent of the flat sides towards the aperture is unknown. The nature of the apical-? openings of the *Sphenothallus* specimens described herein is unknown.

Tube flattening of a thallus wall on death by collapse or shrinkage is equally unlikely to produce the preserved fossilized forms, which are very consistent. Sigmoidal cross-sections have not been described previously for *Sphenothallus* and it would be easy to dismiss this shape as a result of compaction or flattening, however the preservation of the Clare specimens (Fig. 3) leaves little doubt that it is an original growth feature. While it may be that torsion during growth could produce some of the cross-sectional shapes displayed herein, the changing ontogenetic variability in the shape of *Sphenothallus* means that is difficult to confirm. It is clear however that the flat sides, ‘angles’ and sigmoidal cross-section are intimately linked.

It may be that the broad similarity between the flat sides, sharp angle and the evidence for torsion may be evidence for atavism. Atavism is the occurrence of ancestral traits long thought to have been lost in the phylogenetic lineage. These characters which, are known in conulariids, may derive from a common ancestor. Geux (2001) hypothesized for Mesozoic ammonites that sub-lethal stress during extinction events favoured primitive looking forms which are similar to remote ancestors. It may be that the stress of rapidly changing sea-levels in restricted basins (which appears to have driven ammonoid evolution during the Pennsylvanian) also triggered a particular atavism in *Sphenothallus*. However, it is unclear what the evolutionary advantage of the flat sides and sharp angles could have been, or why this one particular glacio-eustatic sea-level change recorded in the rocks of the Kilkee cyclothem should have triggered it.

The 'railtrack junction branching' could be dismissed as two adult specimens overlying each other (twice), but the preservation leaves little doubt that such an explanation is not tenable as it would require an extraordinary coincidence of overlying that is not supported by the evidence in the several specimens showing the feature (Figs. 5–7). This ability to generate replicas of adult tests by 'simple' splitting is a form of cloning. It may be that the conditions were stressful and this type of cloning made reproduction much quicker, speeding up population replacement. However, the size of some specimens (12cm) would suggest that they were able to reach a mature length successfully, although the amount of time it took to achieve maturity is unknown.

Conclusions

Previously undescribed features of *Sphenothallus*, including, flat lateral sides, marginal 'angles' sigmoidal cross-sections and 'railtrack junction branching' demonstrate a morphological plasticity in this enigmatic cnidarian genus. The flat lateral sides and marginal angles may be comparable to the flat sides and corners of conulariids, with which they have commonly been phylogenetically linked. However, an exact comparison cannot be made as the flat sides and angles are only developed on two sides in *Sphenothallus.* The development of flat sides and marginal 'angles' is coincident with the development of a sigmoidal cross-section. This sigmoidal shape may be a modification of an underlying bilaterally symmetrical bauplan, possibly the result of the development of flattened sides which are usually rotated with respect to the median thallus surface. This may represent growth torsion, similar to that described elsewhere for conulariids. The development of these features may be a rare example of atavism in the fossil record.

'Railtrack junction branching' is a newly described form of branching for *Sphenothallus*, that appears to allow duplication of an adult thallus. The mechanism of how this happens is unknown, however it is a form of cloning, which could have significant survival value in a stressful environment.

Acknowledgements

The authors acknowledge the immense contribution made by George Sevastopulo to the palaeontological research of Ireland. ED wishes to acknowledge the support of The Burren and Cliffs of Moher UNESCO Global Geopark, Clare County Council and Geological Survey Ireland. DATH acknowledges support from the Leverhulme Trust (GB). Map in Fig. 1 based on Geological Survey Ireland, redrawn by Dr John Murray University of Galway.

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Figure captions

Fig. 1—(A) Map of location in Ireland. (B) Regional geology indicating *Sphenothallus* location site. (C) Local stratigraphy. * indicates *Sphenothallus* horizon. ALPORT = Alportian regional substage; Amm. Biozone = Regional ammonoid biozones.

Fig. 2—*Sphenothallus* aff. *carbonarius* from the Central Clare Group, County Clare, Ireland. (A) NG:F35396; showing the typical gently expanding lower section. Scale bar = 5cm. (B) NG:F35397; showing mature *Sphenothallus* aff. *carbonarius* with attached budding immature daughter tube (arrow). Scale bar = 4mm. (C) NGF:35398; showing faint transverse bands on thallus as well as wrinkling. Scale bar = 3mm. (D) NG:F35399; showing well-developed transverse bands with no wrinkling. Scale bar = 3mm. (E) NG:F35400; example of diagonal fractures in thallus. Scale bar = 1mm. (F) NG:F35401; probable *Sphenothallus* aff. *carbonarius* holdfast. Scale bar = 2mm.

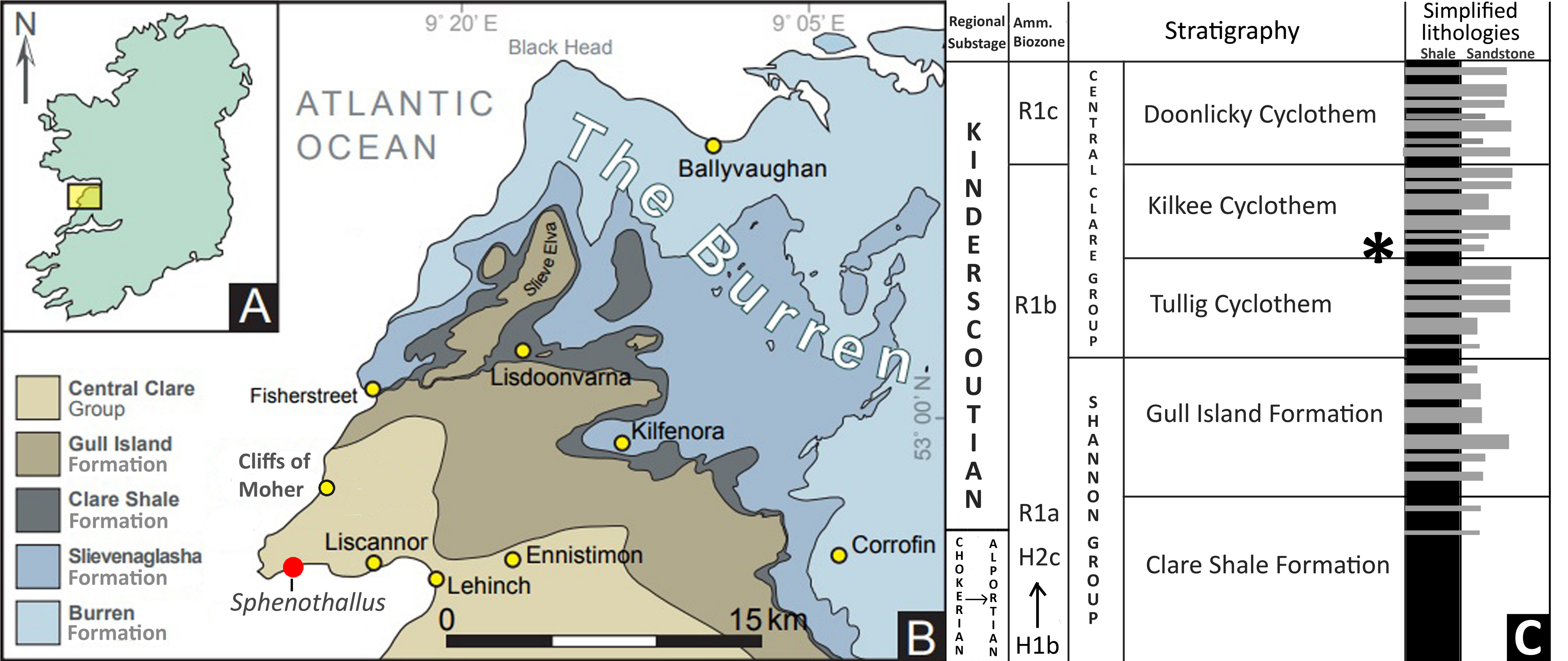
Fig. 3—A–D; NG:F35402–NG:F35405. Examples of tranverse cross-sections through *Sphenothallus* aff. *carbonarius* tests from west Clare, Ireland. Note the flat oblique lateral sides with thickened diagonally opposite corners/angles and sigmoidal appearance. Black arrows indicate diagonal thickened angles, white arrows indicate flat lateral sides. Scale bar = 1mm.

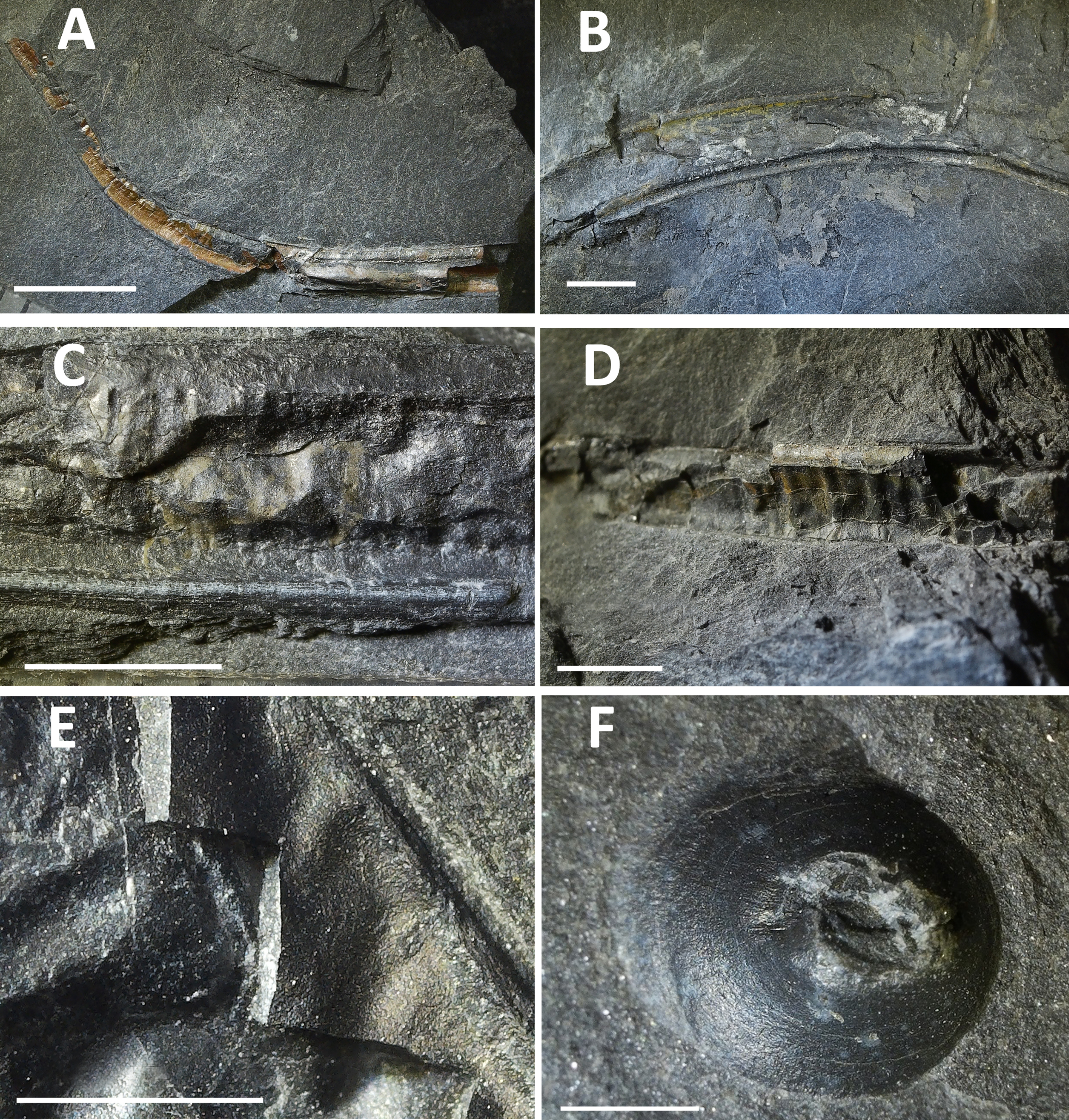
Fig. 4—Outline comparison drawings of six *Sphenothallus* aff. *carbonarius* cross-sections displaying variable but broadly sigmoidal shape with flat edges and ‘angles’. Not to scale.

Fig. 5—NG:F35406 (A). NG:F35407 (B). Two specimens of *Sphenothallus* aff. *carbonarius* from County Clare, Ireland, displaying ‘Railtrack junction branching’. Scale bar = 5mm. Inset boxes A,B shown in detail in figures 6 and 7.

Fig. 6—Inset box A from Figure 5. ‘Railtrack junction branching’ in *Sphenothallus* aff. *carbonarius* from County Clare, Ireland. The entire adult splits in two and diverges resulting in a duplicated thallus. Scale in mm.

Fig. 7—Inset box B from Figure 5. ‘Railtrack junction branching’ in *Sphenothallus* aff. *carbonarius* from County Clare, Ireland. The entire adult splits in two and diverges resulting in a duplicated adult thallus. Scale in mm.


N
A
9° 20' E
9° 05' E
Black Head
ATLANTIC OCEAN
The Burren
Ballyvaughan
Slieve Elva
Lisdoonvarna
Fisherstreet
Kilfenora
Cliffs of Moher
Liscannor
Ennistimon
Lehinch
Corrofin
Sphenothallus
53° 00' N
0
15 km
B
Central Clare Group
Gull Island Formation
Clare Shale Formation
Slievenaglasha Formation
Burren Formation
Regional Substage
Amm. Biozone
Stratigraphy
Simplified lithologies
Shale
Sandstone
KINDERSCOUTIAN
CHOKERIAN → ALPORTIAN
R1c
R1b
R1a
H2c
H1b
CENTRAL CLARE GROUP
SHANNON GROUP
Doonlicky Cyclothem
Kilkee Cyclothem
Tullig Cyclothem
Gull Island Formation
Clare Shale Formation
*
C


A
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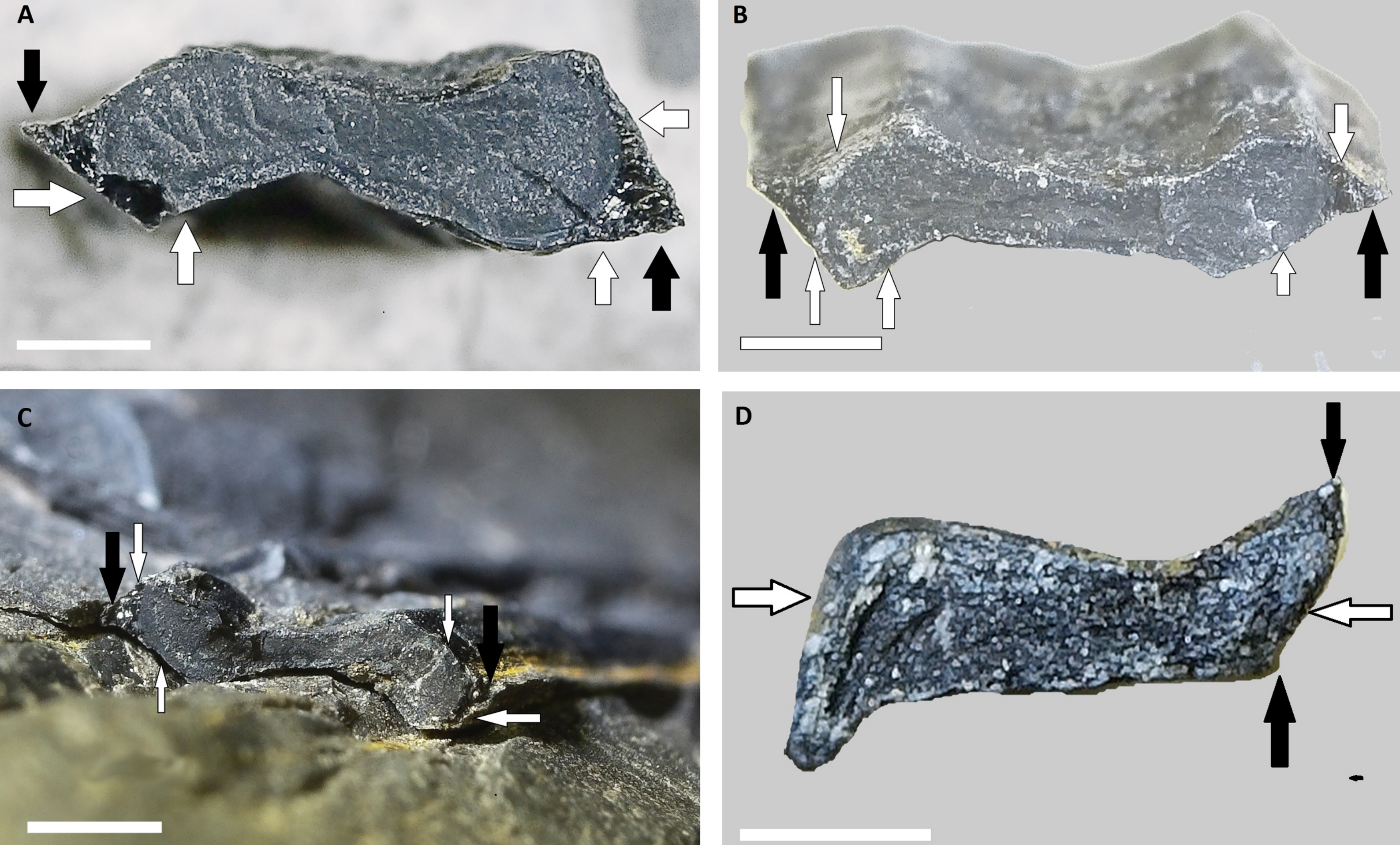
A
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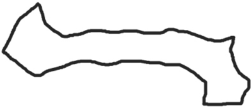

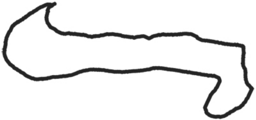

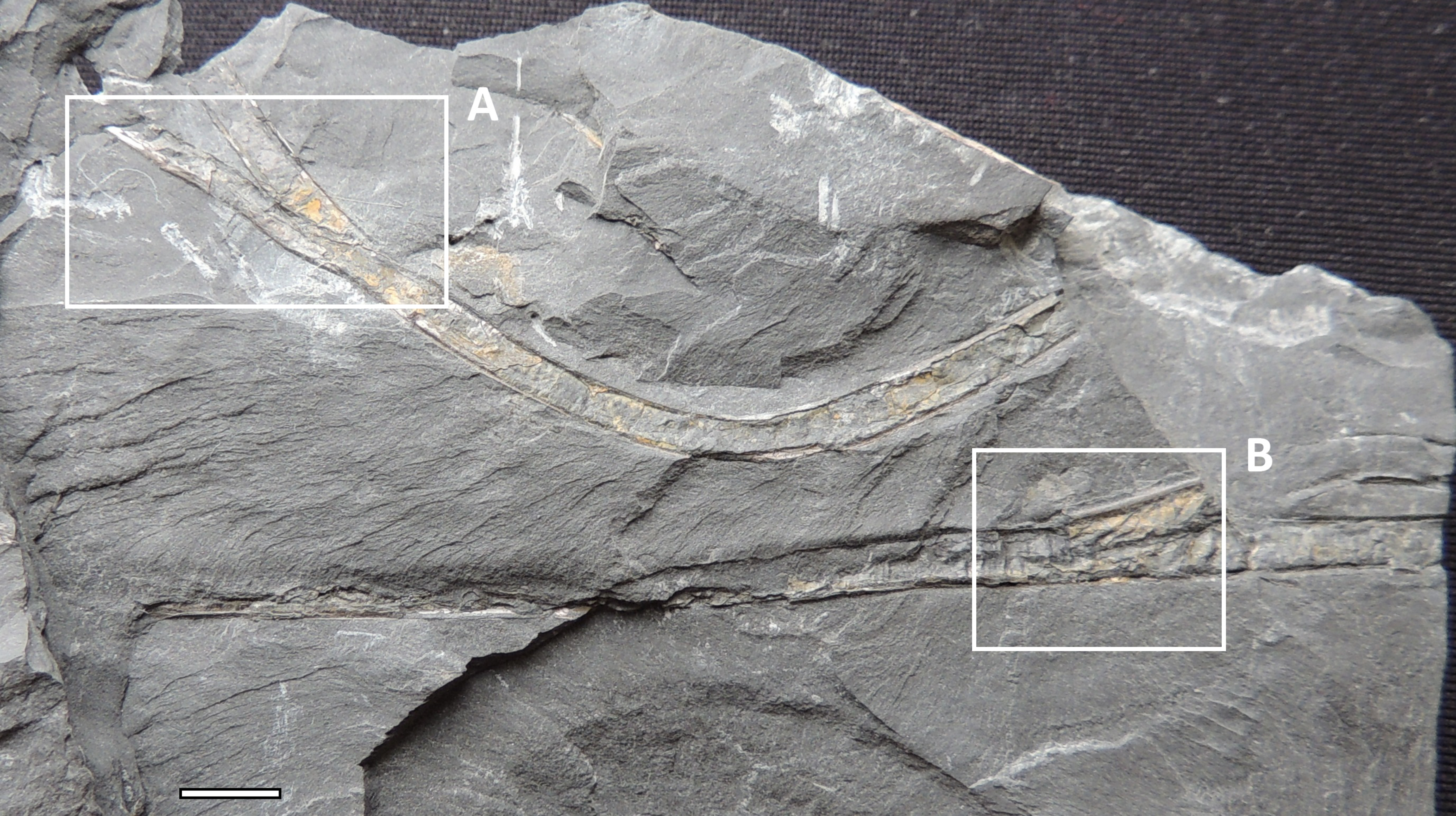
A
B

Citation on deposit: Doyle, E., Ahlberg, P., & Harper, D. A. T. (2024). Insights into the morphology of Sphenothallus (Cnidaria): New features identified in an old genus, from the Carboniferous (Pennsylvanian, Bashkirian) of western Ireland. Irish Journal of Earth Sciences, 42(1), 237-247. https://doi.org/10.1353/ijes.2024.a935031