A beachcomber's guide to neoichnology, part 1 – macroborings

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Abstract: Invertebrate trails, trackways and borings on the beach preserve evidence of diverse forms of organic activity. Borings are moderately diverse in allochthonous clasts. Herein, six ichnogenera are discussed that are likely to be encountered on beaches around Britain and Ireland. *Caulostrepsis* Clarke, *Entobia* Bronn and *Gastrochaenolites* Leymerie are particularly common in lithic (mudrock, limestone) and robust molluscan (oyster) substrates. They are the spoor of spionid polychaetes, clionaid sponges and endolithic bivalves, respectively, and are indicative of the *Trypanites* Ichnofacies offshore. Other, less common borings include *Apectoichnus* Donovan (bivalve borings in wood), *Rogerella* de Saint-Seine (acrothoracican barnacle borings) and *Trypanites* Mägdefrau (sipunculan worm borings). Bored limestone and mudrock clasts on the seashore are robust, easy to collect and provide evidence of the offshore *Trypanites* Ichnofacies.

The naturalist as beachcomber can enjoy a diversity of natural objects to educate, illustrate and collect. Amongst the artefacts that are of interest to the present authors are modern invertebrate traces, particularly borings. This is the area of research of the neoichnologist, whose study concerns modern traces; their fossil equivalents are trace fossils studied by the ichnologist. This contribution is the first of two that are intended to introduce and explain the common sorts of traces that may be encountered on beaches around Britain and Ireland. A second paper will examine surface trails and trackways. Herein, we consider the macroborings found commonly in sedimentary rocks such as limestones and mudstones. For the terminology of traces and trace fossils, see Häntzschel (1975), Bromley (1996) and other references herein.

Traces on the beach represent two distinct spatial environments, separated by both time and space. Surface traces such as trails and trackways are, almost invariably, very recent. Every tide may wash the sediment surface of a beach clean. Thus, traces on the beach will be near-contemporaneous with the observer, originating with each falling tide. The surface is wiped clean and then repopulated by new structures, many, perhaps most, yielding evidence of organisms harvesting the resources of the newly exposed surface of the beach. They are *in situ* and unlikely to be transported except in exceptional circumstances.

Not so borings in limestone and mudstone clasts, which have been transported from offshore and are older, although how much so is impossible to determine. They originate in an environment referred to as the *Trypanites* Ichnofacies, '… characteristic of fully lithified marine substrates such as reefs, hardgrounds, rocky coasts, beach rock, unconformities, and other omission surfaces' (MacEachern *et al*. 2007, p 73; Donovan *et al*., 2018, 2019). So, the beach is a meeting place of traces from two contrasting environments and of different ages. It is the borings of the *Trypanites* Ichnofacies that are considered below.

Localities

The brief locality data below are provided to give substance to the specimens illustrated herein (Figs 1–7). The list is anything but exhaustive, yet may provide ideas for fieldwork for at least some readers.

Locality 1: Isle of Mull

(Adapted from Donovan 2023, p 2.) Beach south of Salen and north of Fishnish by a layby (about NGR NM 615 432), Isle of Mull. The beach debris included wood strongly bored by teredinid bivalves (Fig. 1), ichnospecies *Apectoichnus longissimus* (Kelly & Bromley 1984) (see Donovan 2018). Specimens deposited in the Hunterian Museum, Glasgow (prefix GLAHM).

Figure 1. Apectoichnus longissimus *(Kelly and Bromley), Locality 1, GLAHM X1109, X1110 (after Donovan 2023, fig. 4). Two pieces of bored wood, with broad (upper; GLAHM X1110) and slender diameter shafts (lower; GLAHM 1109). Scale bar in cm and mm.*

Locality 2: Colwyn Bay, North Wales

Specimens deposited in the Natuurhistorisch Museum Maastricht, the Netherlands (prefix NHMM) 2025 07 to 2025 012 (53.2939284, -3.7083726). The temporary storm pebble bank was situated above the high-tide mark just beneath the west promenade (NGR 286229 378803). Access to the beach is possible at a number of places along the promenade especially adjacent to the pier.

Locality 3: Cheswick Bay, Northumberland

Specimens NHMM 2025 013 to 2025 016 (55.7163612, -1.9313018). The bay hosts a long, sandy beach, stretching from Cocklawburn to near Holy Island. Access to the locality (NGR 404414 646995) is from a small car park (the beach is signposted from the A1), through the dunes and onto the beach. The samples were taken from a pebble-supported temporary storm bank above the high tide mark, dominated by pebbles from the adjacent Carboniferous rocks.

Locality 4: Cleveleys, Irish Sea Coast, Lancashire

(Adapted from Donovan 2020a, p 33.) Cleveleys, north of Blackpool, in Fylde, north-west Lancashire, has a coastline trending north-south and fronting the Irish Sea. The south end (about NGR SD 312 430) is easily reached by a short walk from the Cleveleys stop of the Blackpool to Fleetwood tram (Donovan 2021, pp 200–203). Trending north towards Rossall Beach (NGR SD 313 444), the beach, particularly in its upper parts adjacent to the sea wall, has an abundance of cobbles and pebbles of diverse lithologies. At least some of these are limestone, erratics reworked out of glacial deposits, particularly the upper till derived from the Lake District (Ellis 1968, p 144). Specimens in Figure 4 are registered in the collection of the Naturalis Biodiversity Center, Leiden, the Netherlands (prefix RGM).

Locality 5: North Norfolk

The beach between Overstrand (NGR TH 249 410) and Cromer (NGR TH 227 420) (Donovan 2021, fig. 47.1) is dominantly sandy. The beach also has numerous pebbles and cobbles, the majority of which are locally derived from the Upper Cretaceous. It is dominantly cobbles (reworked nodules) of flint and, less commonly, Chalk, the latter not uncommonly bored. Most likely, these came from offshore outcrops rather than from chalk rafts (Burke *et al*. 2010) in the cliffs. The boring in Figure 5 is registered in the collection of the Naturalis Biodiversity Center, Leiden, the Netherlands (prefix RGM).

Locality 6: Walton-on-the-Naze, Essex

(Adopted from Donovan 1988, 2025.) One of the best deposits in England from which to collect abundant and diverse Pliocene–Pleistocene shelly faunas is the Red Crag Formation of East Anglia. A small outlier at Walton-on-the-Naze on the Essex coast was formerly well-exposed in a cliff section (Donovan 2025, figs 26.1, 26.2) and is a Site of Special Scientific Interest, albeit currently disappearing under a growth of bushes. The Red Crag Formation is exposed as a red-orange shell gravel in the upper part of the cliff at this point, overlain by younger, largely unfossiliferous deposits. We suspect that, with a robust pair of boots and a trowel, good collections can still be made from this section—good hunting. A few gardening tools to hack away vegetation might also be useful. On the beach, both fossil and Recent shells are bored. The fossils may bear both fossil and modern borings. The specimen is deposited in the collections of the Natural History Museum, London (prefix NHMUK).

Locality 7: Province of Liège, north-east Belgium

(Adapted from Donovan *et al*. 2019, pp. 227-228.) The specimen is not from a beach locality, but would be hard to beat to demonstrate the 3-D form of *Trypanites*. It is from residual flint deposits excavated in the area between the working chalk pits of Kreco and CBR-Lixhe, in the province of Liège, north-east Belgium and of late Maastrichtian age. Belemnitellid rostra are comparatively rare in these residual flint nodules. Specimen in the NHMM.

Descriptions

Apectoichnus Donovan, 2018 (Fig. 1)

Wood can be washed up on any beach and bored wood is easily recognised. Long, worm-like borings are assigned to *Apectoichnus longissimus* (Kelly & Bromley 1984). These may or may not have a thin calcareous lining. They are invariably the spoor of wood-boring bivalves (Bromley 2004). The mollusc nestles in the globular termination of a boring and reaches the external surface, to feed and breath, by long, slender siphons. The calcareous linings are fragile, but may become detached when the wood decays and rarely can be collected (Pickerill *et al*. 2003).

Caulostrepsis Clarke, 1908 (Figs 2, 3, 4C, D, G)

Caulostrepsis is a U-shaped boring, long and slender, with a central vane and produced, at the present day, by spionid polychaete worms of the genus *Polydora* (Bromley 2004, p 460) of which there are several species known around Britain and Ireland. These borings have a figure-of-eight to slot shape in section (Fig. 2). Gregarious accumulations commonly have borings of a similar size; solitary *Caulostrepsis* may be larger and inhabit oyster valves rather than lithic clasts (Donovan 2017a). These presumably represent borings by different species of *Polydora*.

Entobia Bronn, 1837 (Figs 2B, C, 4A, B, E, F)

The trace fossil *Entobia* is the spoor of boring sponges, mainly members of the family Clionaidae. Its appearance is highly variable due to differences in the style of preservation and because of modifications to sponge colonies as they proceed to maturity, which can radically change the morphology (Bromley & d'Alessandro 1984; also compare and contrast images herein). Surfaces that are essentially uncorraded since infestation are perforated by numerous apertures (Fig. 4A, B, E, F). Shallow corrasion reveals the intricacies of the 3D structure of the sponge borings (e.g. Fig. 4B).

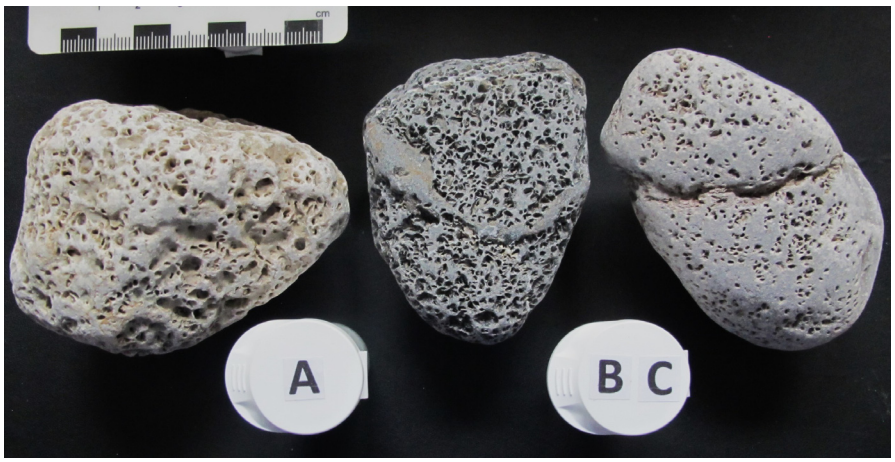


Figure 2 *(above). Recent borings in cobbles of limestone, Locality 2. (A) NHMM 2025 008. A 'busy' surface with numerous slot-shaped borings, some more obviously figure-of-eight shaped and assigned to* Caulostrepsis taeniola *Clarke. These are intermixed with incomplete, concave chambers of the sponge boring* Entobia *isp., particularly to the right. (B) NHMM 2025 010. Another gregarious association of* Caulostrepsis taeniola *Clarke likely mixed with* Entobia *isp., although the latter are not as easily discerned as in (A). (C) NHMM 2025 007.* Caulostrepsis taeniola *Clarke. The central vane is more easily seen in some of these borings. Scale in cm and mm.*

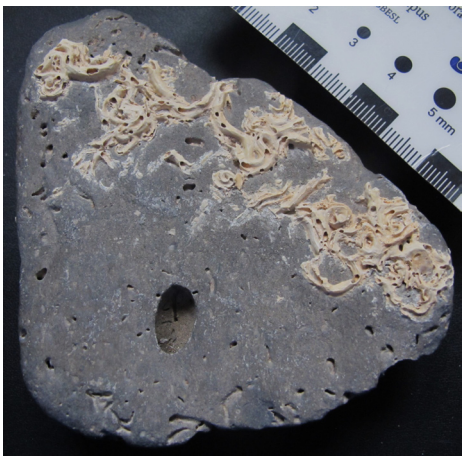


Figure 3 *(above right). Recent borings and encrusted spirorbid worm tubes (white; Donovan et al., 2018) infesting a cobble of limestone, Locality 3. NHMM 2025 014. The large hole in the centre is part of an incomplete* Gastrochaenolites *isp., close to the base.* Caulostrepsis taeniola *Clarke towards the lower and left edges of the surface include incomplete longitudinal sections. Scale in cm and mm.*

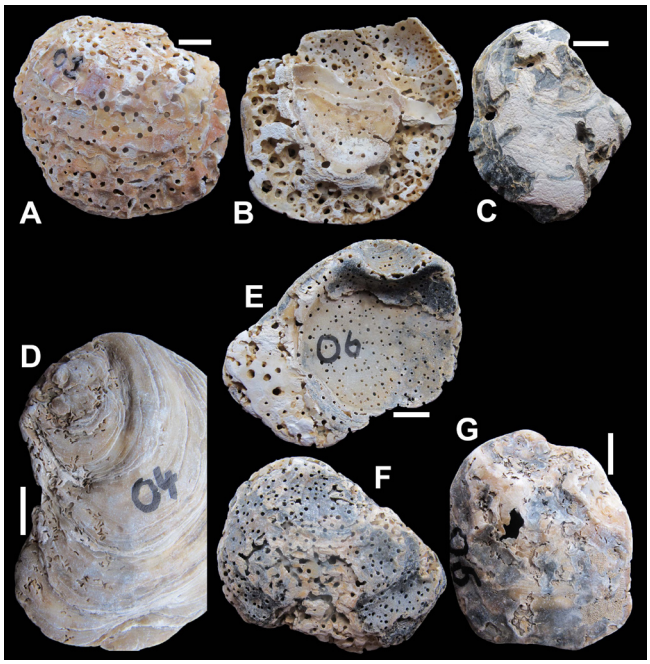


Figure 4*. Bored oysters,* Ostrea *sp., all free valves (after Donovan 2020a, fig. 7), Locality 4. (**A, B**) RGM.1332372, outer and inner surfaces, respectively, of a valve densely infested by* Entobia *isp. (**C**) RGM.1332373, corraded, chalky valve with poorly preserved* Caulostrepsis? *isp. and* Gastrochaenolites? *isp. (**D**) RGM.1332375, external surface of valve densely infested with* Caulostrepsis *isp. cf.* C. taeniola *Clarke. (**E, F**) RGM.1332377, inner and outer surfaces, respectively, of a valve densely infested by* Entobia *isp. (**G**) RGM.1332378, valve with* Caulostrepsis *isp. cf.* C. taeniola *Clarke and bryozoans. The latter are on both the outer shell surface and growing into exposed borings. Specimen uncoated. Scale bars represent 10 mm.*

Gastrochaenolites Leymerie, 1842 (Figs 3, 4C, 5)

Gastrochaenolites is easily the largest of the borings considered herein and may be several centimetres in length. The boring is club-shaped (Fig. 5), most commonly produced by the activities of endolithic bivalves (Kelly & Bromley 1984; Bromley 2004, p 462), of which there are several species known from British waters (Tebble 1976). *Gastrochaenolites* is commonly incomplete on the beach if seen in section in mudrocks and limestones (Fig. 3; Donovan 2011, 2024a, b). The club-shape is most clearly seen if a complete boring is cast in, for example, latex (Fig. 5).

Figure 5*. A modern boring moulded in latex, Locality 5. Club-shaped* Gastrochaenolites lapidicus *Kelly and Bromley from the Recent of north Norfolk (Locality 4) (after Donovan, 2013, fig. 2A), specimen RGM 780 601. The 'cracks' in this specimen show where it was glued back together. The Chalk clast was broken to release the shell of the boring bivalve, the pholadid* Barnea candida *(Linnaeus). Scale bar represents 10 mm.*

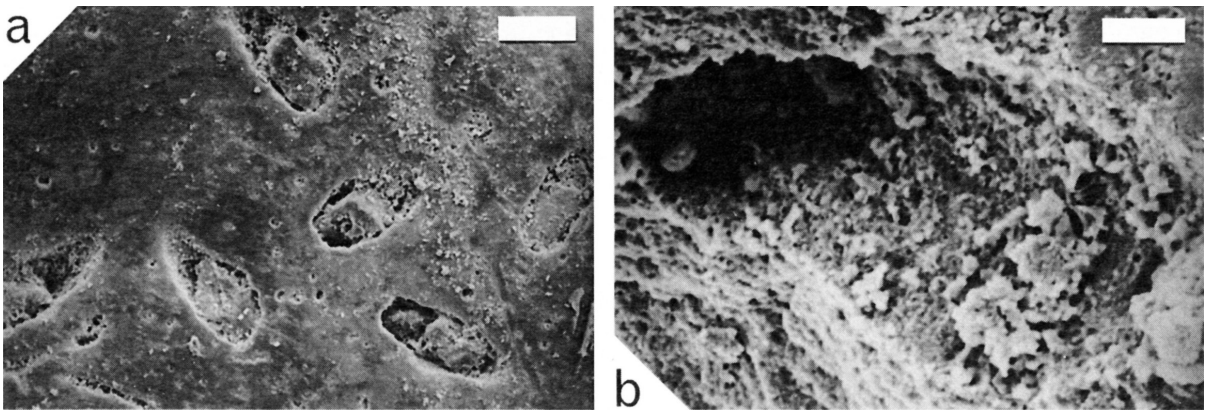
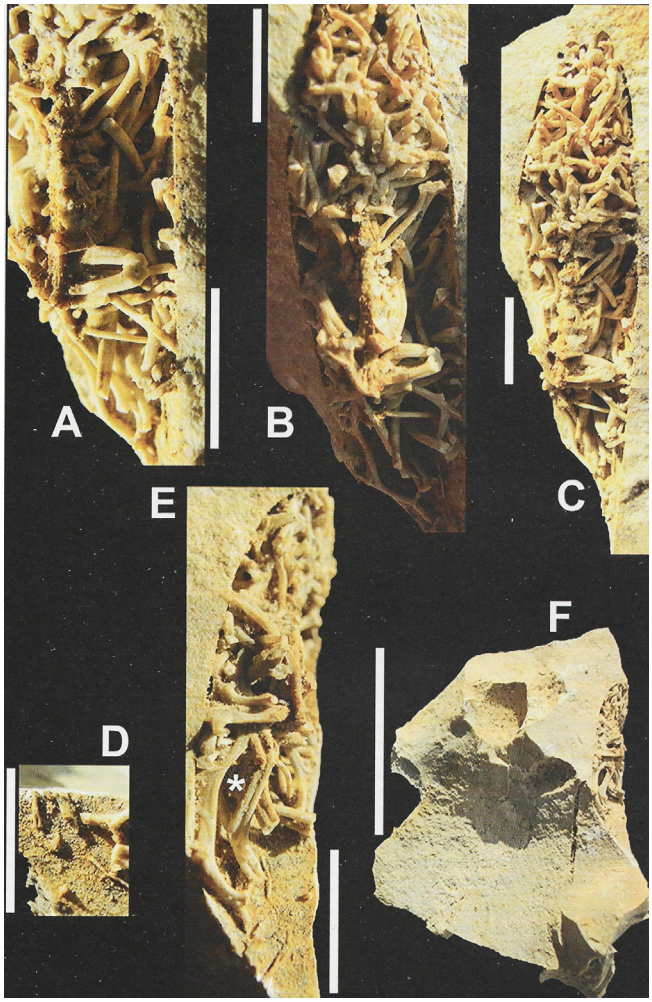


Figure 6. *Scanning electron micrographs of acrothoracian barnacle borings,* Rogerella *isp. (from Donovan & Pickerill, 1999, fig. 3), NHMUK In. 63653, in fragments of bivalve shells from the Plio-Pleistocene Red Crag Formation of Walton-on-the-Naze, Essex (Locality 6). This is also known from modern shells. (A) Wide, oval borings infilled with quartz grains. Scale bar represents 100 µm. (B) Enlargement of a clean boring, showing it to be sock-shaped. Scale bar represents 20 µm.*

Rogerella de Saint-Seine, 1951 (Fig. 6)

Rogerella borings are formed by acrothoracian barnacles (Lambers & Boekschoten 1986; Bromley 2004, p 464). In superficial view they are teardrop-shaped (Fig. 6A). The longitudinal section is shaped like a sock (Fig. 6B).



Trypanites Mägdefrau, 1932 (Fig. 7)

Modern borings referred to *Trypanites* are the spoor of sipunculan worms (Bromley 2004, p 461). 'More or less straight tunnels, usually vertical, 1 or 2 mm wide, without ramification; closely spaced' (Häntzschel 1975, p W136; Fig. 7 herein).

Figure 7 *(left)*. Trypanites *isp., Locality 7 (after Donovan et al. 2019, fig. 2). Belemnitellid rostrum with abundant borings here assigned to* Trypanites*? isp., NHMM 2018 008, from the Kreco quarry (province of Liège, north-east Belgium). (A–C) Three views in essentially the same orientation, but different magnifications, to show the density and detail of the borings. The central structure in the lower part of the rostrum is the flint infill of the apical line that extends from the phragmocone to the apex of the rostrum (see Christensen 1995, fig.10). (D) The narrowest borings (see also lower centre, E). (E) Details of at least three examples of paired, parallel borings (best seen right of *). (F) Complete clast; belemnite in upper right, same orientation as (E); scale bar represents 50 mm. Specimen uncoated. All scale bars represent 10 mm unless stated otherwise.*

Discussion

It is worthwhile to reiterate that borings on the beach are allochthonous, being marine in origin. They are derived by floating (wood), longshore drift and wave action, particularly during storms. They therefore provide a select glimpse of an offshore ecosystem, the *Trypanites* Ichnofacies (MacEachern *et al*. 2007, p 73). The preservation of these borings is commonly only partial. Clasts infested by *Entobia* or gregarious *Caulostrepsis* will be weakened close to their outer surface and fragments will spall off. Thus, these borings will commonly have lost the outer parts of their structure through corrasion (e.g., Figs 2, 3, 4B). Yet sufficient is commonly preserved to enable identification. Gregarious accumulations of large

borings like *Gastrochaenolites* will weaken a whole clast and lead to breakage during storms (e.g., Donovan 2024a, fig. 2).

Borings on the beach are easy to collect. They are commonly incomplete, yet what remains will be robust and unlikely to break easily. Simply wrapping clasts in newspaper or tissue, at most, will provide adequate protection when removing them from the field.

When collecting, be particularly alert for specimens preserving either the producing organism or a subsequent invader of the bored space. Of the suite of borings discussed above, particular attention should be paid to those made by bivalves, namely *Gastrochaenolites* and, less likely, *Apectoichnus*. *Gastrochaenolites* is a large boring and its shells easily seen. It may be found, uncommonly, with the borer *in situ* (Donovan 2013) or, more difficult to determine with confidence, *ex situ* (Donovan 2020b), or with a nestling bivalve such as *Hiatella* (Donovan 2024b, fig. 2B). Encrusting organisms such as bryozoans and serpulid worms may also invade the boring after death or departure of the borer (Donovan 2017b).

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References

Bromley, R. G. 1996. *Trace fossils: biology, taphonomy and applications*. Second edition. London: Chapman and Hall.

Bromley, R. G. 2004. A stratigraphy of marine bioerosion. In: *The application of ichnology to palaeoenvironmental and stratigraphic analysis* / edited by D. McIlroy. *Geological Society, London, Special Publication*, **228**, 455–479.

Bromley, R. G. & Alessandro, A. d' 1984. The ichnogenus *Entobia* from the Miocene, Pliocene and Pleistocene of southern Italy. *Rivista Italiana di Paleontologia e Stratigrafia*, **90**, 227–296.

Bronn, H. G. 1837. *Lethaea geognostica oder Abbildungen und Beschreibungen der für die Gebirgs-Formationen bezeichnendsten Versteinerungen*. In two volumes. E. Schweizerbart, Stuttgart.

Burke, H., Phillips, E., Lee, J. R. & Wilkinson, I. P. 2010. Imbricate thrust stack model for the formation of glaciotectonic rafts: an example from the Middle Pleistocene of north Norfolk, UK. *Boreas*, **38**, 620–637.

Christensen, W. K. 1995. *Belemnitella* from the Upper Campanian and Lower Maastrichtian Chalk of Norfolk, England. *Special Papers in Palaeontology*, **51**, 1–84.

Clarke, J. M. 1908. The beginnings of dependent life. *New York State Museum Bulletin*, **121**, 146–169.

Donovan, S. K. 1988. Palaeoecology and taphonomy of barnacles from the Plio-Pleistocene Red Crag of East Anglia. *Proceedings of the Geologists' Association*, **99**, 279–289.

Donovan, S. K. 2011. Aspects of ichnology of Chalk and sandstone clasts from the beach at Overstrand, north Norfolk. *Bulletin of the Geological Society of Norfolk*, **60**, for 2010, 37–45.

Donovan, S. K. 2013. A Recent example of the boring *Gastrochaenolites lapidicus* Kelly and Bromley and its producing organism in north Norfolk, eastern England. *Bulletin of the Mizunami Fossil Museum*, **39**, 69–71.

Donovan, S. K. 2017a. Two forms of the boring *Caulostrepsis taeniola* Clarke on Queen Victoria's bathing beach, East Cowes. *Wight Studies: Proceedings of the Isle of Wight Natural History & Archaeological Society*, **31**, 98–101.

Donovan, S. K. 2017b. Neoichnology of Chalk cobbles from north Norfolk, England: implications for taphonomy and palaeoecology. *Proceedings of the Geologists' Association*, **128**, 558–563.

Donovan, S. K. 2018. A new ichnogenus for *Teredolites longissimus* Kelly and Bromley. *Swiss Journal of Palaeontology*, **137**, 95–98.

Donovan, S. K. 2020a. Recent borings in glacial erratics (Carboniferous Limestone), Cleveleys, Lancashire. *The North West Geologist*, **21**, for 2019, 31–49.

Donovan, S. K. 2020b. Fossils explained 78: never bored by borings. *Geology Today*, **36**, 232–235.

Donovan, S. K. 2021. *Hands-on palaeontology: a practical manual*. Edinburgh: Dunedin Academic Press.

Donovan, S. K. 2023. Notes on *Aktuo-Paläontologie* of the rocky beaches of the eastern Isle of Mull, UK. *Scottish Journal of Geology*, **59**, 5 pp. doi.org/10.1144/sjg2023-004

Donovan, S. K. 2024a. Life offshore: evidence from a bored Chalk boulder. *Mercian Geologist*, **21**, 42–45.

Donovan, S. K. 2024b. Taphonomy of the boring *Gastrochaenolites* Leymerie: implications for sedimentary geology. *Bulletin of the Geological Society of Norfolk*, **74**, 3–14.

Donovan, S. K. 2025. *Fossils on the seashore: beachcombing and palaeontology*. Liverpool: Liverpool University Press.

Donovan, S. K., Birtle, M., Harper, D. A. T., Donovan, P. H. 2018. Borings and encrustations on cobbles and pebbles, Easington, Co. Durham. *Northumbrian Naturalist*, **85**, 49–61.

Donovan, S. K., with Donovan, P. H. & Donovan, M. 2019. A recurrent trinity of Recent borings in clasts around the southern and western North Sea. *Bulletin of the Geological Society of Norfolk*, **68**, for 2018, 51–63.

Donovan, S. K., Jagt, J. W. M., Deckers, M. J. M., Laffineur, J. 2019. Preservation of a heavily bored belemnite rostrum from the upper Maastrichtian of north-east Belgium. *Proceedings of the Geologists' Association*, **130**, 227–231.

Donovan, S. K. & Pickerill, R. K. 1999. Fossils explained 26: Trace fossils 4 – borings. *Geology Today*, **15**, 197–200.

Ellis, C. 1968 (first published 1954). *The pebbles on the beach*. London: Faber & Faber.

Häntzschel, W. 1975. Trace fossils and problematica (2nd edition, revised and enlarged). In: *Treatise on invertebrate paleontology. Part W. Miscellanea. Supplement 1* / edited by C. Teichert. Boulder & Lawrence: Geological Society of America and University of Kansas, xxi, 269 pp.

Kelly, S. R. A. & Bromley, R. G. 1984. Ichnological nomenclature of clavate borings. *Palaeontology*, **27**, 793–807.

Lambers, P. & Boekschoten, G. J. 1986. On fossil and recent borings produced by acrothoracic cirripeds. *Geologie en Mijnbouw*, **65**, 257–268.

Leymerie, A. 1842. Suite de mémoire sur le terrain Crétacé du département de l'Aube. *Mémoires de la Société géologique de France*, **5**, 1–34.

MacEachern, J. A., Pemberton, S. G., Gingras, M. K. & Bann, K. L. 2007. The ichnofacies paradigm: a fifty-year retrospective. In: *Trace fossils: concepts, problems, prospects* / edited by W. Miller III. Amsterdam: Elsevier, pp 52–77.

Mägdefrau, K. 1932. Über einige Bohrgänge aus dem Unteren Muschelkalk von Jena. *Paläontologische Zeitschrift*, **14**, 150–160.

Pickerill, R. K., Donovan, S. K. & Portell, R. W. 2003. *Teredolites longissimus* Kelly & Bromley from the Miocene Grand Bay Formation of Carriacou, the Grenadines, Lesser Antilles. *Scripta Geologica*, **125**, 1–9.

Saint-Seine, R. de. 1951. Un cirripède acrothoracique du Crétacé; *Rogerella lecointrei*, n. g., n. sp. *Comptes Rendus de l'Académie des Sciences, Paris*, **223**, 1051–1053.

Tebble, N. 1976. *British bivalve seashells*. Second edition. Edinburgh: Her Majesty's Stationery Office.

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