Life offshore: evidence from a bored Chalk boulder

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Abstract: A boulder of chalk, derived from offshore, was collected from the coast in north Norfolk. It is perforated by the borings *Gastrochaenolites turbinatus* Kelly & Bromley and *Caulostrepsis taeniola* Clarke, together suggestive of the *Trypanites* ichnofacies. These are the spoor of boring bivalves (likely *Zirfaea crispata* (Linné) or *Pholas dactylus* Linné) and spionid annelids (probably *Polydora* sp.), respectively. Large modern *Gastrochaenolites* are present in chalk clasts on this beach, but are commonly more poorly preserved. Both suites of borings are gregarious and together represent an association known from other sites; the sponge boring *Entobia* isp. is notably absent, yet associated elsewhere. All borings originated on the same side of the clast, suggesting that the boulder was either loose, but too heavy to roll around, or derived from a bed exposed on the seafloor and subsequently broken up. It is unlikely to have been washed onshore until shortly before it was discovered, otherwise it would have been broken down by repeated collisions with flint clasts. It is probable that the two types of boring were more or less coeval.

Surely there are ample rocks on the Earth to satisfy the interests of all geologists now and forevermore? The question that we must ask is which should we choose to study, for research must be discriminatory. Investigating everything is an impossibility, so we study an informative aliquot of the available guided by our own criteria for selection. Personal choice within the parameters defined by a project helps us to maintain a focus. I have an active research interest in the ichnology of borings in modern reworked clasts on British beaches (see, for example, Donovan *et al* 2018, 2019; Donovan 2023). The specimen described herein was collected as part of this research programme because it displayed a number of unusual features, such as: it is a boulder carried onshore; it is infested by multiple *Gastrochaenolites* Leymerie in close association; this suggests gregarious behaviour by the boring organism; and it is remarkably whole despite the fragility introduced by large borings. In many ways it is a reflection of other bored clasts from the coast of the southern North Sea and elsewhere, yet it deserves to be examined as an individual specimen that shows noteworthy features.

Herein, I document one Chalk boulder collected from the north coast of Norfolk between Cromer and Overstrand. My brother, Mark, and I were beachcombing on this coast for six hours on this particular occasion and the boulder was the one distinctive rock that caught my attention. (Indeed, I used it to demonstrate a point during a lecture that I gave to the Geological Society of Norfolk the next day.) Its recent history was more obvious and unusual than any other specimen. Chalk clasts, presumably mainly derived from offshore, are common on the beach between these towns, which are about 5 km apart.

The largest and most prominent common boring found in reworked limestone and mudrock clasts on the North Sea coast of the British Isles is the bivalve trace *Gastrochaenolites* ispp. (Kelly and Bromley 1984). It is common in allochthonous sedimentary clasts (Donovan *et al* 2019). Only rarely do specimens preserve the boring organism (for example, Donovan 2013a, 2020; Donovan *et al* 2018). Determination of sedimentary environment is likely confused by reworking and taphonomic modification of this boring (Donovan 2024).

Locality and horizon

(Adapted from Donovan 2021, 196.) The chalk and flint cobbles on the beach at Cromer and Overstrand are likely local in origin, derive mainly from offshore. The Chalk of north Norfolk extends from the Cenomanian to the Lower Maastrichtian (Burke *et al* 2010, fig. 1); the latter is unusually young for the English Cretaceous succession (Peake & Hancock 1961; Moorlock *et al* 2002, 3–5). Thus, the specimens are Late Cretaceous in age and older than the Late Maastrichtian. Rafts of Chalk were thrust by glacial ice during the Pleistocene and are similarly Campanian–Maastrichtian based on fossil evidence (Burke *et al* 2010, 621–623).

The beach at Overstrand is about NGR TH 249 410; that at Cromer, east of the pier, is about NGR TH 227 420 (Fig. 1). The beach is dominantly sandy, but with numerous pebbles and cobbles in wave accumulations, the majority of which are locally derived from the Upper Cretaceous, including cobbles of flint and, less commonly, chalk.

The specimen discussed herein is deposited in the collections of the Natuurhistorisch Museum Maastricht, the Netherlands (prefix NHMM). The terminology of borings follows Häntzschel (1975), Bromley (1981, 2004), Kelly & Bromley (1984) and other standard references listed therein.

Description

The boulder, NHMM 2024 008 (Fig. 2), is approximately 200 x 165 x 80 mm. It is a chalk clast, flattened (possibly a reflection of original bedding) and rounded. The clast is intensely bored on one side, as illustrated. There are five borings through the boulder (left in Fig. 2), formed of incomplete necks ± chambers, and a sixth

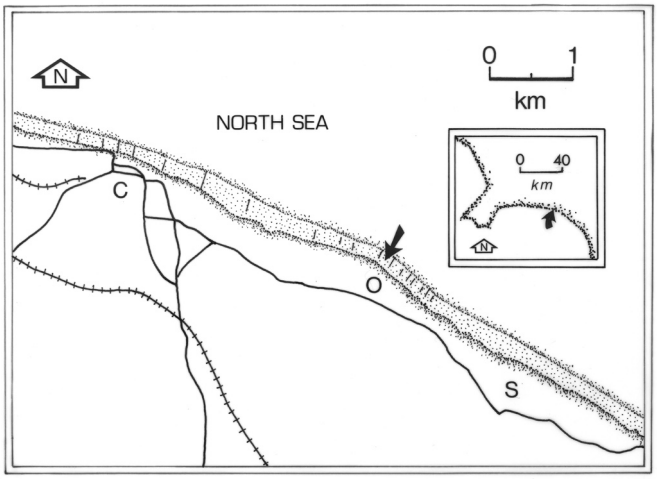

***Figure 1**. Outline map of the north coast of Norfolk between Cromer (C), Overstrand (O) and Sidestrand (S), after Donovan (2021, fig. 47.1). The dark arrow indicates the author's point of access to the beach; the walk to Cromer is possible except at the highest tides. The best collecting is on a falling tide, walking Overstrand to Cromer and return. The stippled area is between the low water mark and cliff top; it includes both the beach (groynes are indicated) and slope of the cliffs. Principal roads are shown as solid lines; railways are shown as trellised lines.*

(centre top in Fig. 2) that preserves only the base (for terminology, see Kelly & Bromley 1984, text-fig. 1); all are referrable to *Gastrochaenolites* isp. All such borings are sub-parallel; all are narrower (= side of origin) in the orientation of Figure 2. That is, the producing bivalves were boring down into the rock from the side shown. The base lacks any prominent sculpture. The necks ± chambers are smooth and unsculptured. One is encrusted by two incomplete serpulid(?) worm tubes; other specimens preserve incomplete remnants of post-mortem encrusters. A seventh, very incomplete *Gastrochaenolites* (in shadow, lower right side, Fig. 2) preserves less than half the width of the neck ± chamber.

Multiple small borings (mainly in shadow, lower right, Fig. 2) are slot-like to figure-of-eight in cross-section. These are *Caulostrepsis* isp.; they are also are found in other areas of the clast, but almost exclusively on the figured surface.

Discussion

Ichnotaxonomy and producing organisms

The ichnogeneric determination of the two common forms of boring in this clast is straightforward, but progress towards identifying the ichnospecies is more tenuous. The large borings are *Gastrochaenolites* Leymerie, but none are complete. All neck ± chamber specimens are large, smooth-walled and gently conical; the one large base is smooth and unsculptured. By reference to Kelly & Bromley (1984, text-fig. 3), NHMM 2024 008 is referred to *Gastrochaenolites turbinatus* Kelly & Bromley, 1984, more commonly found in limestones than shelly substrates (Donovan *et al* 2014). It is 'Distinguished from other ichnospecies of *Gastrochaenolites* by the evenly tapered main chamber which merges imperceptibly with the neck' (Kelly & Bromley 1984, 803). The producer is almost certainly a boring bivalve (Bromley 2004, 462; see below). Large modern *Gastrochaenolites* are present in chalk clasts on this beach, but are commonly more poorly preserved. *Gastrochaenolites ornatus* Kelly & Bromley, 1984, is another large boring known from this coast (Donovan 2011b), but has a distinctive basal sculpture not seen in NHMM 2024 008. *Gastrochaenolites lapidicus* Kelly & Bromley, 1984, has a more conical chamber (Donovan 2013a).

The small, slot-like openings are undoubtedly sections through (not apertures of) *Caulostrepsis* Clarke, developed perpendicular to the surface of the clast. The three-dimensional geometry of the borings is poorly seen, but nothing disagrees with assignment to the common (and type) species, *Caulostrepsis taeniola* Clarke, 1908. They are likely the spoor of annelids, family Spionidae, such as *Polydora* sp. (Bromley 2004, 460). Multiple species of *Polydora* are common around the coast of the British Isles (Bruce *et al* 1963, 98).

Substrate

This may be whimsical as the only common substrate for boring organisms at this site is chalk; flint is clearly inappropriately hard. Although flints on this beach may have large round perforations, these are the spoor of the process of silicification, not borings.

Both *Gastrochaenolites* and *Caulostrepsis* are familiar in association as borings in suitable substrates. For example, they have been recorded in close association in the Isle of Wight (Donovan 2013b) and Margate (Donovan 2020). It is noteworthy that *Entobia* is rare or unknown in these associations, despite otherwise being a prominent third member of the

***Figure 2**. The Chalk boulder NHMM 2024 008. This orientation shows the side from which the* Gastrochaenolites turbinatus *Kelly & Bromley originated, the borings being gently conical and expanding into the rock from this position. Small, slot-like to figure-of-eight borings of* Caulostrepsis taeniola *Clarke are apparent, but partly concealed by shadow in the bottom right corner. Scale bar in cm and mm.*

modern boring trinity around the shores of the British Isles (Donovan *et al* 2019). The association of borings in NHMM 2024 008 is suggestive of the *Trypanites* ichnofacies (Donovan *et al* 2019).

Size of the clast

NHMM 2024 008 is large for a chalk clast on this beach. Flints of similar size are more common, but are, of course, more durable than chalk. The chalk boulder is waterworn and rounded, with marine borings, so it has come from offshore, not a cliff fall. As such, it was probably washed ashore by a major storm only shortly before it was collected. If it had been stranded on the beach for any appreciable period of time, it would have been broken into smaller, irregular and angular clasts by wave action on a beach dominated by flints great and small.

Orientation and function of the borings

All of the borings of *Gastrochaenolites* penetrated from the side of the clast illustrated in Figure 2. At this time the clast must have been recumbent on the seafloor in this orientation. It was either a large, but loose clast too big to be flipped over by minor waves or currents; or, and perhaps more probably, formed part of an *in-situ* chalk seafloor that was subsequently lifted by a major storm. That the boulder was formerly a larger slab is demonstrated by its rounding and the lateral truncation of at least one *Gastrochaenolites* (Fig. 2, lower right). All the borings in NHMM 2024 008 were domiciles, that is, domichnia.

Gregarious habit

Both suites of borings in this clast occur as gregarious accumulations. This is well-known for *C. taeniola* (see, for example, Donovan 2017), which may also show two forms differentiated on size. The gregarious nature of these borings may indicate that the early invaders of the substrate secreted an organic molecule (enzyme?) into the water to attract conspecific larvae, as do, for example, balanid barnacles (Knight-Jones 1953). Such close associations of borings are less well-known in *Gastrochaenolites* and a similar interpretation is perhaps more speculative.

Size of the producer

Presumably the bodies of the producing organisms filled their borings. The annelid producer of *Caulostrepsis* had a hydrostatic skeleton and would have been able to expand within the boring to fill the whole space.

The bivalve producer of *Gastrochaenolites* grew to a minimum diameter of *c*. 40 mm as indicated by the broadest (yet incomplete) specimen. Amongst the bivalve borers of the British Isles, such a size of boring is most likely the spoor of *Zirfaea crispata* (Linné) (Donovan 2011a, 41) or *Pholas dactylus* Linné (Beedham 1972; Tebble 1976).

Concluding remarks

The above discussion leaves one significant question unanswered; were *Caulostrepsis* and *Gastrochaenolites* in NHMM 2024 008 coeval? While uncertain, it is at least plausible. Obviously, the surface of the boulder has been corraded, but *Caulostrepsis* and *Gastrochaenolites* remain separate; *Caulostrepsis* did not invade *Gastrochaenolites* after the death of the boring bivalve. Although no evidence exists for its presence, corrasion of the surface of the boulder may have expunged any evidence of the shallow sponge boring *Entobia* isp. or shelly encrusters such as balanid barnacles.

Acknowledgements

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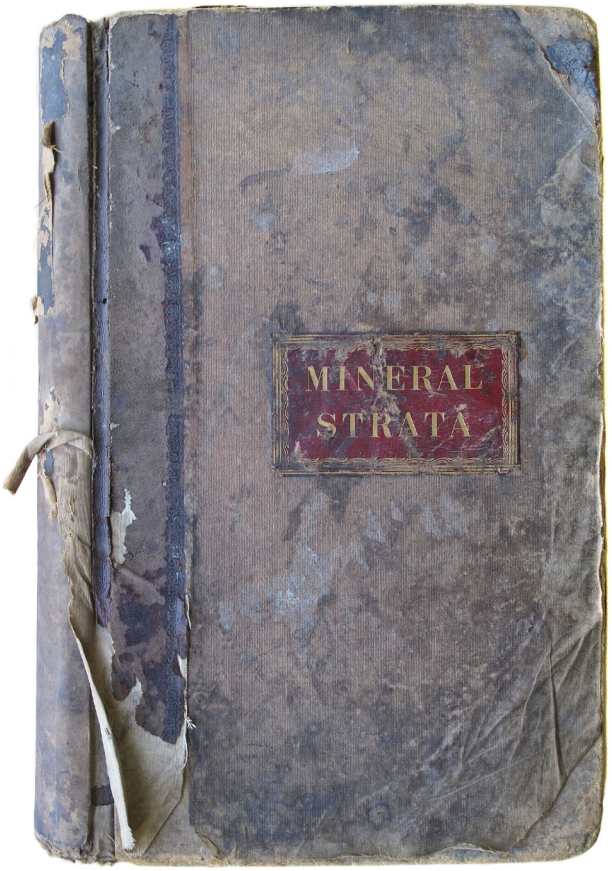
FROM THE ARCHIVES

A manuscript coal-boring register

At the beginning of 2024, British Geological Survey Library Archives at Keyworth received the donation of a 19th-century folio ledger-book containing a manuscript record of around 70 coal borehole and shaft sections relating to collieries principally in Durham and Northumberland, with a few records for Derbyshire, Nottinghamshire, Staffordshire and Yorkshire. In most instances the only locational information given is the name of the pit. The volume appears to have been compiled by William John Wilkinson of Clay Cross Collieries, near Chesterfield—though for what purpose is unclear—but it seems likely that William Coulson, a professional coal borer (whose name appears twice in the register), may have been the source of these records.

The sections logged are listed here for the benefit of those who may be interested. They are presented, with two exceptions, in the order in which they appear in the register. Spellings of place names are given as they appear in the register. Only a limited effort has been made here to identify some of these locations.



Volume of coal borings and shaft sections, British Geological Survey archives GSM/Gx/Wk/1 (Photo: D. G. Bate)

Derbyshire: No. 1 Pit, Clay Cross, 95 yds; No. 2 Pit, Clay Cross, 103 yds; No. 4 Pit, Clay Cross [not totalled]; No. 5 Pit, Clay Cross Company, Morton, 312 yds; No. 7 Pit, Clay Cross Company, Park House, 191 yds; Portland and Butterly Park Collieries [not totalled]; Alton Colliery, 199 yds; Backwell Colliery, 292 yds; No. 1 Pit, Tibshelf Colliery, 392 yds; No. 9 Pit of the Clay Cross Co. at Avenue between Clay X and Chesterfield, 48 yds [this entry added at end of record].

Nottinghamshire: Annesley Colliery No. 1 Shaft, commenced sinking 10 Jan 1865, sunk through the 'Top Hard Coal' 5 Oct 1867, 500 yds; Annesley Colliery No. 2 Shaft, 462 yds, 31 Oct 1878.

Staffordshire: Cannock & Rugby Colliery, New Plant No. 2 Shaft, 352 yds, 1 Nov 1878; No. 3 Ventilation Pit, Cannock Wood Shaft, 16 ft diameter, 210 yds.

Durham & Northumberland (for want of space depths are here omitted): Brancepth [Brancepeth] Park Colliery, commenced 1 Oct 1841, sunk partly by W. Coulson, the remainder by Colliery. Strata bored through below Brancepth Park Pit, 8 May 1843. Sanfield [Tanfield] Lea Colliery, begun 3 Mar 1836. Castle Eden Colliery. Wingate Grange. Sherburn East Pit. Sherburn House North Pit. Whitwell B Pit. Haswellyn Pit. Kibblesworth boring, 14 Nov 1843. Holywell [probably East Holywell], Feb 1828. Chester Moor, W of the Turnpike. West Hetton Engine Pit. Cassop Estate, 1st bore hole. Boring from Hutton Seam in the Hedge Pit, Chatershaugh. Boring on the Carnforth Royalty, about 300 yds W of Garmondsway Public House, 1839. Byers Green Colliery. Boring in Andrew House L. Pit,