ANIMAL, VEGETABLE OR MINERAL? UNUSUAL STRUCTURES FROM THE DARTMOUTH GROUP AT WEMBURY POINT, SOUTH DEVON

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The rocks that crop out on the foreshore at Wembury Point, near Plymouth belong to the Early Devonian Dartmouth Group. The rocks mainly comprise interbedded silty mudstones and siltstones of lacustrine or distal fluvial origin, and have yielded few fossils: mainly fish fragments along with very sparse examples of the gastropod *Bellerophon*. However, at Wembury Point, a number of unusual structures in a rosette form are preserved along bedding planes. The preservation of the structures is unusually good and can be seen to take a radial habit with spokes reaching outwards from a central point. Between the spokes connecting ladder like structures are seen. Although these features resemble fossils from organic forms, such as jellyfish or plants, no fossils of similar morphology have been recorded from the Devonian. Detailed studies of the structures themselves, and the surrounding sediments, suggest that these features were most likely to have formed as mineral growths in a continental evaporite sequence.

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INTRODUCTION

At Wembury Point, near Plymouth, unusual structures in a rosette form have been discovered preserved in the rocks on the foreshore. The host rocks are mudstones and siltstones of the Early Devonian, Dartmouth Group and the structures are found on the upper surface of bedding planes in several different beds. The structures are up to 10 cm in diameter and take a radial form with spokes reaching out from a central point and interconnecting arrays between the spokes making a rosette shape. The Dartmouth Group rocks have undergone deformation during the Variscan Orogeny and show a well-developed, bedding parallel cleavage. However, the structures clearly show preservation of an unusual level of detail. No similar structures have been found within the Dartmouth Group, or rocks of similar age, and their mode of origin is unclear. The aim of this paper is to describe the structures and discuss the potential options for their formation.

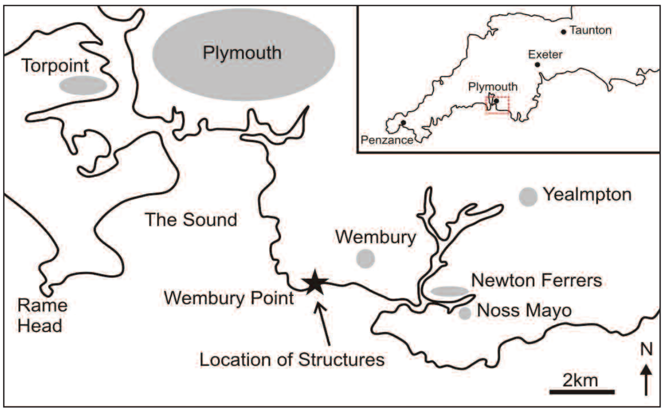

Figure 1. *Map showing the location of Wembury Point in South Devon.*

LOCATION

Wembury Point is situated on the South Devon coast, near Plymouth (NGR SX 253 485) (Figure 1). Wembury is a Voluntary Marine Conservation Area (VMCA) and a Special Area of Conservation (SAC). Wembury also forms part of the South Devon AONB (Area of Outstanding Natural Beauty) and is a SSSI (Site of Special Scientific Interest) for wildlife and geological features. The landowner is The National Trust.

The structures are located on the upper part of the foreshore approx 50 m east of the former boat house slip at Wembury Point, Wembury (NGR SX 253 483). Only a small number of loose blocks have been removed from the site to prevent damage by the tides and the majority of the structures remain to be examined *in-situ*. The structures have only been observed at this particular level within the Dartmouth Group.

GEOLOGICAL SETTING

The rocks at Wembury Point form part of the Early Pragian Dartmouth Group (Figure 2). The rocks mainly comprise silty mudstones and siltstones, with rare sandstones and are thought to have been deposited in a continental setting (Dineley, 1966; Smith and Humphreys, 1989; 1991; Jones, 1992). The siltstones predominant at Wembury Point are grey-green in colour with subordinate purple, red and pale green units (Figure 3). Rare, thin, fine-medium grained sandstone beds also occur. The siltstones and silty mudstones, which make up the majority of the succession, are interpreted as having been deposited from suspension within a body of standing water (e.g. a seasonal lake) (Smith and Humphreys, 1989; 1991; Jones, 1992). The rare sandstone beds are sheet-like in character and have been interpreted as the distal, dilute parts of unconfined sheet floods

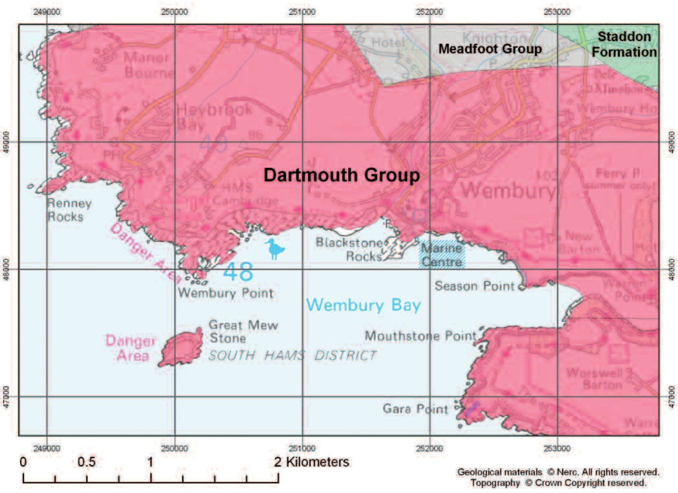

Figure 2. *Regional geological map. The outcrops at Wembury Point are assigned to the Early Pragian, Dartmouth Group.*

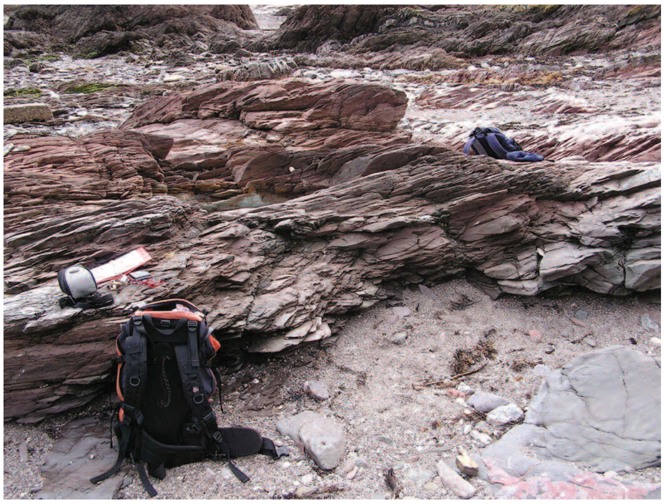

Figure 3. *Typical appearance of the red and green-grey, cleaved siltstones, of the Dartmouth Group on the foreshore at Wembury Point.*

(Smith and Humphreys, 1989; Jones, 1992), although lenticular channel-like beds have also been observed in the field, which may indicate a sporadic fluvial influence. Deposition of the sequence as a whole is considered to have taken place in a non-marine, perennial aqueous environment (Leveridge *et al*., 2002), although Smith and Humphreys (1989) have noted some features indicative of subaerial sedimentation.

Fossils in the Dartmouth Group are not common. The succession usually only yields fish fragments and very sparse examples of *Bellerophon bisulcata*, a primitive gastropod (Ussher, 1907; Leveridge *et al*., 2002), although locally there is some bioturbation (Smith and Humphreys, 1989; Jones, 1992; Leveridge *et al*., 2002). The bioturbation is of a simple nature, usually in the form of a single burrow, but showing a range of orientations relative to bedding. Black phosphatic material is also present locally.

The Dartmouth Group has undergone deformation during the Variscan Orogeny and the rocks at Wembury Point are cleaved, however, the primary sedimentary features remain clearly identifiable in most instances at this locality. Bedding and the primary cleavage are near parallel, dipping towards the south-east. The younging direction is interpreted as towards the south (Smith and Humphreys 1989) and field data demonstrate that the rocks here are the right way up.

The rosette structures are found in close proximity to an igneous intrusion of basic composition. The age of this intrusion is unknown and further investigation would be needed to establish whether this had any role in protecting or preserving the features at Wembury.

Description

The structures are exposed on the upper surface of the bedding planes in the silty mudstones of a particular horizon near to Wembury Point. They are preserved as raised moulds on the surface of the bed, rather than as a negative imprint, and are formed from the same material as the bed. The host sediments are mainly reddish-brown in colour with pale green layering in parts. Colour contrasts in the sediments help to highlight the structures, but do not appear to influence their formation.

The structures generally take the form of spokes radiating out from a central point with interconnecting arrays between them, forming a rosette habit (Figure 4a, 4b). The diameter of the rosette forms ranges from 10 cm to less than 1 cm. The spokes vary in thickness, from 3 mm across in the largest rosettes to hairline, although each rosette contains spokes which vary in thickness from hairline upwards. It is difficult to assess the number of spokes in each rosette form, although the larger forms show in the region of sixteen prominent spokes with many thinner ones in between.

Between the spokes in some places are interconnecting arrays. These are roughly concentric, and help to give the overall rosette appearance, but when examined in detail the individual traces are not consistent in the way they join with the spokes, or the angles with which they intersect them. In some cases a single blade appears to 'float' between the spokes rather than joining to them. The rosette forms appear to coalesce together at the edges, rather than overlapping, although a slight overlap of up to 1 mm is seen in some cases, typically between the larger rosettes.

Figure 4. ***(a)*** *Rosette structures seen along a bedding planes, highlighted by colour contrast in the sediments.* ***(b)*** *Slightly enlarged area of (a) showing the characteristic radial structure.*

Discussion of origin

The structures preserved at Wembury Point are unusual and their origin is uncertain as no exact analogue has yet been identified. Although it is possible the traces are secondary they appear to be the mould of a primary feature that has been lithified within the sediments, therefore an explanation of a primary origin is sought. A number of different origins have been suggested and these are discussed below.

Animal origin - body fossils

At first sight the structures appear to be fossils, formed as a cast of the body of an animal with subsequent preservation within the sediment. The most common animals which could fit with the observed morphology of the structures are jellyfish, corals (Cnidaria) and types of echinoderms such as echinoids and sand dollars. The detailed concentric form of the structures resemble medusa (jellyfish), a free-swimming member of the phylum Cnidaria. Mass strandings of medusa are well-documented, even as far back as the Cambrian (Hagadorn *et al.*, 2002). The presence of fish remains indicates that long-standing bodies of water were present at this time however, no marine fossils have been found within this part of the Dartmouth Group succession suggesting that depositional conditions were largely non-marine (Smith and Humphreys, 1989). Although this evidence alone does not totally exclude the possibility that the structures are medusa it would be unusual to see them all together, lying edge to edge with no overlap, as even mass strandings typically show individual specimens. However, medusa generally show a central convex mound surrounded by a convex sediment ring (Hagadorn *et al.*, 2002) whilst the structures described here do not have a distinct edge to them and show a radiating morphology. Consequently, the structures are not interpreted to be fossil medusa.

It has been suggested that the intergrowths between the spokes of the structures are possible 'dissepiments' as found within a colonial coral group. This would fit with the interconnecting growth seen in places. However, again the environment does not appear conducive to the formation of a colonial coral and no comparable examples have been found. In addition, the structures have very limited depth to them (approximately 1 mm maximum) and they do not appear to penetrate through the rock. This would exclude corals preserved in a growth position.

The suggestion that the structures could be formed by echinoids or sand dollars was proposed due to the apparent pentameral symmetry seen in some of the specimens. However, detailed study of the structures shows that this is an effect given by the grouping together of rosettes of a certain size and not a true representation of the form of the structures. The non-marine environment also largely excludes echinoderms as they are exclusively marine.

Trace fossil

Bioturbation has been found locally within the Dartmouth Group, but in a far more simple form. Burrows pipe-downwards from silty layers, in a range of orientations and some may show branches (Smith and Humphreys, 1989). Clearly the structures described here are not the same as they do not cut down through the bedding. A central 'orifice' is apparent in some of the structures, but a possible 'tube-worm' option appears ruled out by the connecting arrays. The structures do not correspond with any known feeding trace, especially one of Devonian age, although a superficial resemblance to the ichnogenus *Oldhamia* has been noted. The trace fossil *Oldhamia* was most common in the Cambrian, where it was considered an indicator of Cambrian deep-marine strata, but it has also been found in the Ordovician and the Carboniferous (Seilacher *et al.*, 2005). In the Cambrian it commonly consists of networks of burrows radiating outwards from a common point, but later specimens were more pinnate in form. The structures from Wembury are most like the Cambrian forms, however, *Oldhamia* does not tend to display either the connecting arrays or the complex interconnections of the structures. Seilacher (pers comm. 2010), suggests that in his opinion the Wembury moulds are unlikely to be trace fossils.

Plant or algal origin

If these structures are neither animal body fossils or trace fossils, could they have a plant or algal origin ? Although plant life was fairly widespread by the Devonian no plants have been recorded with a morphology similar to the structures documented. It would be difficult to establish plant life in the conditions indicated by the sedimentology of the Dartmouth Group and no soil horizons are noted from this locality. In addition, a mechanism whereby numerous specimens of the same plant could be locally deposited in this one area is difficult to envisage.

An alternative origin to consider is that these structures are the remains of a stromatolite/algal colony. While stromatolites are more common within carbonate environments some have recently been recognised from siliciclastic dominated environments (Martin *et al.*, 1993; Gerdes *et al.*, 2000). Dragants and Noffke (2004) describe microbial build ups within Early Devonian, shallow marine quartzites of the Himalayas. However, there are no recorded fossils of Devonian age with a similar morphology and again the structures lack the depth seen in other examples of microbial build-ups. Consequently, a plant/algal origin for these structures is also dismissed.

Mineral growth origin

The way that the Wembury rosettes structures coalesce into one another is reminiscent of crystal growth developed along the bedding planes, as the structures exhibit fractal or fractal-like growth arrays, similar to many crystals and crack systems (Figure 5). Pseudomorphs and moulds after crystal shapes are well known in a number of different environments throughout the geological record from as early as the Proterozoic (El Tabakh *et al.*, 1999) and from as far afield as Mars (Peterson and Wang, 2006). A number of different minerals may grow in a rosette habit, often radiating a series of needles or acicular prisms outwards from a central 'seed', giving a radial or spoked, wheel-like structure. Looking at the crystal form of an aggregate is often not diagnostic of the original mineral, however, the typical minerals that may be present in a non-marine lacustrine or fluvial environment could include halite and gypsum and anhydrite.

Figure 5. *Structures interpreted to be formed by crystal growths of an unidentified mineral on a fracture plane, Llandovery, Mid Wales.*

During the Early Devonian it is likely that the climate would be arid and evaporative processes may cause evaporite minerals to form. Halite usually forms a cubic structures and is unlikely to form a rosette habit however, calcium sulphate minerals such as gypsum and anhydrite ($CaSO_4$ $2H_2O$) may form a wide variety of shapes according to the conditions at the time. Ephemeral processes between the surface and the water table can cause gypsum to crystallise at the water table, by nucleation around a seed and then grow towards the surface by displacive processes. Experimental work by Cody and Cody (1988), on gypsum nucleation and crystal morphology in terrestrial environments showed that with progressively greater concentrations of organic matter gypsum formed rosettes and rosette-like aggregates. Temperature also affected crystal growth with better formed, larger rosettes being formed in higher temperatures. This study would fit with the known environment of deposition of the Dartmouth Group, as organic matter could be present, and if the crystal growth was in response to a potentially unique combination of conditions at the edge of a lake, with higher temperatures causing evaporation and evaporite mineral growth, this would explain why the rosette structures are confined to a certain horizon.

As the Wembury structures appear on the top of the bedding planes and appear slightly raised it is most likely that they represent minerals which grew slightly under the surface and displaced the sediment above to form the shape, which has subsequently been preserved.

Gypsum is a very soft mineral and often does not last long so if this was the primary mineral forming the rosettes it would not be unusual to find that it had not survived through to the present day. That the Wembury structures represent the moulds of crystals, probably formed as the result of evaporite mineral growth, seems the most likely explanation.

Conclusions

The preservation of distinctive rosette structures at Wembury Point, Devon appears to be unique within the Dartmouth Group. The environment of deposition of the siltstones at this locality is interpreted as non-marine and lacustrine, therefore the most likely origin of these structures is mineral growth, rather than being animal or plant based. The mineral considered as most likely to form these structures is gypsum, an evaporite mineral which grew within the surface layers of the sediment, although no trace remains so other minerals cannot be completely ruled out. The limited extent of these structures means that conditions at Wembury Point at this one time during the Early Devonian were conducive to both growing, and preserving, detailed rosette aggregates along the bedding planes.

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