A PRELIMINARY NOTE ON THE RE-DISCOVERY OF MARINE FOSSILS IN THE LUNDY SLATES

by
Richard J. Twitchett[1,2] and Kenzou W. Twitchett[2]
[1] Natural History Museum, Cromwell Road, London, SW7 5BD
[2] Ganna Park Road, Plymouth, Devon, PL3 4NN
[1] *Corresponding author, e-mail: r.twitchett@nhm.ac.uk*

ABSTRACT

Although fossils were first reported from the slates on Lundy Island more than eighty years ago, the rocks are widely, and erroneously, considered to be unfossiliferous. This paper documents recent discoveries that confirm an abundant fossil marine fauna is preserved in thin, shelly limestone beds within the Lundy Slates. Assemblages include brachiopods, gastropods, ostracods and echinoderms; all of which have been previously reported from Lundy. Bellerophont molluscs, orthocone nautiloids, fish and conodonts are reported for the first time. Conodonts have the potential to provide a definitive age for the Lundy Slates and better correlation to formations elsewhere.

Keywords: *fossil, invertebrate, palaeoecology, Devonian, Carboniferous*

INTRODUCTION

Lundy mostly comprises intrusive igneous rocks (granites and dykes) of Paleocene age that represent the most southerly known outcrop of the North Atlantic Igneous Province (Charles *et al.*, 2017), and which have been studied since at least the 1830s (De la Beche, 1839). These igneous rocks were emplaced into much older, grey, metasedimentary mudstones with well-developed cleavage (i.e., slates) that crop out in the southeast part of the island. Termed the 'Lundy Slate Series' by Dollar (1941), these metasedimentary rocks have hitherto received far less study. Almost all studies that have discussed the Lundy Slates, since Etheridge (1867) and including the most recent British Geological Survey memoir to cover Lundy (Edmonds *et al*. 1979), have stated that they are non-fossiliferous.

Owing to this supposed lack of fossils, the slates on Lundy have been correlated to the Upper Devonian Morte Slates Formation of northern Devon by means of lithological similarity alone (e.g. Etheridge, 1867; Dollar, 1941; Edmonds *et al.*, 1979). This correlation has been questioned a number of times over the past 150 years (e.g. Hall, 1871; Dollar, 1941), but in the absence of new (palaeontological) evidence it has remained untested. Although the rocks are currently mapped as belonging to the Morte Slates Formation, given the lack of firm evidence in support of that correlation Dollar's (1941) informal designation of 'Lundy Slates' is preferred.

Despite the prevailing orthodoxy that the Lundy Slates are unfossiliferous, possible fossils have been reported on at least two occasions. Hall (1871, p. 619) mentions a "very indefinite marking, which may possibly belong to a vegetable impression", but the most convincing and extensive record is that described in Dollar's (1935) PhD thesis and subsequent publication (Dollar 1941). Dollar records the presence of several fossil groups including brachiopods, echinoderms and gastropods, although he notes that some of the identifications are equivocal and none are identified to genus or species level.

This paper documents the recent discovery of unequivocal fossils from the Lundy Slates, and provides preliminary notes on the taxa present, including a number of groups recorded from Lundy for the first time. The importance of this fossil assemblage for understanding the age and correlation of the Lundy Slates is briefly discussed.

METHODS

Following the authors' initial chance discovery in 2019 of fossiliferous pebbles on the small beach between Rat Island and the main island, permission was obtained to conduct a more thorough search of the slate outcrops of Lundy with the aim of finding and sampling *in situ* fossiliferous beds. Fieldwork took place in 2021, and also included a survey of the Landing Beach and the rocky outcrops around the Devil's Kitchen to identify and collect additional fossiliferous *ex situ* pebbles.

Thin-sections were made of all samples, in order to determine their lithology and their fossil content. In addition, selected samples were dissolved in buffered 10% acetic acid, following the methods of Jeppsson *et al*. (1999), in order to release any phosphatic (micro)fossils present. Residues were then sieved into smaller size fractions using mesh sizes of 1 mm, 500 μm, 250 μm, 125 μm and 63 μm, and then picked under a binocular microscope. All samples, residues and specimens are housed in the collections of the Natural History Museum, London (NHMUK).

RESULTS

In total, two *in situ* and 20 *ex situ* samples which have been collected thus far, including the initial discoveries in 2019, have yielded fossils. Importantly, these fossiliferous *in situ* samples have extremely similar lithology, preservation and fossil content to the *ex situ* ones, indicating that the fossiliferous pebbles found loose on the beaches do indeed derive from the local slate outcrops on Lundy and have not been transported in from elsewhere. The two *in situ* fossiliferous samples were collected from the foreshore outcrops of the Landing Beach at N51° 09.804', W004° 39.444' (NHMUK PEI 5537) and N51° 09.782', W004° 39.404' (NHMUK PEI 5538).

The fossils are preserved in thin, shelly limestone beds, between 5 mm and ca. 5 cm thick. Both of the *in situ* samples were lens-shaped scours with erosive bases (Plate 1A). In thin section, samples are predominantly composed of densely packed calcareous bioclasts, with subordinate phosphatic bioclasts and lithoclasts, and have been substantially recrystallized during burial and diagenesis (Plate 2). Although recrystallization partly obscures the original fabric, these rocks may be classified as bioclastic packstones; i.e. they are clast-supported with an infill of mud between the clasts. A range of different fossil marine invertebrate groups can be identified in thin section, albeit only at a very coarse taxonomic level. Almost all of the fossil bioclasts are disarticulated and fragmented and none are in life position.

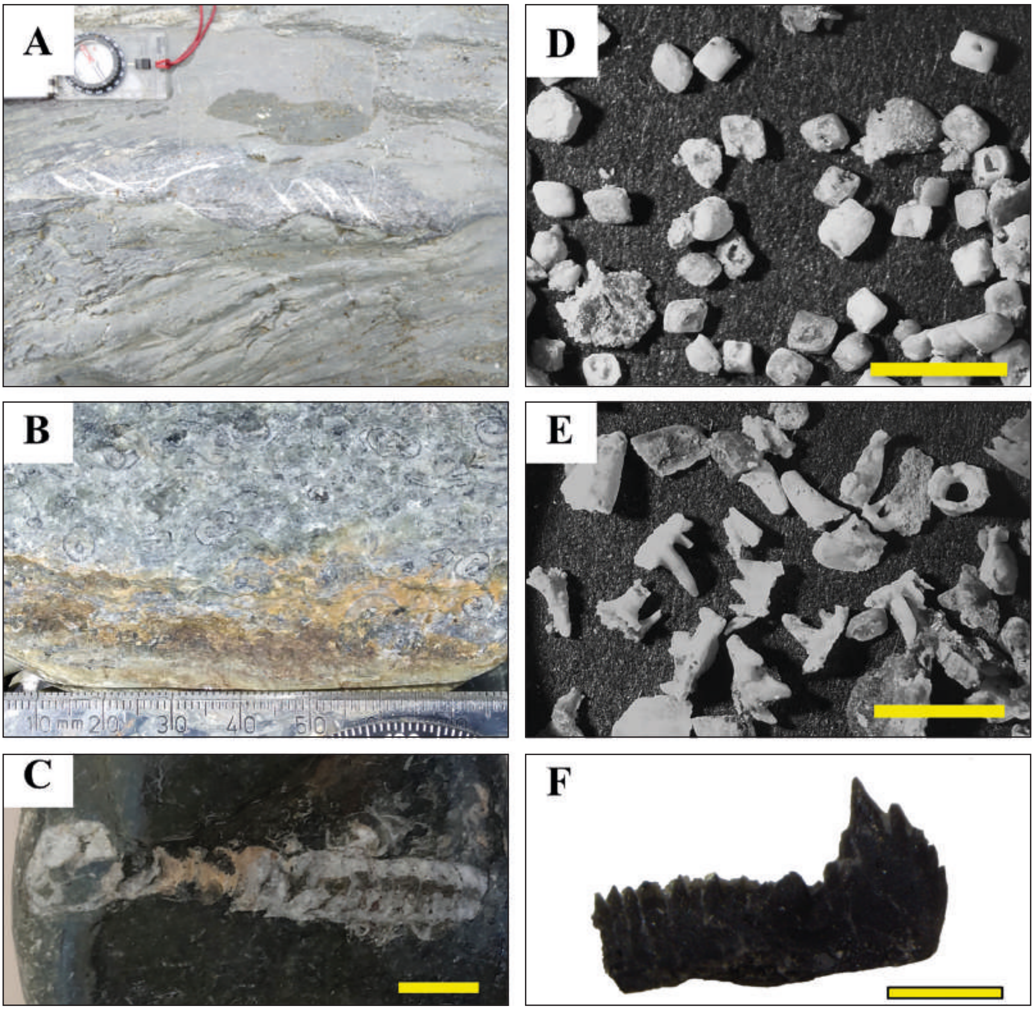

Plate 1. A selection of fossils collected from the Lundy Slates: A) an *in situ* fossiliferous limestone lens from the Landing Beach foreshore [N51° 09.804', W004° 39.444'], NHMUK PEI 5537; B) an *ex situ* hand specimen containing abundant bellerophont molluscs, NHMUK PEI 5558; C) an orthocone nautiloid in an *ex situ* pebble, scale bar = 1 cm, NHMUK PI CN 215; D) acanthodian scales from the sample shown in A, scale bar = 1 mm; E) chondrichthyan teeth from the sample shown in A, scale bar = 1 mm; F) a conodont element (cf. *Bispathodus*) from the sample shown in A, scale bar = 500 µm.

Brachiopods

Brachiopods are common in most samples, mainly represented by fragments of disarticulated valves (Plates 2, 3). Some specimens still preserve hints of original shell microstructure, comprising a thin outer layer and thicker inner layer typical of many brachiopod groups, but most have been recrystallized. It is possible that some recrystallized valves may also be from bivalve molluscs, but owing to their preservation a positive identification cannot be made from the materials examined thus far.

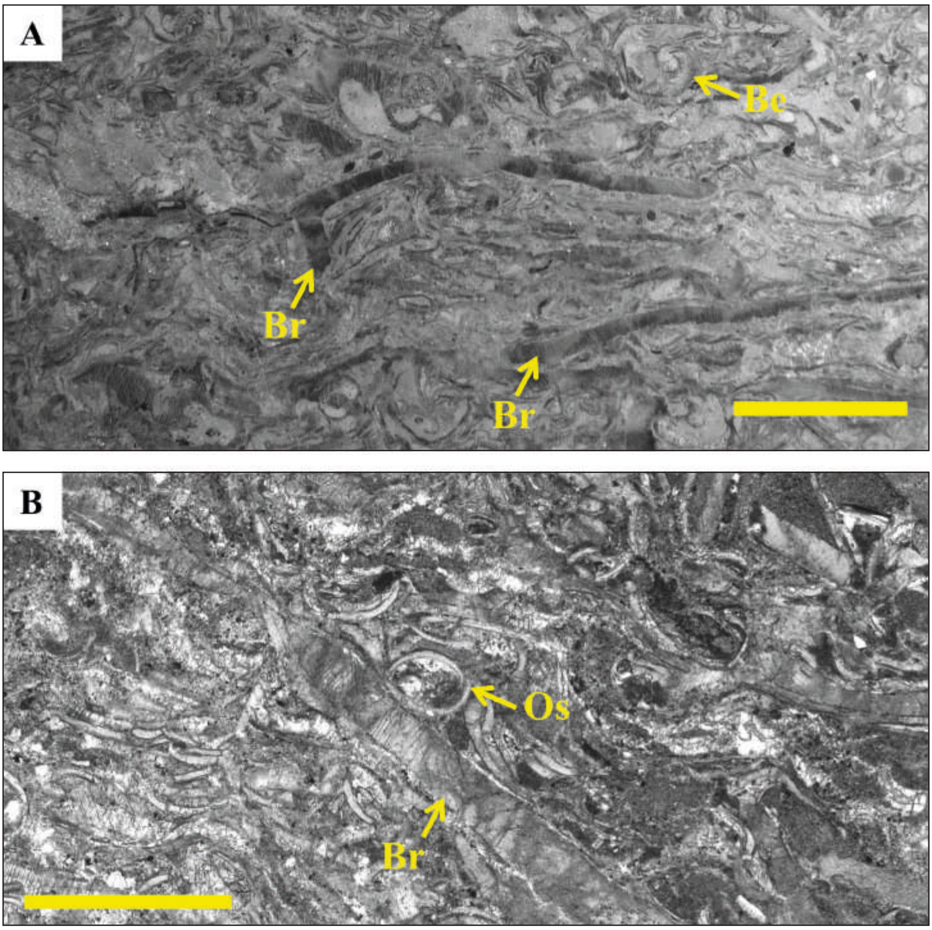

Plate 2. Two thin section views of a typical fossiliferous *ex situ* limestone event bed of the Lundy Slates, NHMUK PEI 5544. The sample can be classified as a densely packed, poorly sorted bioclastic packstone, with an assemblage dominated by brachiopods (Br) and ostracods (Os), and with a few bellerophont molluscs (Be). A) reflected light, scale bar = 2.5 mm; B) plane polarised transmitted light, scale bar = 1 mm.

Molluscs

Molluscs are not present in all of the samples, but are very common in some samples and may even be visible in hand specimen too. Several classes are represented. The most common are relatively thick-shelled, involute and planispirally coiled specimens that are referable to the Superfamily Bellerophontoidea (Plate 3). Bellerophonts are an unusual group of extinct molluscs, ranging from the Cambrian to Lower Triassic, with uncertain taxonomic affinities, and are classified within the Gastropoda or Monoplacophora (e.g. Wagner 2001). The Lundy Slate bellerophonts reach 5 mm in size and may be visible in hand specimen (Plate 1B). True gastropods are also present in the assemblages, although these are rare. Morphologies include a high-spired form and a globose form. Compared to the bellerophonts, these gastropods are relatively thin-shelled.

Two cephalopod specimens have also been found to date. Both are orthocone (straight-

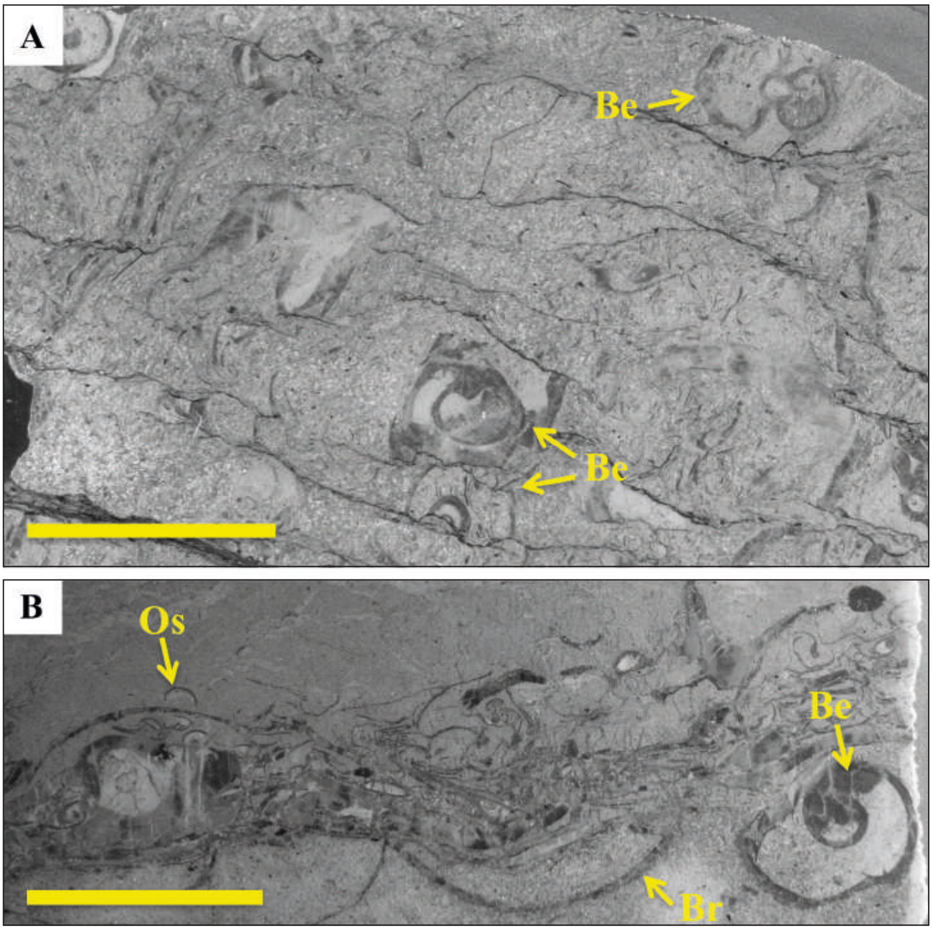

Plate 3. Thin section views of fossiliferous *ex situ* event beds of the Lundy Slates with a silty matrix. A) sample NHMUK PEI 5558 under reflected light; B) a thin lag of bioclasts on the base of a metasiltstone, NHMUK PEI 5542, under reflected light. Br = brachiopod, Be = bellerophont, Os = ostracod. Scale bars = 5mm.

shelled) nautiloids, and may represent the same species although taxonomic work is ongoing. Unlike the other (benthic) molluscs recorded in the assemblage, orthocone nautiloids were nektic or nektobenthic predators that inhabited the water column. The largest specimen is 5 cm in size, and was the first fossil specimen to be found in this study (Plate 1C).

Arthropods

Ostracods are common components of most samples, and dominate the thinnest shell beds. Disarticulated valves are most common (Plates 2B, 3B), but articulated specimens are present too (Plate 2B). To date, no unequivocal trilobite bioclasts have been observed.

Fish

The most common fossils in the acid-prepared residues are the teeth and scales of fish.

Taxonomic work is ongoing but preliminary observations suggest that a number of extinct groups are represented (C. Duffin, pers. comm.). Rhomboid-shaped scales of acanthodians are very abundant in all samples, possibly belonging to the genus *Acanthodes* (Plate 1D). Acanthodians are an extinct class of jawed fish and are sometimes referred to as 'spiny sharks', but they are not true sharks. Teeth belonging to extinct members of the Class Chondrichthyes are, however, also present. For example, common, small 'cladodont' teeth with multiple cusps, used to clutch or grab prey, are recorded in most samples and are identified as belonging to extinct holocephalians from the Order Symmoriiformes (Plate 1E). Some are similar to the Carboniferous genus *Denaea.*

Conodonts

Conodont elements are the tooth-like mouthparts of extinct, jawless marine chordates related to living lampreys and hagfish. They range from the Cambrian to the end of the Triassic, and are extremely useful for biostratigraphy and for correlating marine rocks of that age worldwide. Conodonts are present in every sample residue examined to date, and are reported from the Lundy Slates for the first time. Preliminary identifications suggest that the genera *Polygnathus* and *Bispathodus* (Plate 1F) are present, consistent with an Upper Devonian to Lower Carboniferous age (Corradini *et al.*, 2017).

DISCUSSION

The fossils documented in this study demonstrate without doubt that the Lundy Slates contain an abundant and diverse fossil fauna of marine invertebrates and vertebrates, adding significantly to the geodiversity of Lundy and of southwest England. Fossils are confined to thin, shelly limestone beds within the Lundy Slates, and do not appear to be present in the surrounding mudstones. Most fossils are disarticulated, with the exception of some of the ostracods (Plate 2B), and none are in life position, indicating that the assemblage underwent post-mortem decay and transport prior to final burial. These limestones are interpreted as 'event beds', recording the sudden downslope transportation of dead shells, teeth and scales into a deeper water setting, rather than the *in situ* accumulation or concentration of bioclasts. The two *in situ* beds sampled in this study likely represent scours or gutters that were emplaced during large storms. Transportation and rapid deposition during single storm events is consistent with the dense packing, poor grading and poor sorting of the bioclasts (Kidwell, 1991). Differences in thickness between the fossiliferous beds, and in the relative proportions of the fossil groups preserved in those beds (e.g. the dominance of ostracods in some beds; Plate 2B), demonstrate that multiple events have been sampled. Event beds with slightly coarser, siltier matrix, generally contain fewer ostracods and more thick-shelled bellerophont gastropods (Plate 3A). Such differences probably reflect hydrodynamic sorting and winnowing downslope, with the thinner beds containing a greater proportion of smaller bioclasts being deposited further offshore and/or from weaker flows.

Our re-discovery of marine invertebrate fossils in the Lundy Slates also confirms, after more than eighty years, the observations of Dollar (1935, 1941). Although Dollar did not figure any of his fossil specimens in his 1941 publication, a single photomicrograph in his PhD thesis purports to show a crinoid ossicle (Dollar, 1935, plate 6.3). The senior author has examined Dollar's thesis in the library of Cambridge University, and the image is, unfortunately, somewhat unconvincing. In contrast, however, Dollar's detailed written descriptions of the 'organic remains' he observed in his samples clearly demonstrate that he had undoubtedly discovered fossils in five of his eight Lundy Slate samples, including brachiopods, gastropods and echinoderms, and possibly bivalves and ostracods (Dollar 1935, p. 50-55). The latter group, ostracods, was never specifically named by Dollar (1935, 1941) amongst the fossils that he described, but his descriptions of 'ovoid bodies, with major axes 0.5mm long and minor axes 0.4mm long' are very suggestive of this group. Unfortunately, despite extensive enquiries, the whereabouts of his PhD sample collection is currently unknown and it may have been lost.

It is perhaps worth speculating why Dollar's (1941) discovery of fossils in the Lundy Slates was not followed up at any time in the intervening decades before our chance re-discovery. The timing almost certainly did not help: although Dollar first read his thesis paper at the Geological Society of London on 1st December 1937, it was not published until 1941, in the midst of an ongoing world war. Furthermore, his study was mainly concerned with the mineralogy and age of the granites and dykes of Lundy, and the comments he received at the time also focussed on the same aspects (Dollar, 1941, p. 76-77). One of his main conclusions – that the granites of Lundy were the same age as those of the mainland – was queried at the time (Dollar, 1941, p. 76) and later shown to be false (e.g. Dodson & Long, 1962), so perhaps that error may have affected acceptance of some of the rest of his work too.

Most damaging, however, were probably the less-than-supportive comments he received (and published!) from two palaeontologists he consulted about his apparent discovery of a crinoid ossicle: one thought it may be a calcareous alga whilst the other was "disinclined to express an opinion" (Dollar 1941, p. 45). Unfortunately, he chose not to publish the more supportive comments he evidently received; for example, regarding one of his thin sections, he notes in his thesis that 'there is general agreement among palaeontologists to whom this section has been submitted that many of its calcareous structures are of organic initiation' (Dollar, 1935, p. 54). Had Dollar chosen to figure these other fossil specimens, such as the 'recrystallized shell fragments', 'brachiopods with their loops preserved' or the 'slightly arcuate platy bodies of calcite' that he identified as 'brachiopod-valves or the shells of allied creatures' (Dollar, 1935, p. 51-54), the outcome may have been different.

Age assignment and correlation

As Dollar (1941) and others before and since have lamented, in the absence of fossil evidence it is not possible to confidently determine the age of the Lundy Slates. They have long been assumed to correlate with the Morte Slates Formation (e.g. Etheridge, 1867), and are currently mapped as such by the British Geological Survey (Edmonds *et al.*, 1979), but this correlation is based on scant evidence such as a similarity in colour and grain size, and on the presence of diagenetic quartz veins. As first noted by Hall (1871), the Lundy Slates may instead correlate to the Devonian-Carboniferous Pilton

Mudstone Formation or to overlying Carboniferous units of the mainland. Although detailed systematic work has yet to be completed, it is interesting that the fossil fish fauna, with abundant *Acanthodes*-type scales and *Denaea*-like symmoriiform teeth, seems to be similar to Carboniferous fish assemblages described from elsewhere in the British Isles and Europe (e.g. Ginter, 2022; Ginter *et al.*, 2015; Duffin, pers. comm.).

It is also important to consider the wider geological setting too. The major Sticklepath-Lustleigh fault system runs NW-SE through Devon and the Bristol Channel to the east of Lundy, and the direction of offset and displacement of Palaeozoic rocks recorded along this fault suggests that the Lundy Slates should perhaps correlate with the Pilton Mudstone Formation (Evans & Thompson, 1979, p.5). The widely accepted correlation with the Morte Slates Formation should therefore be regarded as tentative at best; an untested hypothesis.

On present evidence, the fossil assemblage of the Lundy Slates is certainly different to that recorded from the Morte Slates Formation. In their review of the Devonian successions of North Devon, Whittaker and Leveridge (2011, p.734-5) document the fossils that have been recorded historically from the 'Morte Mudstone Formation' (= Morte Slates Formation) of the key locality at Barricane Beach. The assemblage is reported as comprising poorly preserved brachiopods, including the spiriferid *Cyrtospirifer* and unidentified rhynchonellids, possible fragmentary crustaceans, bivalves and crinoid ossicles (Whittaker and Leveridge, 2011). Invertebrate macrofossil groups present in the Lundy Slates, such as orthocone nautiloids, gastropods or bellerophontids, are seemingly absent from Barricane Beach. Although this may reflect real differences between the assemblages, either because of age or environment, it might simply be the result of collection failure. Likewise, the apparent absence of conodonts, fish teeth and scales from the Morte Slates Formation is probably because the fossiliferous horizons at Barricane Beach comprise sandstone lenses (Whittaker & Leveridge, 2011) rather than carbonate-rich lithologies, as on Lundy, that are amenable to acid dissolution.

The discovery of identifiable fossils, in particular conodonts, from acid-dissolution of *in situ* samples means that a much more secure age assignment and correlation is achievable. Detailed taxonomic analysis of the conodont fauna has yet to be completed, but given their importance in biostratigraphy, especially through the Devonian-Carboniferous transition (e.g. Corradini *et al.,* 2017), it is anticipated that they will yield an accurate and precise age for the Lundy Slates. Knowing the correct age of the Lundy Slates will improve our understanding of the evolution of marine ecosystems through the Devonian-Carboniferous transition, an interval of major mass extinction and biotic change (e.g. Caplan & Bustin, 1999), and will also assist in deciphering the geological structure and history of the region.

Thermal history

Conodonts are also useful indicators of the thermal history of the rocks in which they are found, as they have been shown experimentally to undergo a predictable and irreversible colour change with increasing temperature (Epstein *et al.*, 1977). All conodonts recovered from the Lundy samples are black in colour (Plate 1F), which equates to a Colour Alteration Index (CAI) value of 5 on the Epstein *et al*. (1977) scale, and indicates that the conodonts have experienced temperatures of 300-480°C. This is consistent with the mineralogy of the slates themselves, which indicates a low level of metamorphism equivalent to greenschist facies (Edmonds *et al*., 1979). Greenschists typically form during regional metamorphism at temperatures of 300-450°C.

CONCLUSIONS

The Lundy Slates are fossiliferous, and yield a marine assemblage of brachiopods, ostracods, bellerophontid molluscs, gastropods, orthocone nautiloids, fish (chondrichthyans and acanthodians) and conodonts. Fossils are concentrated in thin, bioclastic 'event' beds that record the transport and subsequent deposition of biological remains from shallower to deeper water settings during individual storms. Many of the fossil groups are documented from Lundy for the first time, and detailed taxonomic work is still ongoing. Identifiable fossils, in particular the conodonts, are reported for the first time from Lundy and with further study should provide a definitive age estimate for the Lundy Slates. The currently accepted Upper Devonian age for the Lundy Slates and current correlation with the Morte Slates Formation are not based on any fossil evidence, and should be considered tentative at best. Conodonts are black in colour (CAI = 5), indicating that they have experienced temperatures of 300 to 480°C, consistent with mineralogical evidence that the slates have undergone regional metamorphism to greenschist facies. Given that the authors have only surveyed a fraction of the available outcrop of the Lundy Slates, it is highly likely that future work will reveal additional fossiliferous horizons and an even greater richness and diversity of fossil remains.

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