Signs of Life: Trace fossils from the Kimmeridgian (Late Jurassic) deposits of Dorset, UK, held in The Etches Collection Museum of Jurassic Marine Life.

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Introduction

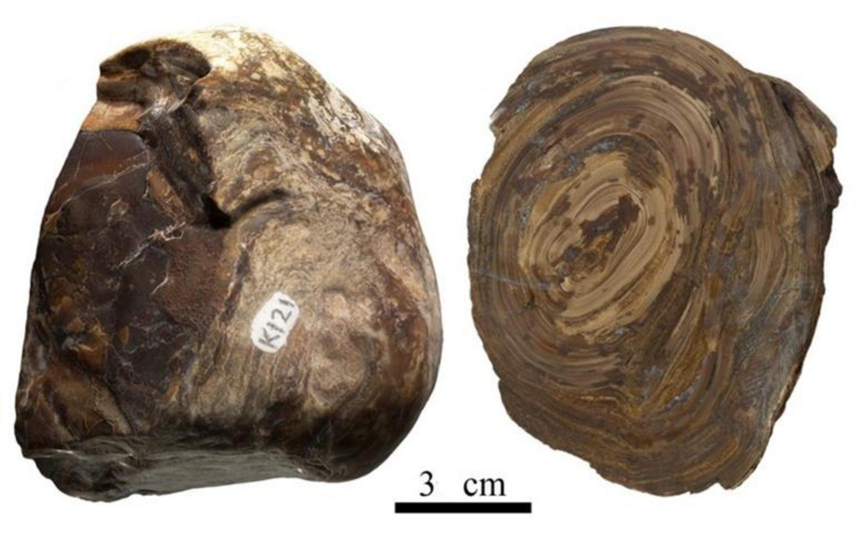
'The Etches Collection: Museum of Jurassic Marine Life' is an independent fossil museum located in the village of Kimmeridge in Dorset, UK, that displays the internationally significant collection of c.2,500 fossils discovered along the Kimmeridge coastline by the palaeontologist Steve Etches over the last 40 years (Noè et al, 2019). These fossils are principally from the Late Jurassic Kimmeridge Clay Formation (KCF) comprising the Kimmeridgian and Tithonian stages and date approximately to between 157 and 152 million years ago. The museum was opened in 2016 so that the collection could be shared with the public and remain accessible permanently.

Trace fossils are abundant at certain horizons within the Kimmeridge Clay Formation and include ichnotaxa not reported from elsewhere. The trace fossils held in the Etches Collection comprise not just hundreds of coprolites, scores of predation and scavenging traces and dozens of invertebrate burrows and borings, which one might expect, but also includes the first recorded example of ammonite eggs, the world's oldest fossil urolith (kidney/bladder stone) possible regurgitate and possibly the traces of the world's oldest bone-eating worms. These trace fossils help us to more fully understand the complex interactions of the fauna living in the Late Jurassic seas in which many taxa of marine reptiles thrived.

Examples of the trace fossils in the collection

Urolith – the oldest on record: Calculi (such as enteroliths, kidney or bladder stones) are near-spherical objects with a layered structure, sometimes with a hollow centre. Where the calculus is mineralised, each layer is composed of parallel crystals oriented perpendicular to the surface – the only time this occurs in nature. Often, the external texture is mammilated. Uroliths are known in the archaeological record but are almost entirely absent from the fossil record, most likely due to them simply not being recognised for what they are.

The fossil calculus from the KCF (specimen K121) is apparently only the second time in the world that such a trace fossil has been found relating to a marine environment. Importantly, it is the oldest calculi known and extends the temporal range of known calculi in the fossil record by at least 59 million years. It is likely to have been produced by a large marine reptile (Henton et al 2018). More must exist in the fossil record but have not been identified as they are easily dismissed as nodules.



The urolith K121: the external surface (left) and polished section (right).

Coprolites – many and varied: In the KCF, large coprolites are rarer than the smaller ones and are thought to be from marine reptiles or large fish though possibly also large squid (Martill & Wignal, 2020). The smaller coprolites are presumed to be from fish and spiracular coprolites from sharks. Inclusions within the coprolites can often be identifiable and include fish bones (actinopterygian ganoid scales, vertebra, fin rays or even complete fish jaws), saurian bones and the chitinous hooklets of teuthoids. The coprolites are preserved as microcrystalline fluorapatite and are usually buff-coloured on the outer surface and black or dark brown internally. They can be divided into distinctive morphologies: spiral; massive irregular; elongate cylindrical; and irregular pelleted (the latter usually lacking inclusions) (Martill & Wignal, 2020).

The different forms and sizes relate not just to the makers but also the specific chemistry of the immediate preservational environment. Spiral and massive coprolites frequently contain black bone inclusions. Some specimens exhibit toothmarks, presumably from fish that were at least partially coprophagus (e.g. K1933, below right).

Predation/scavenging: Bite marks on marine reptile bones are not uncommon in the KCF and although predation marks are largely indistinguishable from scavenging marks, it is interesting to note that a high proportion are found on the upper and lower jaws of marine reptiles in the collection, indicating head-to-head fighting. Also, the rear portions of some ichthyosaur skulls seem to have been completely bitten off, maybe as a killer bite (e.g. K1009, below). Presumably all the tooth marks relate to other marine reptiles. Matching the marks to the producer is difficult but not always impossible. Trihedral holes match the teeth of pliosaurs. One plesiosaur bone (K92) has tooth marks in two parallel lines, indicative of a narrow snouted crocodilian. Sometimes, a tooth remains embedded in the bone, such in the plesiosaur humerus K2336.

Above: a perfectly preserved ichthyosaur mandible with the rear section missing in a manner suggesting predation or scavenging.

Above: tooth marks on the posterior section of the a mandibular ramus of an ichthyosaur. Right, a partially devoured pliosaur paddle bone.

Ammonites frequently shown signs of predation: the shell is bitten in the same place at the back of the body chamber (e.g. K563). As no tooth marks are left behind, this may be evidence of predation by a larger cephalopod using a beak to crush the shell and remove the flesh.

Lobsters hiding inside ammonite shells whilst moulting – the only know record: The collection has two examples of partial carapace of a small lobster in the posteriormost part of the body chamber of an ammonite (a *Aulacostephanus* macroconch). In both instances (specimens K1366 & K1963) the lobster seems to have sheltered there whilst moulting and therefore vulnerable to predation and left behind some of the shed carapace. There are worm tubes on the outside of the ammonite shells and this together with the use inside of the shell as a temporary home for the vulnerable moulting lobster demonstrates that conditions were not always anoxic at the sea floor.

Whilst other examples of arthropods undergoing moulting are preserved in the fossil record, these are the only known examples of them doing so whilst sheltering in an empty ammonite shell.

Ammonite eggs – the first ever recorded: Steve Etches was the first person to find and identify the fossilised eggs of ammonites. He initially found occasional examples of what looked like tiny egg sacs, resembling those of cuttlefish (spherical and subspherical eggs of nacreous lustre, formed in small strings or groups) but it was only when he finally found them in association with ammonite remains more than once that they could be conclusively identified as ammonite eggs rather than those of some other cephalopod. These are incredibly rare but eight clusters from Kimmeridge are now known (specimens K633, K1058, K1090, K1273, K1429 K1486, K2277 & K2284). They are thought to represent two eudemic genera *Aulacostephanus* and *Pectinatites* that dominate the biostratigraphy of the ammonites in the range of the Kimmeridge Clay in which they occur (Etches et al, 2009).

Trackways - delicate worm tracks: Occasionally, very delicate trackways are preserved (e.g. specimen K166, right), created by unknown makers but presumably a type of worm.

Burrows: Traces of burrowing organisms are common in some KCF horizons although they are most visible in sediment that has not been bioturbated. These traces (including elongate U-shaped burrows up to 300 mm long) may represent annelid worms or filter-feeding shellfish etc. Some organisms such as arthropods produce burrows with reinforced walls lined with pellets of sediment or fragments of bivalve shells. Some worms create burrows (above right) and some worms, such as serpulids, secrete tubes of calcium carbonate in which to live (e.g. right, attached to an ammonite(K2254)).

Borings: Boring traces are rare in the KCF due to the scarcity of hardgrounds but hard substrates such as large oysters and corals can exhibit borings made by sponges, bryozoa and bivalves: e.g. a *Lithophaga*-like bivalve that has bored into a *Isastraea* sp coral (K1104, see photo, right) and the bryozoan *Ropalonaria* boring into *Deltoideum* bivalves.

Below: K2342, proximal end of a scavenged pliosaur femur and possible evidence Osedax worm holes.

Bone-eating worms – the oldest known examples in the fossil record? The proximal ends of various pliosaur limb bones appear to show the burrowing activities of Osedax, bone-eating worms (deep-sea siboglinid polychaetes). Modern Osedax are known to bore into the bones of whale carcasses on the sea floor to reach enclosed lipids on which they rely for sustenance and these burrows can also protect them from predators. If confirmed, these traces from the KCF will extend the range of these worms in the fossil record by 50 million years.

Discussion

The Etches collection contains some trace fossils that were the first of their kind to be described (ammonite eggs and moulting lobsters hiding in ammonite shells) and specimens that greatly extend the known range of their kind (fossil urolith, possibly bone-eating worms) plus a wide range of well-preserved examples of other traces of long-extinct life.

Therefore, this collection of just c.2,500 fossils punches way above its weight in the quality, number, uniqueness and importance of its trace fossils. Is this due to exceptional preservation in the Kimmeridge Clay Formation, or exceptional collecting? It must be a mixture of both. Whilst it is true that some sorts of trace fossils are abundant at certain horizons within the Kimmeridge Clay Formation (principally burrows), some of the trace fossils in the Etches collection are unique, are world firsts or greatly extend their known stratigraphic range. That has to be down to the combination of good preservation initially and – of no less importance - the dedication and perseverance of the collector who has specialised in a very specific geographical area and stratigraphical unit and the fact that he physically prepares all his own finds and can examine every millimetre of every specimen in more detail than would be usual for a normal museum. These trace fossils must be present in other KCF localities but these sites are not so intensively collected and studied by a single individual.

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