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Inferior Oolite (Middle Jurassic) hardgrounds and the associated faunas at Coombe Quarry, Mapperton, near Beaminster, Dorset

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Summary

Coombe Quarry near Beaminster exposes an example of the incomplete succession of Inferior Oolite rocks that typifies South Dorset. There are two large non-sequences within the succession, one in the Lower and one in the Middle Inferior Oolite, that are marked by distinct hardgrounds. These show different features that can be related to their contrasting mode of formation. The first occurrence of Gastrochaenolites lapidicus *within the Inferior Oolite of Dorset is recorded.*

During the Middle Jurassic the area of South Dorset around Beaminster was near the centre of what has become known as 'the Dorset Swell' (Penn 1982; adapted in Callomon and Cope 1995). This part of the seafloor was elevated relative to adjacent areas due to tectonic activity at that time. Its topography, together with syn-sedimentary faulting and differential pene-contemporaneous erosion on a very localized scale, has given rise to thin beds separated by hardgrounds and non-sequences of variable duration and hence large-scale variations in the preserved thicknesses of Aalenian and Bajocian strata over very small distances. Here the term 'hardground' is used to define sedimentary discontinuities at which the substrate became lithified, with evidence of borings or encrustations indicating that the surface lay exposed on the seafloor for a variable length of time prior to further sedimentation. In some cases lithification was followed by physical or chemical erosion resulting in fossils being planed off at the surface; in others unlithified sediment was burrowed and subsequently cemented. In all cases the hardground surface has been preserved by sediment cover.

The stratigraphical succession and palaeontology of Coombe Quarry (Mp-CQ) are discussed in detail in the preceding paper from which the bed numbers and lithostratigraphic names are derived (Chandler and Callomon 2009). The purpose of this communication is to describe two very different discontinuity-surfaces and some of the faunas associated with them.

Lithology and fauna

The Comptocostosum Bed (Bed 2): Lower Aalenian, Scissum Zone, upper part

The top part of the Comptocostosum Bed (bed 2 of Chandler and Callomon 2009) was examined in detail using sawn sections of samples from the centre of the quarry. The bed can be separated into two courses, a lower (bed 2c) and an upper (bed 2d). Bed 2a and bed 2b were not relevant to this investigation.

Bed 2c is a fine-grained, well-cemented, intensely and coarsely burrowed, dark grey ironshot oosparite, with lenses of poorly sorted small to medium-sized ooliths. It is a highly fossiliferous bed containing many horizontally aligned ammonites particularly near the top of the bed as well as large bivalves and gastropods and much shell debris.

Bed 2d is a conglomerate of pebbles, limonite crusts and limonitic pockets in a matrix of densely ironshot, highly ferruginous limestone. It is capped by a flat but somewhat pitted surface covered with stromatolitic crusts, oncolites and masses of serpulids and occasional planed off ammonites and nautiloids. Cavities extend down from the hardground surface for varying depths of about 0.07m which is generally where the separation from Bed 2c occurs. The cavities have narrow openings of from 0.01–0.06m in cross section and open out to as much as 0.10m as they extend downwards. The upper part of many cavities is filled with laminated limonitic layers similar in appearance to sections through a 'snuff box' (Figures 1a and 1b). These upper parts of the cavities may contain masses of serpulids often following the limonitic layers. The deeper portions of the cavities are filled with oomicrite, or in some cases with very fine-grained purplish deposits of uncertain affinity.

A diverse fauna of gastropods and bivalves and ammonites occurs in beds 2c and 2d, the gastropods being particularly concentrated at the base of the cavities where they often lie in pockets of fine-grained purplish matrix. Gastropod specimens are commonly slightly eroded or damaged prior to fossilisation but in many cases fine sculptural detail is well preserved. The bivalves and ammonites in the cavities are usually less than 0.06m in diameter. The following species of gastropods have been identified on the basis of the descriptions by the original authors and the revisions provided by Fischer and Weber (1997).

Ataphrus laevigatus (J. Sowerby)
Cirrus leachi J. Sowerby
Delphinula alta-acanthica Huddleston
Discohelix dundriensis (Tawney)
Discohelix pulchior (Hudleston)
Natica dundriensis Tawney
Perotrochus allionta (d'Orbigny)
Pleurotomaria (Talantodiscus) baugieri d'Orbigny

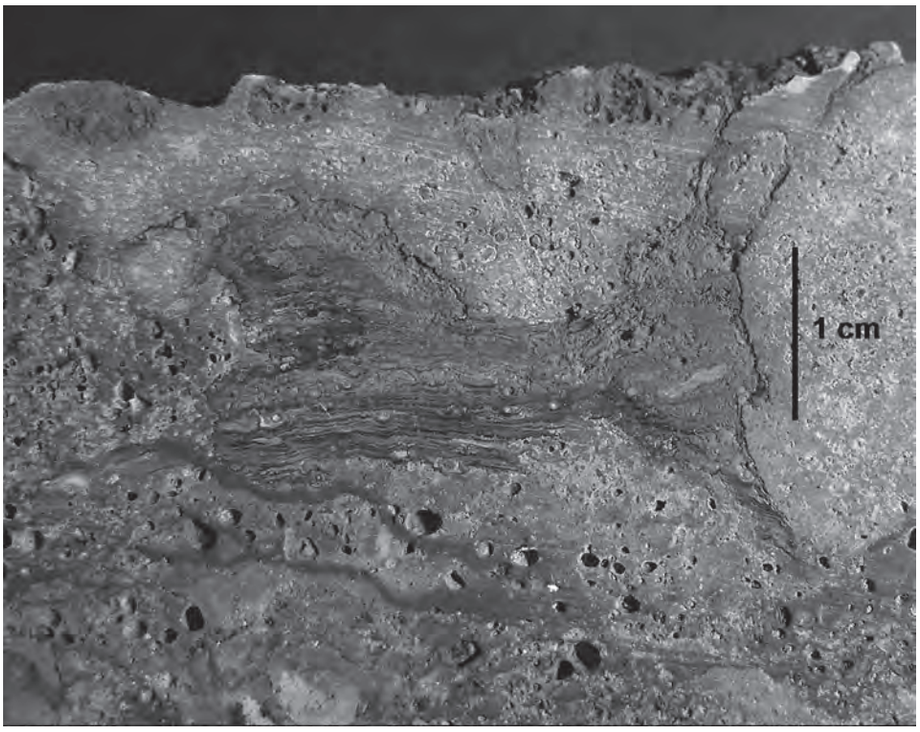

Figure 1a: Sawn section of the hardground at the top of the Comptocostosum *Bed (Bed 2) showing a cavity filled with limonitic algal layers containing serpulids. In some cases the laminae pass around the undersides of the serpulid tubes*

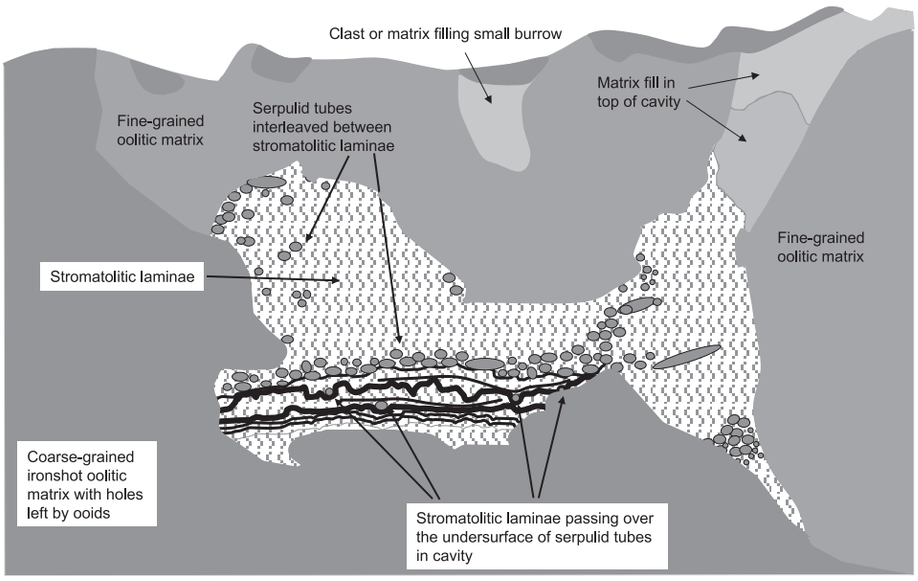

Figure 1b: Schematic drawing of the key features seen in Figure 1a

Pleurotomaria (Talantodiscus) mirabilis J.A. Eudes-Deslongchamps
Pleurotomaria actinomphala J.A. Eudes-Deslongchamps
Pleurotomaria fasciata J. Sowerby
Pyrgotrochus bicingulata (Hudleston)
Pyrgotrochus elongatus (J. Sowerby)
Pyrgotrochus punctata (J. Sowerby)
Pseudomelania lineata (J. Sowerby)
Pseudomelania procera (J.A. Eudes-Deslongchamps)

Disarticulated valves of the bivalve *Cucullea oblonga* J. Sowerby are particularly common both within and outside the cavities. Other bivalves, predominantly occurring in bed 2c are:

Ceratomya bajociana (d'Orbigny)
Ctenostreon pectiniformis (Schlotheim)
Entolium corneolum (Young and Bird)
Gresslya abducta (Phillips)
Gervillella intermedia (Whidborne)
Inoperna plicatus (J. Sowerby)
Pholadomya fidicula J. Sowerby
Pleuromya uniformis (J. Sowerby)
Pseudisocardia cordata (J. Buckman)
Trigonia costata Parkinson

Solitary corals of the genus *Chomatoseris* are frequent. The ammonites are discussed by Chandler and Callomon (2009).

The Horn Park Ironshot (Bed 3): Lower Bajocian, Discites and ?Ovale Zones

This thin bed represents all that is preserved of the Middle Inferior Oolite at this location. The bed has a wedge-shaped development across the quarry, thickening from a barely divisible 0.10m at the western end (containing ammonites indicating Bj-2) to 0.30–0.35m at the eastern end (containing, at the top, ammonites indicating Bj-3–4?), where it is divisible into three courses. The top of the bed is diachronous as where it is thicker it contains ammonites typical of higher biozones. The body of the rock is a medium- to coarse-grained densely ironshot limestone, locally biosparitic, ferruginous, marly to argillaceous, with pockets of very coarse-grained, light brown ooliths in grey matrix; strongly burrowed, with occasional oncolites ('snuff-boxes'). The ammonites are listed by Chandler and Callomon (2009). The commonest bivalves are:

Trigonia costata Parkinson
Plagiostoma richardsoni (Cox)
Isognomon ['*Gervillia*'] *bathonicus* (Morris and Lycett)

The bed was examined in detail using sawn sections from samples collected near the centre of the quarry, where it was about 0.10m thick and easily separated as a single layer from the underlying Comptocostosum Bed (Bed 2 of Chandler and Callomon 2009).

The contact between the Comptocostosum Bed and the overlying Horn Park Ironshot is sharp and flat with the heavily burrowed, encrusted, lithified surface of the Comptocostosum Bed directly overlain by a 0.01–0.02m thick concentration of shell fragments and belemnites generally lying flat and accompanied by iron-staining in a matrix of poorly sorted biomicrite with oolitic lenses. None of the body-fossils appear to be attached to the contact between the beds. The full thickness of the bed contains well preserved macrofossils, the shells of some of the molluscs preserved as recrystallized calcite (Figure 2). Large ammonites are aligned horizontally, though fragments may lie at all angles up to vertical, occupying the upper 0.07–0.08m of the bed. These fragments are sometimes cut across by the sharp and planar erosion surface at the top of the bed. Specimens of *Sonninia (Euhoploceras)* spp. frequently have damaged body chambers, their fragments lying partly attached or close by. Ammonites are encrusted by serpulids primarily on their under surfaces. Bivalves are usually disarticulated and frequently broken. Large ferruginous oncoliths are occasionally present in the lower 0.05m of the bed. Most of the thick shells and the belemnites are perforated by borings ranging from 0.5–2mm in diameter.

The upper surface of the Horn Park Ironshot has a very thin, patchy calcareous limonitic encrustation and is penetrated by infrequent flask-shaped (clavate) borings (Figure 2). The borings have a thin calcareous lining and may be readily recovered intact from the matrix. The necks of the flasks open to the erosion surface and are lined by calcareous laminae. In large ammonites cut across by the erosion surface, a boring may in some cases enter the bodychamber, as seen in the example of a *Sonninia (Euhoploceras)* sp. shown in Figure 3.

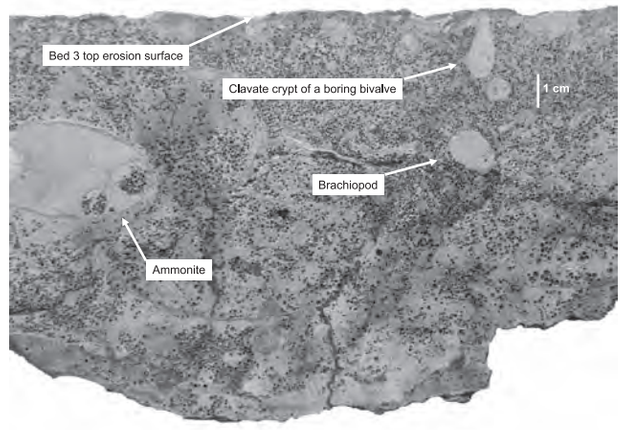

Figure 2: Sawn section of the Horn Park Ironshot (Bed 3) showing a clavate crypt of Gastrochaenolites lapidicus *penetrating down from the top erosion surface*

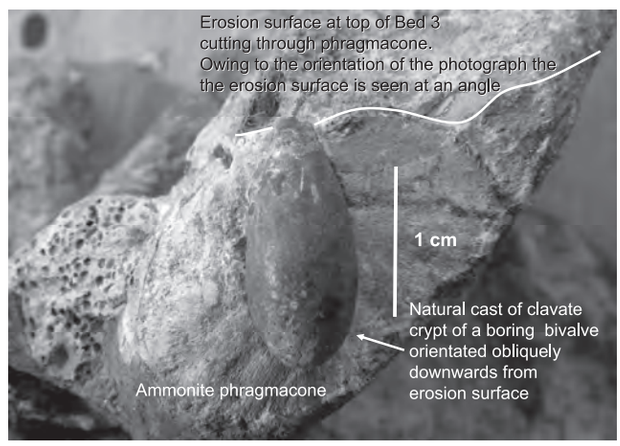

Figure 3: Sample of Horn Park Ironshot (Bed 3) showing part of a truncated ammonite Sonninia (Euhoploceras) sp. *with a clavate crypt of* Gastrochaenolites lapidicus *which has been partially developed from the matrix. The boring penetrates obliquely downwards into the phragmacone from the top erosion surface of Bed 3*

Discussion

The Comptocostosum Bed (Bed 2)

The hardground at the top of the Comptocostosum Bed contains evidence of a complex series of events resulting from excavation by burrowing organisms and subsequent lithification. The general appearance is very similar to that described for the Bajocian of Calvados (Fürisch 1971) and the proposed processes of its formation are similar. We suggest the following sequence

of events: *Thalassinoides*, the feeding traces attributed to semivagile and vagile deposit-feeding decapod crustaceans (Neto de Carvalho *et al*. 2007) were made in firm sediment. The upper surface of this sediment was then lithified to form a hardground while the lower part remained soft. Surface erosion occurred and the *Thalassinoides* were enlarged, perhaps by chemical dissolution, bio-erosion, current action and collapse, to form pockets of varying size which became partially filled with sediment and then colonised by layers of serpulids and stromatolites. Finally shallow marine oncolites and stromatolites were deposited on the hardground surface.

In the case of the Comptocostosum Bed at Mapperton, the tops of many burrow cavities are filled with limonitic laminae. The laminae are interleaved with layers of serpulids and serpulid tubes occur as masses sometimes on the under surfaces of the putative cavity roofs. The laminae underneath the tubes sometimes pass around them as though they were deposited after the tubes grew as seen in Figure 1a and 1b. This arrangement of the serpulid tubes between the limonitic laminations strongly suggests that the serpulids grew on the base of the laminae and thus that the entire laminated structure of successive layers of laminae and serpulids grew downwards from the top of the cavity into the space below. Difficult as this is to imagine it accords with the view put forward by Palmer and Wilson (1990) that the accreting side of 'snuff boxes' was downward facing. The preference of serpulids to grow in cavities and on under surfaces is also seen in the Horn Park Ironshot (see below). The characteristic corrugated structure of the laminates typifies them as laminae formed by stromatolites (Radley 1986). By analogy with modern stromatolites they are thought to have been formed by carbonate sediment trapped by mats of blue-green algae and bacteria. Although they typically occur today in shallow water facies they are not dependant on photosynthesis and may grow at depths of 1,000m or more.

The occurrence of gastropods, together with small disarticulated bivalves and ammonites, in pockets of the fine-grained purplish matrix at the bottom of apparent burrows, suggests that they may have been washed into them by current action. However we cannot exclude the possibility that the purplish matrix was laid down before the burrowing and formation of the hardground and was moved into the cavities by bioturbation. There is no evidence to suggest that this is a dwarf or juvenile fauna inhabiting the burrows.

The Horn Park Ironshot (Bed 3)

The 'tumbled' orientation of quite large ammonites and the presence of shell fragments and ammonites spanning almost the full thickness of the Horn Park Ironshot indicates very active bioturbation by large burrowers. Much of the shell damage can probably be attributed to this. This suggests that the sediment was unconsolidated for the duration of its deposition, an interpretation furthered by the common occurrence of the infaunal bivalve *Trigonia costata*.

Sedimentation of the Horn Park Ironshot at Mapperton was probably slow as indicated by the presence of oncolites ('snuff boxes') (Gatrall *et al*. 1972). These curious structures are at present believed to have originated when fragments of shell or other debris were coated by mucilaginous bacteria active at depths in and beyond the photic zone. These coatings in turn trapped and were covered by successive concentric crusts of sediment rich in ferric iron. The evidence suggests that they accumulated as concretions lying free on a sea bottom where there was current winnowing (Palmer and Wilson 1990). This may also explain the concentration of shells and fragments at the base of the bed and the presence, on the underside of ammonites, of serpulids that typically grew on the roofs of cavities beneath shells where sediment has been washed away (Palmer and Fürsich 1974; Hallam 1975, 66; Palmer and Wilson 1990). However the regime must have been one of relatively low energy as most of the fossils are well preserved, lacking mechanical abrasion and curved shells lie both concave and convex side uppermost suggesting little current sorting (Hallam 1963). The damage that has occurred is probably the result of bioturbation and predation rather than current action as fragments of ammonites often abut the specimens from which they are derived. On the larger scale, the Lower and Middle Inferior Oolite of Dorset as a whole is remarkable for the absence of any signs of higher-energy water movements, such as cross-bedding, suggesting an enduring position below storm-wave base.

The small irregular borings which are very common in shell fragments and belemnites are typical of the ichnogenus *Entobia* and may possibly be attributed to the activity of the sponge '*Cliona*' sp. (Palmer and Fursich 1974).

The occasional flask-shaped clavate crypts at the top of the Horn Park Ironshot exhibit a thin calcareous lining with concentric laminae around the neck and, based on their shape, can be assigned to the ichnospecies *Gastrochaenolites lapidicus* Kelly and Bromley 1984. The supposed inhabitants of the borings were bivalves of the genera *Lithophaga* and *Gastrochaena* (Kelly and Bromley 1984). These shells bore into the substrate when young and grow in the crypt by enlarging it. The narrow siphonal tube is an adaptation to escape predation by surface dwelling organisms (Carter and Stanley 2004). Lithophagid and gastrochaenid species appeared in the late Triassic and have been described from the European Middle and Upper Jurassic (Fürsich *et al*. 1994), though, as far as we are aware, this is the first record from the Inferior Oolite of Dorset. Their presence, together with the planed off macrofossils, unequivocally indicate that this hardground was cemented before being eroded. The very flat smooth surface at the top of the Horn Park Ironshot suggests

that the abrasive action of a temporary mobile sediment cover was probably the dominant erosive agent, though bioerosion may also have made a contribution (Goldring and Kazmierczak 1974).

The bed commences with ammonite biohorizon Bj-2 extending up to Bj-3–4? in some places at the eastern end of the quarry (Callomon and Chandler 1990). However where it is only 0.10m thick in the centre of the quarry this residual part of the bed may represent a shorter time frame, possibly only Bj-2 or even a small part thereof. The presence of fossils spanning the full thickness of the bed where it is at its thinnest suggests that it remained unconsolidated for the duration of its deposition. Above the erosion surface at the top of the Horn Park Ironshot there is a non-sequence spanning the Ovale to Garantiana zones, faunal horizons Bj-5–Bj-23. This massive gap of five ammonite zones above the erosion-plane probably represents a duration of some 4 million years (Callomon 1995) and the variation in thickness of the Horn Park Ironshot around the quarry suggests that sediment may have been repeatedly deposited and removed during this time. The infrequency of borings suggests that the hardground was only exposed for a small part of this time or suffered significant late erosion.

The two hardgrounds that we have described show very different features. The surface of the Comptocostosum Bed is a hardground at the top of a highly condensed succession that has been burrowed in a semi-consolidated state, lithified and undergone surface colonisation followed by a long period of non-deposition, with oncolite growth. In contrast the top of the Horn Park Ironshot is a hardground in sediments that were lithified and then planed off by erosion as indicated by the sections of ammonites and other fossils and the planar nature of the surface. This surface has then been bored by bivalves to produce clavate crypts, described here for the first time from the Inferior Oolite of Dorset. There is no evidence to indicate to what extent the non-sequence above the bed, or the diachronous nature of its upper surface, represents the removal of material or non-deposition.

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