Field excursion to Culverhole Point, The Slabs and Goat Island, east Devon, 5th January, 2012

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Twenty three members assembled at the old road bridge [SY 2530 9012] over the River Axe at Seaton, the oldest surviving concrete bridge in Britain, on a blustery January morning. The purpose of the field trip was to examine the transition from the terrestrial environments of the latest Triassic to the marine environments of the early Jurassic, the basal Cretaceous unconformity, and some of the best exposures of the Upper Greensand Formation and the Chalk Group in the UK. The walk also traversed the spectacular Bindon Landslide of Christmas Day 1839.

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Introduction

The group followed the river eastward from the bridge to its outfall below Haven Sea Cliff (Figure 1), the western entrance to the 8 km-long Axmouth to Lyme Regis Undercliffs National Nature Reserve (NNR). Between this point and the western end of the Bindon (1839) Landslide the highest part of the Triassic Mercia Mudstone Group, the Branscombe Mudstone and Blue Anchor Formations (Figure 2), is wholly exposed over a distance of 1,750 m. Here, and elsewhere along the east Devon and west Dorset coasts, long exposures of gently dipping strata give the impression that there is little faulting in the region. However, air photographs taken at times when the water is clear show sea-bed features in water depths of up to 10 m.

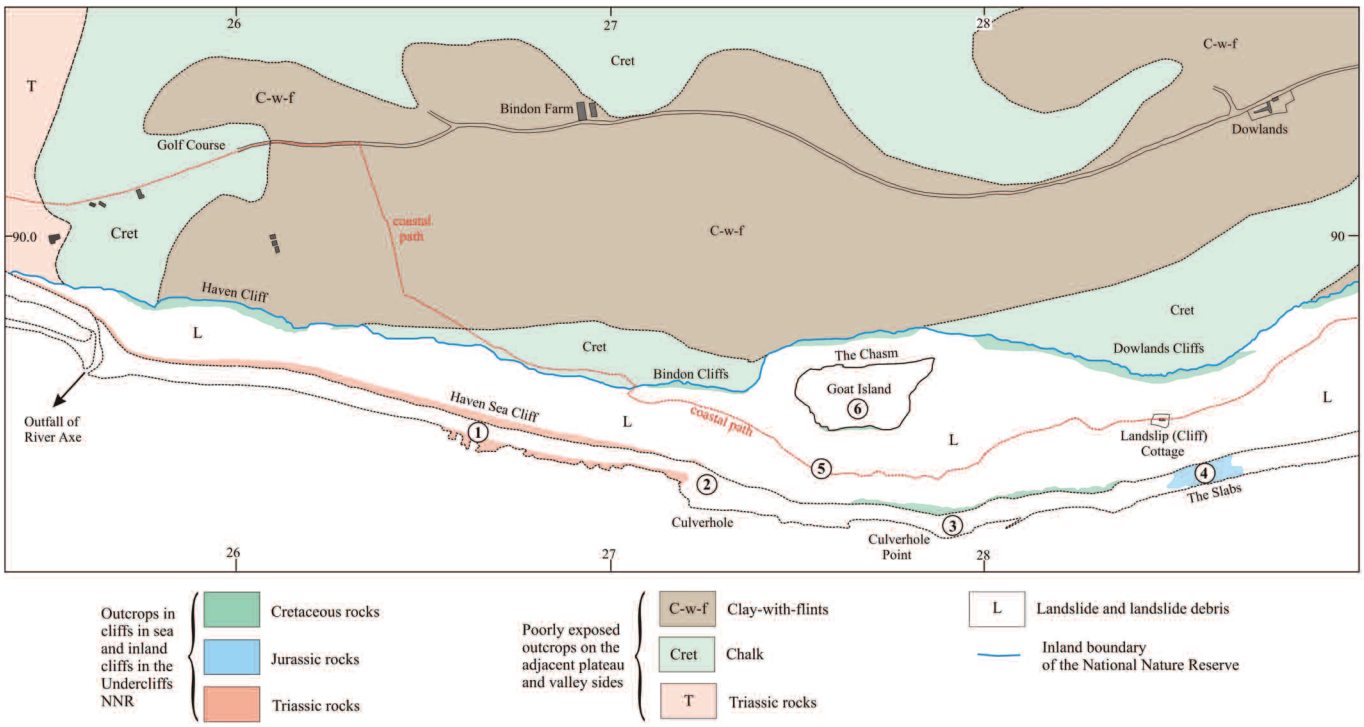


Figure 1. *Geological sketch map of the route and locations referred to in the text.*

When combined with sonar images of the nearshore area it can be seen that many of the cliff outcrops are within or adjacent to E-W trending fault belts that run sub-parallel to the cliffs. These are intersected by N-S trending fault zones that underlie each of the river valleys in the region (Gallois, 2012). The more prominent of these, such as the fault zone that underlies the Axe Valley, are pre-Variscan structures that were intermittently active from the early Permian to the Miocene (Edwards and Gallois, 2004).

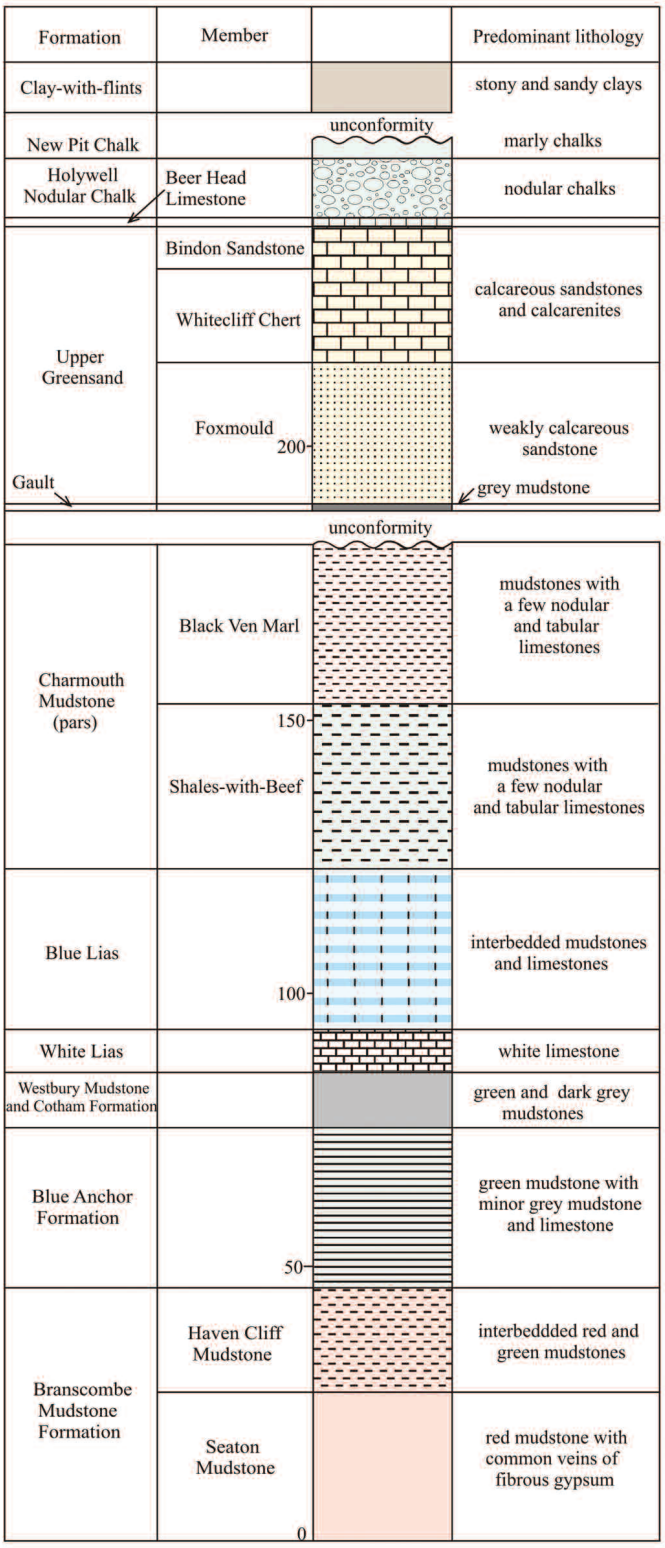


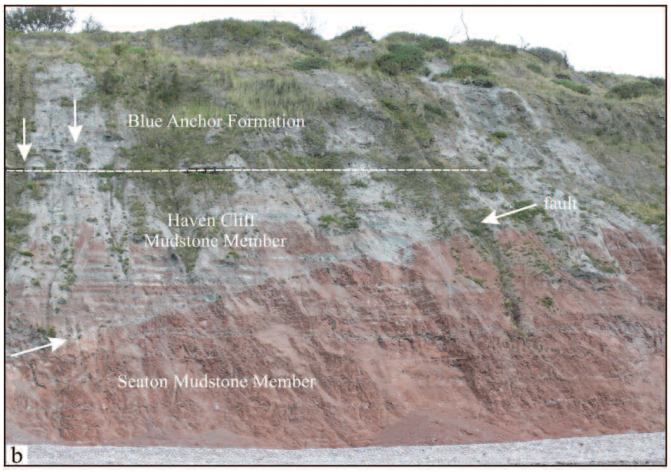
Figure 2. *Generalised vertical section for the strata that crop out on the route.*

Locality 1: Haven Sea Cliff

The coastline between the Axe outfall and Culverhole [SY 272 894] consists of an upper cliff (Haven Cliff) of Upper Greensand and Chalk that is separated from a lower sea cliff of Triassic rocks by a bench covered with debris of Cretaceous material that accumulated as the result of landslides along failure surfaces in the lowest part of the Upper Greensand. The sea cliff provides a continuous exposure in gently folded red and green silty mudstones of the late Triassic Seaton Mudstone Formation, and green and grey mudstones of the Blue Anchor Formation (Figure 3a). Part of the succession is repeated as a result of faults that run almost parallel to the cliff face and beneath the foreshore (Figure 3b). The oldest beds exposed are in typical 'Keuper Marl' facies, reddish brown silty mudstones with lines of green blotches and a few thin green beds. The mudstones contain few sedimentary structures,

Figure 3 right. *(**a**) A continuous cliff (Haven Sea Cliff) that runs eastward from the outfall of the River Axe at Seaton towards Culverhole Point exposes the highest part of the Triassic Mercia Mudstone Group. Red and green mudstones in the highest part of the Branscombe Mudstone Formation pass up into green and grey mudstones with thin beds of limestone of the Blue Anchor Formation. This succession of lithologies represents the late Triassic change from hot deserts (sabkhas) to brackish marine environments. View west towards Seaton and the Chalk cliffs at Beer. (**b**) One of several steeply dipping, E-W trending faults that intersect Haven Sea Cliff at a low angle. View north to where the highest part of the Branscombe Mudstone, thinly interbedded red and green mudstones of the Haven Cliff Mudstone overlain by green and grey mudstones of the Blue Anchor Formation, are downfaulted c. 50 m to the north against red mudstones of the underlying Seaton Mudstone. (**c**) Blue Anchor Formation in the background, White Lias Formation in the foreground and a brisk walk in the January sun. What better way to celebrate the 50th Anniversary of the Ussher Society? Photograph courtesy of John Renouf. (**d**) At the eastern end of Haven Sea Cliff the Blue Anchor Formation is faulted against the Westbury and Cotham Mudstones (concealed by beach deposits at the time of the field trip) and the White Lias. At the back of the cliff, the White Lias (c. 200 Ma in age) is unconformably overlain by the Cretaceous Upper Greensand Formation (c. 100 Ma). The unconformity (arrowed) crops out as a sub-horizontal in situ surface and in back-tilted and toppled blocks that have been undermined by the sea. (**e**) Dark grey, clayey glauconitic fine-grained sands with small pebbles at the base of the Upper Greensand rest with sharp lithological contrast on a burrowed and bored erosion surface of White Lias limestone. Indurated mineralised bioturbated horizons, and slump and dewatering structures in the limestones are indicative probable emergence and seismic activity. Photograph courtesy of John Bennett. (**f**) Negotiating blocks of Upper Greensand (Whitecliff Chert Member), the more durable debris left over from the 1839 Bindon Landslide, on the way to Culverhole Point. (**g**) The field trip leader demonstrating the uncanny resemblance of a typical Upper Greensand 'Cowstone' to a Devon Red. Cliffs of collapsed Upper Greensand and Chalk on the left, Culverhole Point in the background. Photograph courtesy of Richard Porter. (**h**) View east to Culverhole Point, a large intact mass of Upper Greensand and Chalk that retained its stratigraphical integrity when it moved seaward during the 1839 Bindon Landslide. Its original in situ outcrop lay c. 600 m north of here. The arrows indicate the positions of widespread erosion surface, mineralised and burrowed hardgrounds, that mark the boundaries of the Upper Greensand members. (**i**) At Culverhole Point the Foxmould Member (weakly calcareous, dark green glauconitic sandstones that weather to loose foxy brown sand) is separated from the overlying Whitecliff Chert Member (calcareous sandstones and calcarenites with cherts) by two mineralised erosion surfaces (hardgrounds) with extensive burrowing (A and B arrowed). Photograph courtesy of John Bennett.*


a

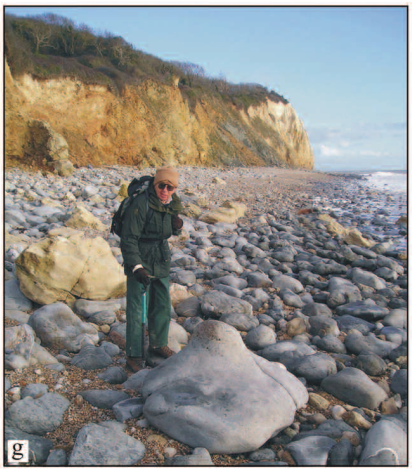

Blue Anchor Formation
Haven Cliff
Mudstone Member
fault
Seaton Mudstone Member
b


c


d


e


f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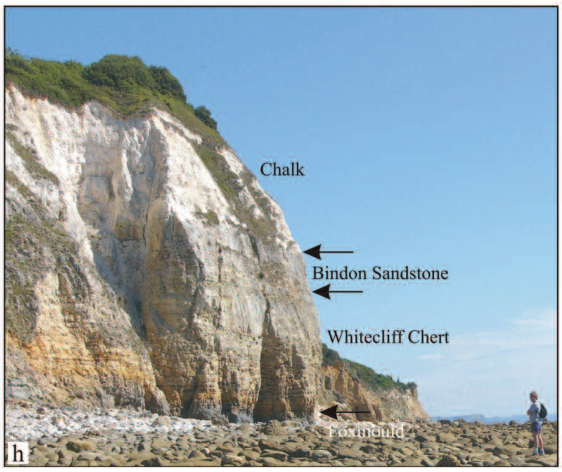
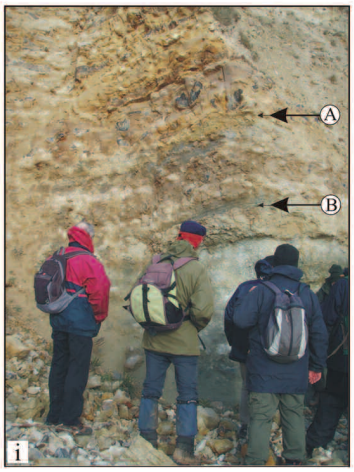

Chalk
Bindon Sandstone
Whitecliff Chert
Foxmound
h


A
B
i

largely because they have been disturbed by insolation (diurnal heating and freezing in a desert environment) and the repeated crystallisation and dissolution of salt and gypsum. No fossil has been recorded other than rare rhizocretions that formed around poorly preserved rootlets. The red colouration, lithology and sedimentology are indicative of inland sabkha environments in a hot dry climate similar to that in parts of the present-day Persian Gulf and central Australia. A prominent bed of coarse green siltstone (0.8 m thick) marks an upward change to alternations of red (60%) and green (40%) silty mudstones that were called the Variegated Marls by Woodward and Ussher (1911): now the Haven Cliff Mudstone Member (Figure 2). These distinctively striped beds represent a regional change to a slightly wetter environment, and can be traced in ploughed fields and inland exposures via Devon and Somerset to South Wales.

The base of the overlying Blue Anchor Formation is taken at the base of a thin (0.3 m thick), laminated dolomitic limestone that forms the lower of two prominent limestone ribs (arrowed) in the cliffs (Figure 3b). It marks the incoming of thin beds of limestone and dark grey mudstone that were deposited in fluviatile environments, probably in brackish water. Thin beds of red mudstone continue into the lower part of the Blue Anchor Formation, but these die out upwards as the dry desert conditions were replaced by a wetter climate. The highest part of the formation contains gypsum nodules, possible algal structures and slump structures indicative of deposition in coastal sabkhas, shallow lagoons and on tidal flats.

Locality 2: Culverhole

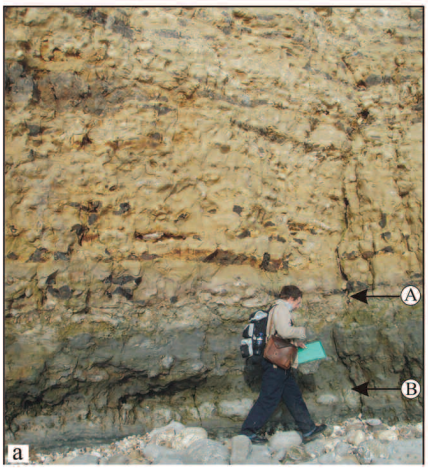
The highest beds of the Blue Anchor Formation and the mudstones of the overlying Westbury Formation and Cotham Formation crop out on the foreshore at Culverhole [SY 273 894] in front of a low cliff of White Lias (Figures 3c and d). *In situ* exposures in the lower beds are only seen at times when there is little beach shingle, a rare event in recent years. Most of the Westbury and Cotham Formations lithologies can be observed in disturbed exposures above the beach where they have been pushed up in the toe of a landslide. The dark grey pyritic mudstones of the Westbury Formation, with the Rhaetic Bone Bed at its base, rest unconformably on the Blue Anchor Formation throughout southern England. Mary Anning collected fish and marine reptile teeth and bones from the bone bed at this locality. The mudstones contain an abundant, low-diversity fauna dominated by bivalves (including *Rhaetavicula contorta* (Portlock)) and gastropods that indicate deposition in brackish lagoons that were connected from time to time to a shallow sea. The overlying Cotham Formation comprises pale green mudstones with thin bone beds, and ripple trains composed of sand and limestone ooids. The highest bed, the distinctive algal limestone known as the Cotham (Landscape) Marble, has been recorded here but only as loose blocks.

The low cliffs of *in situ* and landslipped White Lias are composed almost entirely of fine-grained, white-weathering limestone (Figure 3d). At Culverhole and elsewhere on the east Devon coast the White Lias consists of alternations of flat-bedded limestones, cross-bedded limestones that infill broad channels, and complexly distorted slumped beds. These last contain angular clasts of densely cemented limestone that have been derived from mineralised hardgound surfaces that occur throughout the succession (Figure 3e). A low diversity fauna of bivalves, gastropods and solitary corals (*Montlivaltia rhaetica* Tomes) combined with the slumping and hardgrounds suggests deposition in intertidal and shallow subtidal environments of almost normal salinity. The limestones are overlain by grey pebbly, clayey sand at the base of the Upper Greensand that rests on an irregular bored surface (Figure 4e). This, the basal Cretaceous unconformity, represents a gap of over 100 million years of Earth history at Culverhole. Westwards from there, the unconformity oversteps progressively older rocks until it comes to rest on Permian sediments west of the River Exe.

Locality 3: Culverhole Point

The group continued eastwards along the beach to Culverhole Point [SY 279 892] at the foot of the 1839 Bindon Landslide (Gallois, 2010). The boulder-strewn beach here is composed large blocks of calcareous sandstones and calcarenites derived from the Whitecliff Chert and Bindon Sandstone Members of the Upper Greensand (Figure 4f), and rounded doggers (Cowstones) of calcareous sandstone derived from the Foxmould Member. These durable blocks contrast with many published accounts of the Upper Greensand that describe the formation as a glauconitic sand. When fresh, much of the upper part of the formation consists of strong calcareous sandstones and sandy calcarenites that form vertical cliffs on the east Devon coast. They were formerly a major source of building stone that was used (under the name Salcombe Stone) for the exterior of Exeter Cathedral and numerous local churches. The fallen blocks are the best place to examine the complex bedding and bioturbation structures at this stratigraphical level, the cliff sections being mostly inaccessible. The doggers that cover the beach here were likened by some medieval romanticist to a herd of resting cows (Figure 3g), and the name Cowstones has continued to be used as a geological term.

Figure 4 right. *(**a**) At Culverhole Point, the type section of the Culverhole Hardgrounds, two erosion surfaces (A and B) separate glauconitic calcareous sandstones with partially silicified concretions (quasi cherts). The sedimentary breaks represented by the hardgrounds are present in the Upper Greensand throughout southern England. In more eastern and northern counties, where the succession is thinner than in Devon, the erosion surfaces combine to form a single hardground. Photograph courtesy of John Bennett. (**b**) The Slabs, a series of seaward dipping, thinly interbedded Jurassic limestones and mudstones include the highest bed of the Blue Lias Formation and lithologically similar limestones in the lowest part of the Charmouth Mudstone Formation: an example of fault-related lateral lithological variation over a short distance. At the eastern end of the outcrop the Upper Greensand rests unconformably on the Blue Lias. Back-tilted masses of Chalk in the distance are part of the Dowlands Landslide of 1840. (**c**) An ideal place to take refreshment in the sun and out of the wind before tackling the vegetation of the Undercliffs. Photograph courtesy of John Renouf. (**d**) The exit from The Slabs via a smooth, algae-covered limestone pavement. Large angular boulders of Whitecliff Chert and Bindon Sandstone, the most easterly remains of the Bindon Landslide, litter the foreshore. (**e**) Winter corn that had remained undamaged when Goat Island slid forward on Christmas Day 1839 was harvested in August 1840 amid great rejoicing by local village maidens dressed as attendants of Ceres, the Roman Goddess of the Harvest. Part of William Dawson's print of the ceremonial reaping (in Conybeare et al., 1840). (**f**) View north across The Chasm, now partly infilled with collapsed Upper Greensand and Chalk debris, from the northern edge of Goat Island to the in situ Upper Greensand, Beer Head Limestone (arrowed) and Holywell Nodular Chalk. Vegetated Pleistocene solution pipes infilled with collapsed Clay-with-flints and Head Deposits extend down up to 15 m into the Cretaceous rocks. (**g**) The vegetated route to Goat Island, a combination of brambles and Blackthorn that is even more unkind to GORE-TEX® than it is to Nikwax Analogy®. (**h**) Cliff of Upper Greensand and Chalk on the route from Goat Island. The porcellanous and pebbly Beer Head Limestone (arrowed), 0.5 m thick here, is the correlative of the full thickness (c. 60 m) of the Lower Chalk of the Sussex type area. The limestone contains in situ and reworked ammonites indicative of all the zones and subzones of the Cenomanian. (**i**) The outfall of the River Axe at Seaton, view west across the Axe Valley fault zone from the top of the descent that leads to the start and end points of the field trip. In early medieval times, prior to the eastward migration of the shingle spit, the river entered the sea at the western end of what is now the promenade.*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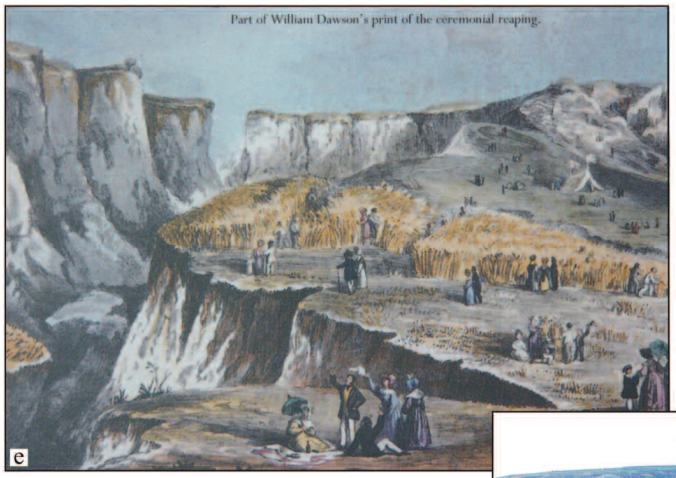
b


c


d


Part of William Dawson's print of the ceremonial reaping.
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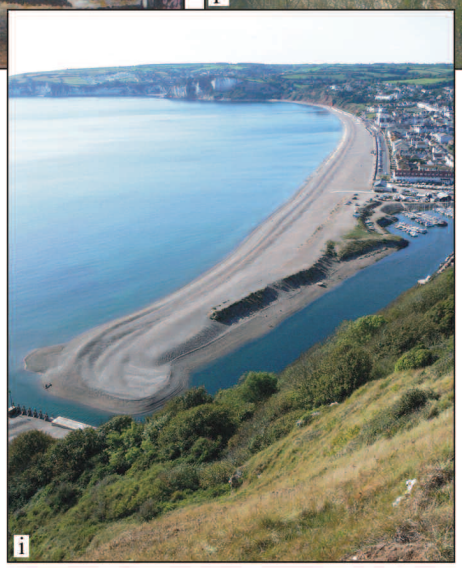
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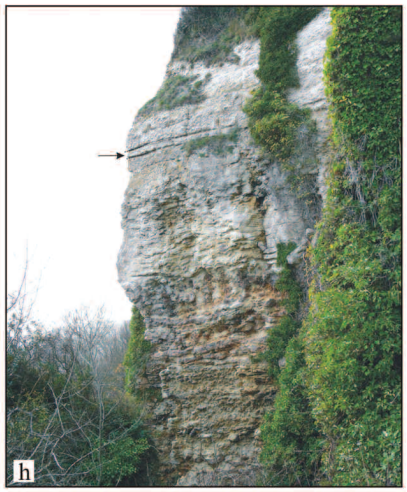
h

Culverhole Point is composed of a large mass of Upper Greensand and Chalk that remained largely intact when it was displaced from its outcrop several hundred metres to the north. It probably represents the remains of a large mass of Cretaceous rocks that was displaced during an earlier landslide and was pushed into its present position by the seaward movement of Goat Island in 1839. This is one of the few localities in Devon where almost the whole of the Upper Greensand can be accessed at or close to beach level. The formation can be divided into three members in southern England, each of which is separated from its neighbour by one or more erosion surfaces (Figure 4h). The lowest of these unconformities, the lower of the two closely spaced Culverhole Hardgrounds, is well exposed at beach level (Figures 3i and 4a). It separates the weakly calcareous sandstones of the Foxmould with its Cowstone doggers and tabular calcareously cemented beds from the highly calcareous Whitecliff Chert with its abundant chert (Gallois, 2004).

The fauna and sedimentology of the whole of the Upper Greensand indicate deposition in relatively shallow (<50 m deep) current-agitated, fully marine environments. The succession is highly bioturbated at all levels, but fossils other than thick-shelled bivalves, such as oysters and pectinids, and serpulids are rare with the result that the stratigraphical and geographical distribution of the preserved material is uneven. Species of the Albian ammonites *Callihoplites, Goodhallites* and *Hysteroceras* (Hancock, 1969) have been recorded *in situ* in slipped masses of Foxmould at Culverhole Point and from loose Cowstones on the foreshore. In contrast, there are published records of fragments of only four ammonites, all species of *Mortoniceras*, from the Whitecliff Chert in east Devon. The overlying Bindon Sandstone has yielded six species of ammonite, all from a single concentration of shells in an inland quarry, including the zonal index of the latest Albian *Stoliczkaia dispar* Zone (Hamblin and Wood, 1976).

Locality 4: The Slabs

The group continued eastwards along the beach to the series of seaward dipping limestone beds [SY 286 894] known locally as The Slabs (Figures 4b and c). The upper surface of the most prominent limestone bed is crowded with large specimens of the early Jurassic ammonite *Paracoroniceras*, which identifies it as Grey Ledge, the highest bed of the Blue Lias Formation. At Lyme Regis, 5 km ENE of here, this limestone marks a sudden upward change to mudstones with few limestone beds (the Shales-with-Beef Member). At The Slabs up to five beds of limestone are present above Grey Ledge and these should, following the formal definition of the base of the Shales-with-Beef (Cox *et al*., 1999) as the top of the highest limestone, be included in the Blue Lias. This lateral lithological variation appears to be due to an unconformity at the base of the Shales-with-Beef that cuts out successively more of the basal beds when traced from west to east (Gallois and Paul, 2009). In addition to abundant ammonites and bivalves, the site has yielded almost complete marine reptiles.

Locality 5: SW Coastal Path

The path from The Slabs (Figure 4d) to the Coastal Path passes the ruins of Landslip Cottage where walkers were served tea and cakes until the late 1930s. The cottage was built with stone salvaged from the remains of Rock Cottage after it had been destroyed by the 1839 Bindon Landslide (Campbell, 2006). An opening [SY 274 894] in the largely tree-covered Undercliffs 1 km west of The Slabs provides a view northwards of a cliff face of Upper Greensand and Chalk. Despite appearances, this is not *in situ* but is the south face of Goat Island, a *c*. 10 million-tonne detached mass of Cretaceous rocks that slid forward about 150 m over a period of several hours on Christmas Day 1839 as part of the Bindon Landslide. Fissures appeared in the cliff top on December 23rd and culminated in the main movement during the night of the 25-26th December when Rock Cottage was damaged beyond repair. This was the first landslide in Europe to be topographically and geologically recorded in detail. The published account (Conybeare *et al*., 1840) provides a description and analysis of the mechanism of a quality that few subsequent landslide studies have achieved. The landslide attracted large numbers of sightseers from all over southern England in the months that followed, including several thousand who came to observe the ceremonial reaping of winter corn that had remained undamaged when Goat Island moved seaward (Figure 4e).

Locality 6: Goat Island

The vegetated path to Goat Island (Figure 4g) leads to a gently sloping plateau with, on its south side, panoramic views across Lyme Bay to the Isle of Portland and across Torbay to Berry Head and beyond. The northern edge of the 'island' affords views across The Chasm to the *in situ* cliff of Upper Greensand and Chalk (Figure 4f) that marks inland limit of the landslide. At the base of the Chalk the Beer Head Limestone (formerly the Cenomanian Limestone) is a highly condensed, intensely bioturbated, richly fossiliferous limestone with abundant ammonites and common brachiopods, echinoids, gastropods and sponges. It was deposited in shallower, more current-agitated marine environments than those in which the typical marly chalks (Lower Chalk) of much of the Anglo-Paris Basin were contemporaneously deposited. The ammonite assemblage is especially diverse with over 50 species recorded, some of which are not known elsewhere in Britain (Mortimore *et al*., 2001). The overlying Holywell Nodular Chalk consists of nodular, gritty chalks rich in inoceramid bivalve debris.

The Coastal Path continues westwards to emerge from the wooded Undercliffs on to the Clay-with-Flints, an early Tertiary deposit that was tectonically modified in the Miocene and dissected in the Quaternary. The route back to the starting point of the trip provides splendid views of the Tertiary planation surface, and of the Upper Greensand and Chalk cliffs on the opposite side of the Axe Valley Fault Zone. An alternative more rugged route overlooks Seaton Bay and the recurved spit at the entrance to Axmouth harbour (Figure 4i).

Acknowledgements

For heath and safety reasons the general public are advised to keep to the South West Coast Path which runs the entire length of the Undercliffs National Nature Reserve. Tom Sunderland, Natural England Manager of the NNR, is thanked for his advice and guidance enabling this educational visit to access areas of the reserve away from the Coastal Path. The author is also grateful to all those members who contributed the photographs shown in Figures 3 and 4.

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