# Field excursion to the Isle of Portland on the 5th January, 2016

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The purpose of the field excursion was to examine aspects of the sedimentology, and palaeontology above and below the Portland–Purbeck transition at a number of locations. There was also an opportunity to see the raised beaches on the west and east sides of Portland Bill, as well as some of the cryoturbation structures. The Mesolithic site at Culverwell was also visited.

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## Introduction

After the Annual Conference of the Ussher Society at the Rembrandt Hotel in Weymouth, Tony Brown, Alan Holiday and Geoffrey Walton, led a field excursion to the Isle of Portland on the 5th January, 2016. The island is formed of gently folded, hard, well-jointed Purbeck and Portland limestones, overlying the Kimmeridge Clay Formation, on the northern flank of the Shambles Syncline. Jointing reflects the axes of the syncline and the NNE–SSW fault pattern of the Purbeck Anticline. This controls the pattern, distribution and size of the frequent landslides that occur on Portland (Brunsden *et al.*, 1996). The landslides occur predominantly in the winter months, after heavy rainfall, and are related to the overall evolution of the landscape which has been driven by the processes of lateral spreading, loading, clay extrusion and erosional unloading (Brunsden *et al.*, 1996).

## Chesil Beach

The first stop on the excursion was at The Heights, from where there is a spectacular first view (Fig. 1) of the longest beach-barrier system in Europe (29 km): see May (2003). It is thought to have developed in the early Holocene as a beach-barrier which then rolled inland (as sea level rose) connecting to Portland and making it appear to be a tombolo: perhaps this is a common process of tombolo formation?. The beach is composed of flint, chert and quartzites (probably from the Budleigh Salterton Pebble Beds), forming a ridge up to 14.7 m above mean high water (*c.* 18 m OD), and the pebble size increasing from west to east as a result of an increase in wave energy in the long-shore direction which prevents deposition of fine gravels and sands. It impounds a brackish water lake called the Fleet and has periodically been breached by large storms. Recent research, using ground penetration radar, has revealed the internal structure of the barrier and proposed a three-stage model of beach evolution (Bennett *et al.*, 2009). In this model the beach began as a long narrow barrier beach which moved back towards the higher ground as sea level rose in the early Holocene. In phase two the beach grew up and bulked out, probably due to a slowing down of the rate of relative sea level rise and erosion of periglacial debris at the base of the cliffs to the west. In phase three the beach humped (prograded) and moved back out towards the sea, again after relative sea level had attained (approximately) its present height around 6000 BP. Evidence of the old land-surface and coastal lagoon over which the beach developed can be seen in blocks of peat ripped up from the sediments in front of the beach and deposited on it by large storms. If relative sea level continues to rise, it is quite likely that sediment supply will not keep pace and it will breach again in the near future.

## King Barrow Quarry

After discussions of the processes involved in the formation of Chesil Beach, and also the current – and future – management of the barrier the party walked the short distance to **King Barrow Quarry**. Here the stratigraphy and palaeoenvironmental setting of the Portland and Purbeck limestones were described. Of particular interest are the fossil algal ‘burrs’ around the tree trunks in the fossil forest of the lowermost Purbeck beds (Figs 2, 3). These structures are now thought to be the product of cyanobacteria and may more probably be regarded as thrombolites comparable to those seen in the modern Lake Thetis, Western Australia (see, for example, Grey *et al.*, 1990). These are similar to the coeval exposures seen to the east of Lulworth Cove, but more easily accessed.

The lowest horizon readily accessible is the Roach (top of the Portland Stone) which are highly fossiliferous, including *Aptyxiella* (a high-spired gastropod) and *Laevitrigonia* (an highly ornamented bivalve) mostly with moldic preservation. The environment of formation was marine, as the sediment is oolitic (Townson, 1975). Moving up the sequence into the Lulworth Formation of the Purbeck Beds, relative sea level fell and a non-marine environment was established with, adjacent to low-lying land, sabkhas, lagoons, hypersaline lakes and freshwater lakes being developed. Conifer trees grew on the land surface (Francis, 1983a, b, 1996) and, when increased water levels flooded the area, the trees died off and the trunks were surrounded by algal ‘burrs’. No tree remains are visible at Kingbarrow but a fine example of a silicified tree trunk can be seen in the grounds of the Heights Hotel nearby (see cover photograph).

***Figure 1.*** *View of Chesil Beach and the Fleet from the Heights. Image © Malcolm Hart (2009).*

***Figure 2.*** *Kevin Page (foreground) explaining the setting of the fossil forest horizon in the lowermost part of the Lulworth Formation (Purbeck Group). Image © Dave Allen.*

***Figure 3.*** *Geological succession exposed in King Barrow Quarry, from the 'Roach' (Portland Stone) to the Great Dirt Bed (lowermost Lulworth Formation). Image © Alan Holiday.*

## Portland Bill

After the short drive to Portland Bill the party visited the well-known raised beaches on both on the western and eastern cliffs. Portland Bill is the classic location in Southern England for studies of Pleistocene raised beaches (Campbell *et al*., 1998). Originally only one beach was recognised which was attributed to high global sea levels during the last interglacial: the Ipswichian (or Eemian in Europe) and which is now correlated with marine isotope stage (MIS) 5e or 5.5. This beach at 6–10 m above present sea level and has been identified from many locations in the British Isles, although chronometric dating has been relatively sparse. It is now believed that there are, in all probability, at least three fossil beaches on Portland. The classic study by Davies and Keen (1985) used a combination or levelling, biostratigraphy and early amino acid racemisation dating to show that the West and East Raised Beaches were probably of different ages.

The West Beach, which extends under the Admiralty Underwater Weapons Establishment (AUWE), which could only be viewed from a distance (Fig. 4). It consists of up to 2.5 m of well-sorted sandy gravel in as many as seven fining upward units grading from pebbles to coarse sand. It only contains shelly fossils at the base and these include rocky-shore gastropods (*Nucella lapillus, Littorina littorea* and *Patella* spp.) and a number of species of the bivalve *Cerastoderma*. The party were able to visit the East Beach, which crops out on the eastern cliff between the Bill and Longstone Ope Quarries. The gravels are poorly-sorted and generally thin, and are also heavily deformed by cryoturbation. Although this deformation is generally thought to be post-depositional there is some evidence of cryoturbation of the underlying Purbeck limestone below undeformed gravels. The deposits are richly fossiliferous and dominated by rocky-shore gastropods (*Littorina* spp., *Gibbula* spp., *Patella* spp., *Nucella lapillus*) and the bivalve *Turtonia minuta*. Levelling shows that the base of the West Beach lies at 10.76 m OD and the base of the East Beach lies at 6.95 m OD. The amino acid racemisation D/L ratios (D-alloisoleucine: L-isoleicine) suggested that the East Beach is older than the West Beach and they correspond with MIS 7 (*c*. 210,000 BP) and MIS 5e (125,000 BP). The difference in height between the beaches is most likely attributable to regional uplift (Westaway, 2011).

A point of discussion was also the head deposits which lie above the raised beach. These comprise a succession of loams (loess), with calcareous nodules, which thicken inland. These sediments also display extreme periglacial deformation (frost heaving) which extends into the bedrock (Fig. 5). Ostracods suggest the presence of brackish pools, so it is likely that these loams were deposited adjacent to a high sea level and, stratigraphically, should date to the last cold stage (Devensian). It was stressed how the new discovery of an intermediate raised beach on Portland (Gallois, 2013), and the revised chronostratigraphy on Portland, illustrates that – around the southern British Isles (and Ireland) – there are multiple wave-cut platforms and beach deposits of a variety of ages, and that they do not all date to interglacials with high eustatic sea levels. The relative role of isostatic depression and eustatic change in creating this 'staircase' of Late Pleistocene erosional and depositional coastal features has yet to be fully disentangled.

***Figure 4.*** *The West Beach on Portland Bill, which is located immediately below the fences of the Admiralty Underwater Weapons Establishment (AUWE). Image © Malcolm Hart.*

***Figure 5.*** *John Renouf looking for fossils in the Whitbed of the Portland Limestone at Sheat Quarry. Image © Dave Allen.*

## Culverwell

After lunch the party walked along the eastern coast and then inland to the Mesolithic site at Culverwell. Here we were welcomed by a group of archaeologists led by Martin Blundell from the Association for Portland Archaeology who kindly gave us guided tours of this important archaeological site. Culverwell is the only open-air Mesolithic archaeological site easily visible, and open to the public, in the British Isles. The Mesolithic is the period from the beginning of the Holocene (*c.* 11,700 BP) to the development of agriculture in the Neolithic period (*c.* 6000 BP). During this time-period the humans who occupied the British Isles and Ireland were hunter-gatherer-fishers/foragers (h-g-fs). The classic Mesolithic site in Britain, which has formed our typical view of Mesolithic life, is Star Carr in the Vale of Pickering, Yorkshire, but this is an inland lake edge site and is of early Mesolithic age. Culverwell presents a rather different picture and is, therefore, of great archaeological value.

The site which lies at 26 m OD above the cliff on the eastern flank of Portland, was excavated from 1968–1997 by Susann Palmer and the Association for Portland Archaeology, with the results published in 1999. The excavated site is located on a spring-line and is 270 m north from the modern Culver Well. Trenching suggests that the site extends over 700m$^2$. Surrounding the site is a medieval lynchet system which had collapsed over the site. The stratigraphy of the site consists of a shell-dominated midden deposit preserved within a natural gully. This midden contains of mostly *Patella* spp. (limpets), *Monodonta lineata* (thick top shell), *Gibbula umbilicus* (purple top shell), *Littorina littorea* (edible periwinkle), *Littorina obtusata* (flat periwinkle) and *Nucella lapillus* (dog whelk) and it is thought to be the remains of food consumption resulting from coastal foraging activity. The three most abundant species show significant changes in frequency through the midden: Thomas and Mannino (1998) have interpreted this as possible resource depletion due to over-gathering. Only two fish bones were recovered and a few teeth (mostly of pig) but the charcoal included oak, hazel, ash, blackthorn/cherry and hawthorn/apple. Radiocarbon dating of charcoal from the shell midden deposits has given dates of 6350–5700 BC and 5620–5360 BC and, along with AMS dating of shells, this suggests an overall range for site occupation of *c.* 7200–7000 BP. More recently, Mannino *et al.* (2003) have used oxygen isotopes to try and estimate the season of collection of the inter-tidal gastropod *Monodonta lineata* with data from Culverwell suggesting autumn to winter, with possibly some early spring collection. This suggests that the site might have been a seasonal camp. In addition to the midden, it is claimed that above the midden a living-floor is preserved with the remains of a low wall (possible windbreak), and four hearths possibly for cooking using the hot-stone method. The site is rich in artefacts and particularly microliths, scrapers, knives, chopping tools, pounders and picks. These picks are particularly important as they are characteristic of Portland ('Portland Picks') and are distinctively mid–late Mesolithic.

Overall the archaeology suggests that a small group of Mesolithic people may have lived on the site, on what was at the time a true island, in a few simple huts overlooking the sea and within or close to mixed deciduous forest. The site is now owned and managed by the Association for Portland Archaeology and remains of great potential and importance for our understanding of Mesolithic life in the British Isles.

## Sheat Quarry

After the visit to Culverwell, the party moved northwards to Sheat Quarry which we entered from the coastal footpath. Portland Stone is one of the principal building stones produced in a significant quantity in the UK and the visit to the island's eastern coastal strip concentrated on the economic geology of the stone as exposed along the coastal path near Southwell and in the remains of the abandoned Sheat Quarry. Three beds of Portland Limestone Formation that lie immediately below the base of the Purbeck beds are of commercial interest (1). From the top these are:

1. **The Roach**. This is a very shell-rich limestone, honey-combed by the often empty moulds of marine fossils, merging below into a more solid, oolitic and shelly limestone. It is mostly about 1.5 m thick. Some silicified fossils and small chert nodules often occur near the top of the unit. The Roach is sometimes used externally, as in the base of the Olympic Monument at the Heights, but is mainly used for internal decorative stonework.
2. **The Whitbed**. This bed is commonly 2–3 m thick and is less shelly than the Roach. It is the strongest of the three beds. Locally it can show rapid variations of thickness and some foreset bedding is often inclined at angles of < 45°, with chert nodules along the inclined bedding in places (Townson, 1975). Chert nodules are also often found towards the base of the bed. This bed is widely used in external cladding. It was formerly used as a blockstone: i.e., as a component part of the load bearing structure in buildings such as St Paul's Cathedral (post-1666) and the Mansion House (1619–1622) in London.
3. **The Basebed**. This bed is less shelly and is whiter than the overlying beds. It is a slightly weaker stone than the Whitbed: near Southwell it is up to about 1.25 m in thickness and in places was not worked locally, probably due to the presence of chert. However, it is seen in the market as 'traditional Portland Stone' and is a valuable material for cladding and memorials. It was only exposed below the coastal path.

The recovery of stone for masonry purposes typically requires the removal of large blocks suitable for routine processing with semi-automated saws to produce regularly sized slabs for cladding, etc., as well as for other architectural uses such as lintels, sills and mullions. The *in-situ* block sizes are governed by the frequency and spacing of the main joint sets. There are four main joint sets on the island, all of which have been identified near Southwell and some of these have complimentary sets. The most obvious set is the NNE–SSW trending set, known locally as the 'southers' which were seen as joint faces running sub-parallel to the coastal path. As elsewhere in Jurassic and some other strata, master joints have been opened up by cambering processes during Quaternary periglacial conditions to form gulls sometimes up to 0.6 m wide and partially filled with collapsed fines from the overlying Purbeck Beds. Other joint sets trend NW–SE, NE–SW, ESE–WNW and all trends have a variation of about +/- 15°.

As indicated above, chert is often irregularly present and its occurrence is a major constraint on the selection of suitable stone as it seriously damages saws used in ornamental stone production. Variations in bed thickness, and especially the presence of foreset bedding, also act to restrict the volume of recoverable rock. Stone not suitable for masonry is used for coastal defence work or crushed for construction fill.

These several factors act to significantly reduce the volume of recoverable stone for masonry use. Observations from active quarries indicate that only 12% of the combined *in-situ* thickness is recovered for masonry work: this can be improved by about a third to 16% by using in-pit masonry saws and wire cutting techniques. With careful layout and modern underground room and pillar mining using saws, etc., the recovery reaches 30%. Hence, for a 6 m thick column of the three beds, the recovery by basic quarrying methods would be about 0.6 cubic metres per square metre in plan. The preferred way to work Portland Stone near Southwell would be by underground mining. No site investigation consistent with current good practice has been undertaken of the Portland Stone resource in this area and the recoverable tonnage of the un-worked consented deposit near Southwell is a resource – not a reserve – and is at best, a partially proven resource. Any future quarry workings would need to comply with a recent Modification Order requiring such workings to stay at least 3 m behind the crest of the slope above the coastal footpath as well as being compliant with the findings of an Environmental Impact Assessment consistent with a modern review of the mineral planning permission.

Sheat Quarry, worked until the middle of the last century, was seen from a track leading off the coastal path. There is a 20 m high southern face in which up to 13 m of Purbeck strata were present and would need to be removed if conventional quarrying techniques were used to win the underlying Portland Stone. The existing face, without benches, currently breaches Quarries Regulations guidance. Several of the limestone beds in the Purbeck have previously been recovered for masonry purposes, but if quarried all the overburden is likely to be excavated, re-handled and used in approved restoration by backfilling. The northern face of the Sheat Quarry is backfill from the previous workings with up to 4 m of stacked blocks at the toe of the slope. The blocks are of a size that, today, would commonly be used for coastal defence, with un-compacted general quarry waste placed behind and above the stacked blocks. This slope is also about 20 m high and would not have been placed in a manner consistent with modern quarry practice: i.e., in accordance with the current Quarries Regulations. The duty to ensure the stability of such slopes is defined under the 1971 Tips Regulations as the responsibility of the local authority and the land owner; under the 1999 Quarries Regulations the duty lies with the quarry operator.

The field excursion ended back at the car park and the party dispersed at 16.30.

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