Portland Bill

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Highlights

Portland Bill is one of the most important raised beach sites in Britain. It shows evidence of pre-Stage 5 shoreline deposits and terrestrial sediments, a Stage 5 raised beach deposit and Devensian head. The beach sediments and Devensian head have yielded mollusc faunas which have been used to reconstruct former environments and for amino-acid dating.

Introduction

Portland Bill is one of the few places on the south coast where two separate raised marine deposits, in association with terrestrial sediments, can be demonstrated. The site was first described by De la Beche (1839) who noted the existence of marine deposits. Later authors mentioned aspects of the succession and its fauna (Bristow, 1850; Weston, 1852; Damon, 1860; Whitaker, 1869; Prestwich, 1875; Baden-Powell, 1930; Arkell, 1943, 1947; Green, 1943; Carreck, 1960; Pugh and Shearman, 1967; Macfadyen, 1970; Mottershead, 1977b). Of these, Prestwich's (1875) description was the most comprehensive and has been used by most later writers as a stratigraphical basis. The marine fauna was summarized in detail by Baden-Powell (1930). In recent times, full descriptions of the deposits and their included faunas have been published by Keen (1985) and Davies and Keen (1985). The latter authors also presented preliminary isoleucine epimerization data to provide a geochronology for the deposits. This method was also used by Bowen *et al.* (1985) who suggested alternative dating schemes.

Description

The full Quaternary sequence at Portland Bill [SY 677 681] does not occur in superposition in any single section, and separate localities and deposits are needed to describe the sequence adequately. The key elements comprise the Portland West Beach and the Portland East Beach (Davies and Keen, 1985), and the Portland Head and Loam (Prestwich, 1875; Arkell, 1947; Keen, 1985) which are described separately below and shown in (Figure 6.1).

Portland West Beach

The earliest comprehensive description of this part of the site was by Prestwich (1875). The main section today stretches for 40 m south of [SY 6750 6860] in the grounds of the Admiralty Underwater Weapons Establishment (AUWE). The widespread occurrence of loose beach gravel, for 200 m south of the current section, probably indicates the former extent of the raised beach deposits. The beach deposit also crops out at [SY 6805 6885] in a disused quarry 100 m south-west of the Old Lower Lighthouse (now the Portland Bird Observatory). The beach deposits rest on a lightly wave-smoothed surface cut in Jurassic limestone. In the main AUWE section, the beach consists of up to 2.5 m of well-sorted sandy gravel arranged into as many as seven fining-up units, each grading from pebbles to coarse sand (Figure 6.1). The deposits are planar-bedded and cemented by calcium carbonate, although considerable voids also occur. The pebbles of the beach comprise a variety of lithologies: flint makes up between *c.* 85–90%, with the remaining clasts comprising chert and limestone from the local Portlandian, and quartzite, chalk, and Greensand. In addition to these pebble-types, Prestwich (1875) noted ferruginous grit (Tertiary), micaceous sandstone (Devonian), red and purple sandstone (Triassic), red feldspar porphyry and red granite. The source of much of this non-local material was probably the South-West Peninsula. The Portland West Beach is largely devoid of shelly fossils, except in its basal layers, but enough fragments of rocky shore gastropods — *Nucella lapillus* (Linné), *Littorina littorea* (Linné), *Patella* spp. and bivalves *Cerastoderma* spp., *Mytilus edulis* (Linné) — were recovered for amino-acid analyses (see below).

Portland Loam and Head

The Portland Loam and Head were also first described in detail by Prestwich (1875). The two units rest on the cemented shingle of the West Beach and are best seen in the AUWE section (Figure 6.1). The deepest part of the section shows the following sequence:

4. Head with limestone clasts and small quantities of mollusc shell (1.2 m)

3. Silty head with numerous shells (1.4 m)

2. Silty head with few clasts and very numerous shells (0.3 m)

1. Loam with calcareous pellets and topped with a weathering horizon (0.5 m)

The loam is devoid of shell, despite Prestwich's (1875) assertion that both loam and head are shelly. Keen (1985) showed that the calcium carbonate content of the loam had been completely reworked so that no shell remains were present. This reworking has allowed the development of calcareous concretions in the loam which is otherwise silty in texture and devoid of coarser material, except for a few pebbles near the base derived from the underlying raised beach deposits.

The head (beds 2, 3 and 4) overlies the loam with a sharp boundary (Figure 6.1). The matrix of this deposit also consists largely of silt, but limestone clasts, up to 0.25 m long, are also present. Both the loam and the head are crudely bedded, with the former dipping south at 3°, with individual beds being picked out by lines of calcareous pellets. The head is more steeply inclined at 5–10° to the south. The top metre of the head is disrupted by periglacial structures similar to the festoons described widely in southern England (Williams, 1975). Deeper disruption occurs near the south-eastern end of the section where an inclined zone of disturbance reflects reverse faulting under periglacial conditions (Keen, 1985; (Figure 6.1)). At its eastern extreme, the entire thickness of the head deposit is disrupted by periglacial structures which extend into the Jurassic bedrock (Pugh and Shearman, 1967). The head is not decalcified and contains abundant land shells. The total fauna comprises fourteen species of which only three — *Pupilla muscorum* (Linné), *Lymnaea truncatula* (Müller) and the slug genus *Deroceras* sp. — are numerous (Keen, 1985). The head also contains fossil ostracods which may have lived in small brackish pools on the land surface where the head was accumulating (Keen, 1985).

Portland East Beach

The deposits of this beach crop out north-eastwards for 1.5 km between Portland Bill and Longstone Ope Quarries (SY 688 691; (Figure 6.1)). They consist of subangular clasts of Portland and Purbeck limestone with a few pebbles of flint and chert and calcareous fossil debris in a sandy matrix. The largest clasts are *c.* 60 cm in diameter and in places these represent the whole thickness of the beach. Elsewhere, the beach deposit is less than 45 cm thick and consists of shell which infills interstices between the larger clasts. The deposits of the beach are structureless, probably due to post-depositional cryoturbation (Pugh and Shearman, 1967). Unlike the West Beach, the East Beach is almost entirely uncemented and is richly fossiliferous: a 2 kg sample from the most fossiliferous part of the exposure, 200 m north-east of Portland Bill, yielded 6670 individual shells (Davies and Keen, 1985). The fauna is dominated by rocky shore gastropods — *Littorina* spp., *Gibbula* spp., *Patella* spp., *Nucella lapillus* (Linné, *Rissoa* spp., and the bivalve *Turtonia minuta* (Fabricius). A total of 34 gastropod taxa, one chiton, and 17 bivalve taxa were recorded from the East Beach by Davies and Keen (1985). A further seven species of gastropod and four species of bivalve were recorded by Baden-Powell (1930). Other faunal remains include foraminifera, *Balanus* spp. plates, and crab and echinoderm fragments (Davies and Keen, 1985).

Interpretation

The sequence of deposits at Portland Bill provides evidence for two high sea levels and two phases of terrestrial deposition in the Upper Pleistocene. Amino-acid ratios (D-*alloisoleucine:*L-*isoleucine*)derived from fossil shells in the sequence, enable these events to be placed in relative stratigraphic order and provide a tentative chronological framework.

Portland West Beach

Planar bedding in this sediment indicates that the Portland West Beach was deposited under high energy conditions. The few shell fragments it contains are suggestive of sea temperatures no colder than now and a sea level perhaps 10 m higher (Davies and Keen, 1985). Amino-acid D/L ratios suggest the beach is older than the East Beach and Davies and Keen (1985) concluded that an age of 200 ka t 30 ka BP was likely. The West Beach could therefore have been deposited during Oxygen Isotope Stage 7 of the oceanic record.

Portland Loam

The decalcified nature of this deposit makes it difficult to determine its environment of formation and its age. However, it may be a slope deposit and, since it overlies the West Beach, it must be younger than Oxygen Isotope Stage 7. A Stage 6 age for the loam seems probable and thus the weathering horizon which separates it from the head may have formed in the temperate conditions of Stage 5 (see below).

Portland East Beach

The thin deposits of the East Beach (< 0.6 m) give little sedimentological evidence for its conditions of deposition. However, its fauna, more extensive than that from any other raised beach deposit on the south coast, gives comprehensive details of the contemporary marine environment and, through amino-acid D/L ratios, of its age. The earliest detailed work on its fauna was by Baden-Powell (1930). He concluded that sea temperatures were approximately 4°F (2.2°C) colder than those of the current Channel, because 'northern' species of mollusc, such as *Margarites helicinus* (Fabricius), were present. Recent work by Davies and Keen (1985) shows that most of the fauna comprises species still found today in the Channel. Molluscs with a restricted northern range, such as *Tricolia pullus* (Linné), outnumber those with a northern distribution today, thus indicating that sea temperatures were no colder than at present. These conclusions are supported by fossil foraminifera recovered from the East Beach. These comprise, exclusively, modern-day English Channel-types, including one species — *Elphidium crispum* (Linné) — which is now found no farther north than the Channel (Davies and Keen, 1985).

Amino-acid ratios presented by Davies and Keen (1985) suggest that the Portland East Beach accumulated during Oxygen Isotope Stage 5e. The ratios were calibrated with a Uranium-series date obtained from travertine in similar raised beach deposits at La Belle Hougue Cave, Jersey, some 130 km to the south (Keen *et al.,* 1981). Further amino-acid D/L ratios derived from raised beach shells elsewhere in western Britain (Bowen *et al.,* 1985) suggest that the Portland East Beach could be younger than Oxygen Isotope Stage 5e, perhaps dating from Stage 5a. These amino-acid ratios were obtained by a different preparation method and gave slightly lower, thus younger, ratios than those obtained from other raised beach sediments in South Wales: the latter were dated by Bowen *et al.* (1985) to their Pennard, or 5e, Stage.

Portland Head

The sediments and included fauna of the Portland Head together are indicative of a terrestrial origin. Because the species of mollusc found in the head can still be found in Britain today, both Prestwich (1875) and Arkell (1947) assumed that it had formed under conditions like those of the present. However, the deposit is ill-sorted, contains angular clasts and has a restricted fossil mollusc fauna indicative of open-ground conditions. Together, these characteristics point to the deposit having accumulated under cold conditions (Keen, 1985). Its age, however, is uncertain. The fauna it contains is unlike those of Devensian late-glacial deposits described from Kent (Kerney, 1963; Keen, 1985), and the occurrence of the relatively thermophilous mollusc, *Helicella itala* (Linné), appears also to rule out a Middle Devensian age. These comparisons led Keen (1985) to propose that the head accumulated during the Early Devensian and was then cryoturbated in the Middle or Late Devensian.

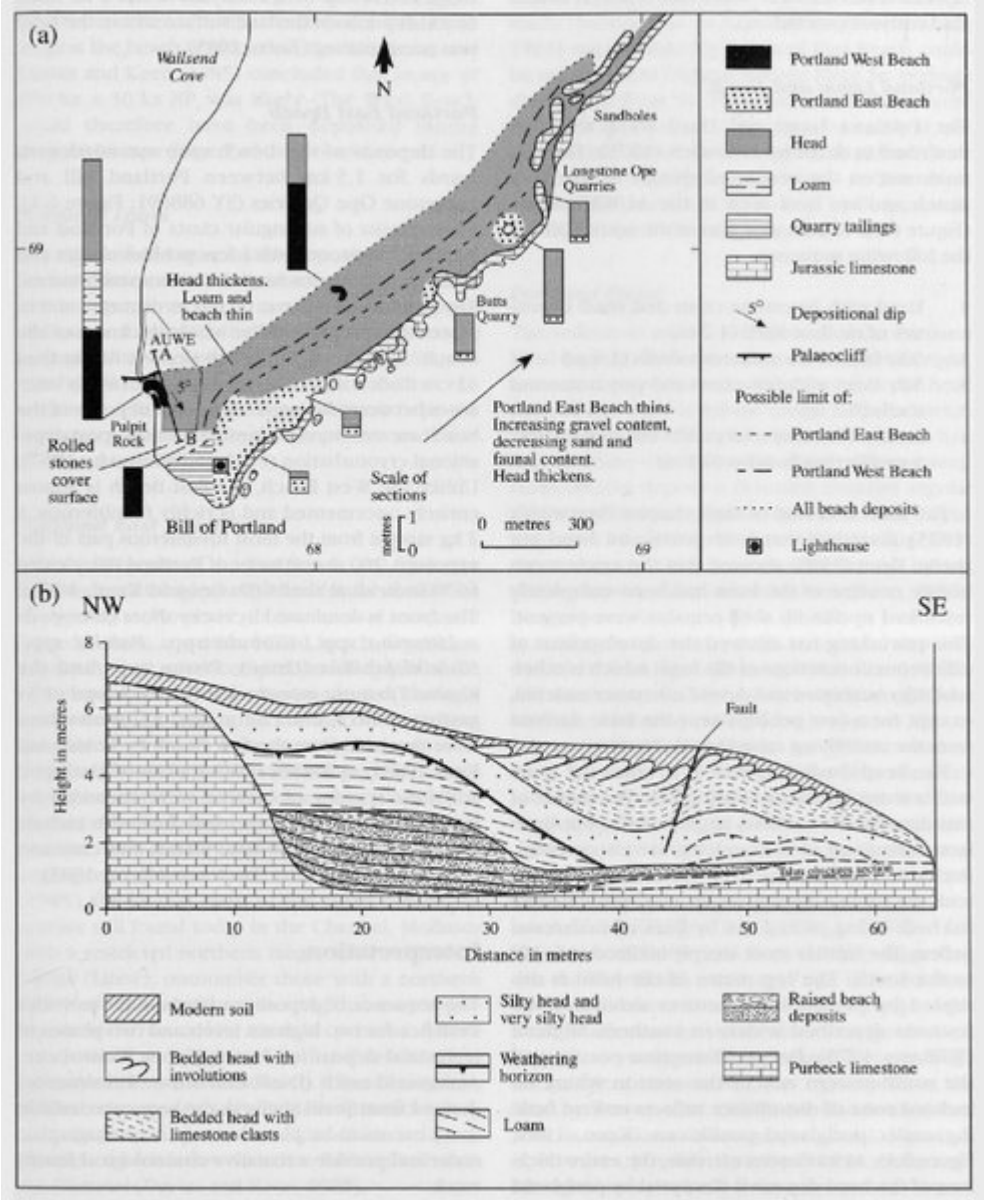
Bowen *et al.* (1989) presented a small number of amino-acid ratios derived from *Trichia* shells in the head: the deposit was considered to have accumulated during Oxygen Isotope Stage 7. This is at variance with Davies and Keen's (1985) suggestion that the West Beach is of Stage 7 age. If the Portland Head indeed dates from Stage 7, then the age of the West Beach must be much older, Oxygen Isotope Stage 9 at youngest. The Oxygen Isotope Stage 7-equivalent

amino-acid ratios reported from the head by Bowen *et al.* (1989) are also inconsistent with its origin as a cold-stage, periglacial, deposit. It is, however, possible that the *Trichia* shells were reworked into the head from a 'temperate' Stage 7 terrestrial deposit, but no such source has so far been identified at Portland. At present, the least problematical interpretation of the sequence is to regard the West Beach as an Oxygen Isotope Stage 7 deposit, and the overlying loam and head as cold-climate materials formed later in the Pleistocene.

Conclusion

The Pleistocene deposits on Portland Bill present a fascinating association of terrestrial and marine sediments ranging from perhaps 200 ka BP. The faunal content of the marine units is unrivalled along the south coast and allows a palaeoenvironmental reconstruction of considerable detail and value. The use of amino-acid geochronological techniques has enabled this complex of marine deposits to be dated to Oxygen Isotope Stages 7 and 5 of the deep-sea record: this preliminary ascription might suggest that the cold-climate deposits and structures at the site date from Oxygen Isotope Stages 6, 4 and 2. The evidence of two raised beach deposits, of different ages, confirms Portland Bill as a critical reference site with regard to interpreting coastal Pleistocene sequences throughout southwest Britain.

References



(Figure 6.1) (a) Quaternary deposits at Portland Bill, adapted from Davies and Keen (1985). (b) The Quaternary sequence at AUWE, adapted from Keen (1985). The cross-section follows line A–B shown in plan above.