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# Broughton Bay

## Highlights

A remarkable Devensian multiple till sequence yields evidence of former ice limits. Raised beach sediments and derived faunal elements in the till provide evidence for an earlier temperate interglacial event in the Ipswichian.

## Introduction

Broughton Bay [SS 417 930] is a site of considerable interest, for its deposits contain materials that have been used to date major geomorphological events and changing environmental conditions of regional significance since the Ipswichian Stage. Sedimentologically, the deposits are interesting because of their glaciotectionic structures. Holocene dune sands overlying the Pleistocene sediments also contain dateable horizons. Although the Pleistocene sequence has only been revealed by coastal erosion within the last 10 years, the site has attracted considerable interest, and it was first described by Campbell *et al.* (1982) when an amino acid analysis of molluscan shells was published. Further, similar dating was discussed by Davies (1983), Bowen (1984), Campbell (1984), Campbell and Shakesby (1985, 1986a, 1986b), Bowen *et al.* (1986) and Worsley (1986). The site was also described by Campbell and Shakesby (1982, 1983), Stephens and Shakesby (1982), Bridges (1985) and Shakesby and Campbell (1985). Details of the Pleistocene and Holocene sequences can be found in Campbell (1984), and Lees (1982, 1983), respectively.

## Description

The exposures run east from Twlc Point [SS 417 931] for about 300m and attain a maximum thickness of about 10m. The stratigraphy (Campbell 1984) is:

7 Holocene dune sand

6 Colluvium (1.5m)

5 Soliflucted till and head (5.0m)

4 Stony till (5.0m)

3 Bedded till containing marine shell fragments and pieces of wood (2.0m)

2 Limestone head (0.5m)

1 Raised beach conglomerate

The stratigraphy at the site is shown in (Figure 9). The basal raised beach deposits are fragmentary and are only found near Twlc Point. They rest on a Carboniferous Limestone, probably marine-cut, platform and contain abundant marine shell fragments, principally of *Littorina littoralis* (L.). The raised beach grades upwards into limestone head, which is overlain by till units in which the bedding is often well defined, and from which an assemblage of 21 identifiable shell species has been recognised (MacMillan *in* Campbell *et al.* 1982; Campbell 1984). Wood fragments (Salicaceae) have also been recovered. Overlying the shelly tills (bed 3) and a thin discontinuous sand and gravel layer, is an unfossiliferous bed of stony till (bed 4), which is succeeded by redistributed till, head and colluvium. The colluvium fills well developed cracks which penetrate the stony till, and, in plan, form a polygonal pattern. Both the shelly and stony tills at Broughton Bay show glaciotectionically induced folds, most clearly displayed by close bedding in the shelly till. These structures are also seen, under favourable circumstances, in plan form on the foreshore. The structures appear as gentle anticlines and synclines in the sections and in an elliptical pattern elongated north to south on the beach (Campbell 1984).

## Interpretation

The results of amino acid analysis of specimens of *Littorina littoralis* from the raised beach deposits indicated an Ipswichian Stage (Campbell *et al.* 1982) age, but shells from the till (bed 3) were of similar age or possibly slightly younger. However, faunal evidence suggested that the assemblage of shells in the till was fully interglacial, with several species found only at more southerly latitudes today. Campbell *et al.* (1982) concluded that it must have been ice of Devensian age and no older, which, moving southwards across the eastern part of Carmarthen Bay, incorporated shell litter that had accumulated during the preceding interglacial; the fabric pattern and erratic content of the shelly till at Broughton Bay was consistent with this view. A study of amino acid ratios from raised beaches around Gower by Davies (1983), showed that most of the deposits were of the same age, and they were provisionally ascribed to the Ipswichian (Oxygen Isotope Sub-stage 5e). This study included further data from Broughton Bay. With an improved method of analysis, and using calibration provided by Uranium-series ages from Bacon Hole Cave, it was confirmed that the raised beach deposits at Broughton Bay could be ascribed to Sub-stage 5e (Bowen *et al.* 1985; Bowen and Sykes 1988).

The data of Campbell *et al.* (1982) did not, however, determine the point at which the Broughton Bay (shelly) Till was deposited during the Devensian, and attempts were made to establish the age more precisely by radiocarbon dating of Salicaceae fragments (Campbell and Shakesby 1985). An initial determination of >42,000 (HAR-5443) was obtained by radiocarbon dating. A second sample was dated using the isotopic enrichment method and yielded a date of 68,000 +13,000 –5,000 BP (GrN –12508). Campbell and Shakesby noted a relatively close correspondence between the Broughton Bay date (GrN –12508) and the date of 60,800 ± 1500 BP (GrN –1475) (for example, Worsley 1980) for the Chelford Interstadial site in Cheshire. They concluded that the wood may therefore have been from a temperate willow species growing during the Chelford Interstadial but later incorporated into the Broughton Bay Till by ice of probable Late Devensian age. They had doubts about the radiocarbon date, however, and did not rule out an Ipswichian (or even earlier interglacial) or pre-Pleistocene age for the wood. Worsley (1986) noted that the date could be seriously misleading, and suggested that its apparent association with the Chelford Interstadial event was possibly the result of a radiocarbon assay on contaminated material, and this possibility was acknowledged by Campbell and Shakesby (1986b).

Bowen *et al.* (1986) recorded that the till at Broughton Bay contained shells of *Macoma balthica* (L.), the youngest of which (by amino acid and radiocarbon dating) could be shown to be Late Devensian (c. 17,000 BP) in age (see also Bowen and Sykes 1988) and therefore indigenous, unlike the derived Ipswichian elements. Although a Late Devensian age for the till was also favoured by Campbell and Shakesby (1986a), certain difficulties were noted in reconciling the new radiocarbon and amino acid dated evidence to existing data from the site. Amino acid ratios from *Macoma* correspond with ages of c. 17,000 BP elsewhere in the Irish Sea Basin, and could show that the shelly diamict is glacio-marine in origin — see Chapter 1.

Campbell (1984) applied a variety of detailed techniques, including Scanning Electron Microscopy, to interpret the following sequence of events at Broughton Bay. 1) During high sea-levels in the Ipswichian Stage, the raised beach deposits (bed 1) accumulated. 2) Towards the end of the Ipswichian, as climate deteriorated and sea-level fell, the Loughor Estuary and Carmarthen Bay became dry land. 3) During the Late Devensian, ice advanced southwards across the Loughor Estuary and Carmarthen Bay, incorporating marine shells, pieces of wood and estuarine sediments, and depositing tills (beds 3 and 4) at Broughton Bay. The stony upper till represents farther travelled debris within the ice-sediment profile, although it is believed to have been deposited contemporaneously with the lower till. 4) Following the wastage of Late Devensian ice, a phase of periglacial conditions occurred, and the upper layers of the till were rearranged by solifluction, and deposits of locally-derived head were formed (bed 5). Frost-cracking of the head and till deposits may have occurred during this periglacial phase, and surface washing of the unvegetated sediment surface may have given rise to the colluvial deposits (bed 6) which filled the cracks and capped the sequence.

The Quaternary sequence at Broughton Bay is completed by Holocene dune sands (bed 7) which run the full length of the bay, but which reach their maximum height west of Broughton Farm. The archaeology and depositional history of these dunes was studied by Lees (1982, 1983). The age of the dunes is not yet clear, but it appears that they were already in existence by the Roman period, with a renewed phase of sand mobility in late Mediaeval times when intense storms are known to have affected much of the South Wales coast (Lees 1982, 1983).

Considerable interest is provided by the glaciotectionic structures in the Pleistocene sequence at Broughton Bay. The origin of these structures has not yet been established, but various models of formation have been suggested (Campbell and Shakesby 1983; Campbell 1984). The Late Devensian ice-sheet may have been near its maximum extent locally, and the contortions in the till layers could have been caused by oscillations of this ice front. Alternatively, the structures may have formed as a result of differential ice or overburden loading. Campbell and Shakesby (1983) and Campbell (1984), however, thought that they resulted from horizontal stresses set up in the sediments as the constricted ice moved southwards between Burry Holms and Llanmadoc Hill.

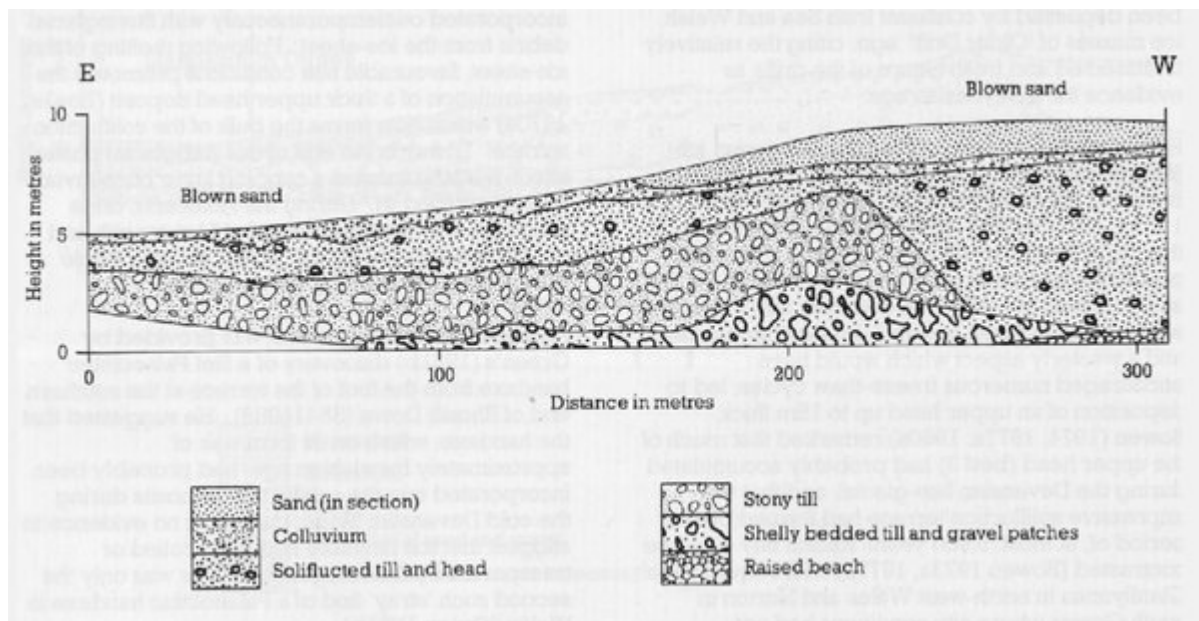
Stratigraphic data from Broughton Bay and other Pleistocene sites in Gower, suggests that the Late Devensian ice-sheet was near its maximum southward limit at Broughton Bay. It is only at Broughton Bay, and east of Llangland Bay (east Gower) that till *in situ* is seen to overlies raised beach sediments of Ipswichian age (Bowen 1984). This shows that the Late Devensian ice-sheet impinged upon the east and west margins of the peninsula where major valley glaciers emerged from the South Wales Coalfield. Broughton Bay is notable for being the only permanently exposed multiple till sequence in central South Wales, and for being one of the first sites in Britain where both glacial and interglacial beds have been dated by amino acid geochronology.

Broughton Bay provides a record of Late Pleistocene environmental changes in central South Wales, and in particular, new evidence for the glacial and interglacial history of west Gower. Its raised beach conglomerate, deposited during Oxygen Isotope Sub-stage 5e (Ipswichian Stage) is overlain by a sequence of tills deposited during the Late Devensian. Glaciotectionic deformation structures in the till, and Holocene dune sands with archaeological and organic material, enhance the interest of the site.

## Conclusions

Broughton Bay shows a sequence of deposits which span the last 125,000 years or so. It also provides an important constraint on the limit of the last Welsh ice-sheet. The shell fauna from some of the glacial deposits could be evidence that the earth's crust was depressed considerably in this area about 17,000 years ago.

## References



(Figure 9) Quaternary sequence at Broughton Bay (after Campbell et al. 1982)