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A RE-EXAMINATION OF THE VALLEY-FILL DEPOSITS AT WEST ANGLE BAY, PEMBROKESHIRE

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The cliffs at West Angle Bay in Pembrokeshire [SM 853 031] display till, apparently of pre-Devensian age, overlain by a sequence of Late Pleistocene deposits. This section has been the subject of conflicting interpretations and has remained enigmatic since it was first described by Cantrill for the British Geological Survey in 1916. A re-examination was prompted by the discovery of new macrofossil material and the fact that, although part of the section has been described as "marine" or "estuarine" in character by various authors, there is no published record of any systematic micropalaeontological work to support such an interpretation.

The picture that has emerged from the current work is that of a valley excavated in bedrock during the Early Pleistocene and subsequently filled by till during a glaciation which transported erratics of igneous material and sediments of Mesozoic and Westphalian age from the north and west. During a subsequent interglacial, drainage was impeded by the build-up of a dune belt at the coast. Alluviation took place in a slack behind the dune belt and it is some of this material that is now exposed in the coast section.

Subsequent cold cycles were marked by gully erosion and by two phases of solifluction. Deposits from the early phase are distinguished by the fact that they contain re-distributed erratic material. There is also evidence for landslipping or subsidence involving partially frozen ground, perhaps following the erosion of a coastal dune belt.

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INTRODUCTION

West Angle Bay [SM 853 031] displays an exposure of till which is apparently of pre-Devensian age, overlain by a sequence of Late Pleistocene deposits. The site therefore offers significant evidence of the glacial history of Wales but previous workers have produced conflicting interpretations. The work was summarized in the Geological Conservation Review by Campbell and Bowen (1989), but the conflicts remained unresolved.

The main section, indicated on Figure 1, is about 100 m in length with additional exposures in the small bay to the north. A succession of workers, notably Cantrill (1916), Dixon (1921), John (1969; 1970), Mitchell (1972), and Bowen (1974; 1977), have described the stratigraphy, while Stevenson and Moore (1982) made a detailed examination of the palynology of a monolith obtained from the southernmost part of the section. Much of the exposure is on the seaward face of a relatively narrow baulk of unworked material between an infilled brick pit and the sea and, following recent erosion, this baulk is collapsing and little of it now remains undisturbed. Some of the material exposed has been variously regarded as estuarine (John, 1970), marine (Bowen, 1974), or of salt marsh origin (Stevenson and Moore 1982) and presented as evidence of an interglacial marine transgression during which sea level reached at least 4.5 m O.D. (John, 1970) but there is no published record of any micropalaeontological work to support this. The recent development of models for glaciation in the Celtic Sea by Eyles and McCabe (1989) and Lambeck (1995; 1996), together with the suggestion from Bowen (1994) that the "giant erratics" of southwest England may have been emplaced by ice-floes during pre-Devensian Heinrich events, has emphasised the importance of sections that offer field evidence for coastal events and a chronology against which such new ideas can be tested.

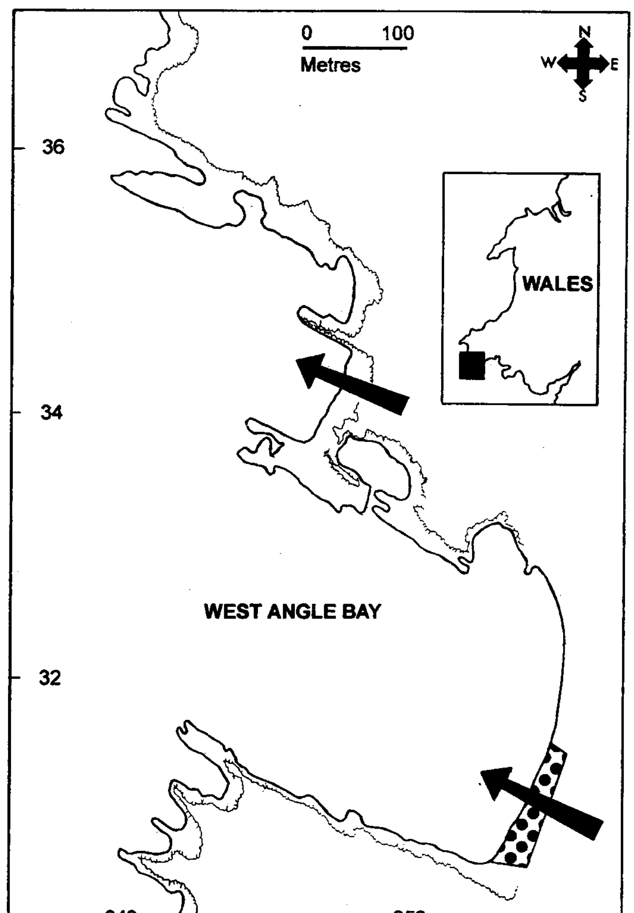

Figure 1. West Angle Bay. The main section is stippled. Two major infilled gulleys are marked by arrows.

SOLID GEOLOGY

West Angle Bay lies in the eroded core of a syncline in the Lower Limestone Shales. The main axis of this structure is crossed by a series of parallel faults trending north-east — south-west which break the shore platform on the south side of the bay into a series of flat reefs. One of these faults defines the eastern shoreline of the bay and the protection from wave action afforded by the reefs is probably responsible for the preservation of the Pleistocene section in the south-eastern corner. The material is preserved in a shallow valley excavated in the Lower Limestone Shales with the valley floor at about the present mean tide level.

DRIFT

Previous workers have generally regarded the main section (Figure 2) as complex. However, although slumping has obscured parts of the cliff face from time to time, it was possible to re-examine all the units described by previous workers during the summer of 1995. The simplified succession below was published by Campbell and Bowen (1989) and for the purpose of comparison these sequence numbers are retained in the following account.

Unit 5 - Sandy loam

Unit 4 - Red gravel

Unit 3 - Sands, silts, loams and peat

Unit 2 - Cemented raised beach deposits

Unit 1 - Irish Sea till

The conflict of ideas can be demonstrated by the fact that Unit 4 has been previously interpreted as till (John, 1969), a soliflucted till of Saalian age (Mitchell, 1972) and head (Bowen, 1977).

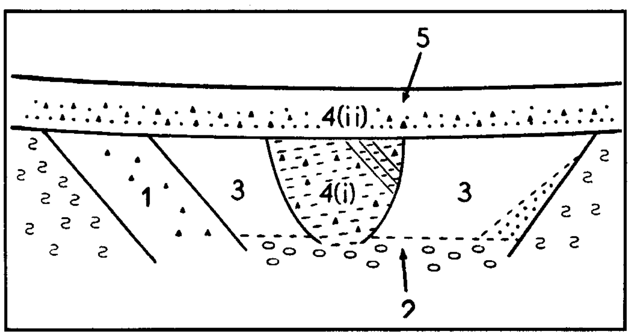

Figure 2. The main section in West Angle Bay with the unit numbers used in the text.

Unit 1. The oldest material to be exposed in the cliff section can be divided into two facies, with distinctly different characteristics. These may be examined at beach level below the Dwr Cymru pump house at the northern end of the main section and correspond to the descriptions of Dixon (1921), who had access to exposures in the old brick pit while it was still actively worked, and of Bowen (1974) who relocated them by "mechanical excavation".

The basal facies is a dark bluish-grey (5B4/1) plastic clay interbedded with bands of silt, which rests upon a weathered surface cut from the Lower Limestone Shales. This is succeeded laterally by a grey and more sandy facies (5GY5/1). It is unclear from the present exposure whether there is a simple succession or if the two facies are tectonically mixed but, from examination of more extensive exposures in the old brick pit, Dixon (1921) clearly regarded them as a succession. The basal facies is pyritiferous and is composed entirely of clay-silt grade material, with no sand. Dixon (1921) suggested that this was either Lower Limestone Shales "rotted *in situ*" or an ancient estuarine mud. The first of these suggestions can be rejected as the the clays dip steeply southwards, while the bedding of the underlying Lower Limestone Shales is horizontal. In addition the author has recovered an abraded valve from a bivalve of Ostrea type and, although care must be taken not to place too much significance upon a single sample, this seems to preclude a Carboniferous age. An estuarine origin also seems unlikely in view of the steep dip, while a careful examination failed to discover any evidence of the fauna that would characterize an estuarine environment.

The upper facies is also composed predominantly of clay-silt grade material but can be distinguished from the material below by its colour and by the presence of a fine sand fraction. This facies was clearly identified as a till by Dixon (1921) who recorded scratched clasts and erratics from former exposures in the old brick pit and his observations were supported by Bowen (1974). An examination of the sand fraction shows that it contains fresh, angular, quartz grains and considerable quantities of muscovite together with small chips of vitrinite.

Although the evidence is limited, it is clear that the two facies are distinct and that neither is of local derivation. The vitrinite in the upper facies is likely to be derived from the Coal Measures (Westphalian) which also contain fluvial sandstones rich in detrital muscovite. In contrast, the absence of sand from the basal facies suggests a predominantly fine-grained source with the presence of Ostrea indicating that it is derived from strata younger than the Carboniferous. Accepting the views of Dixon and Bowen that the upper facies is till, the presence of material derived from the Carboniferous is consistent with glacial transport from the north-west, although the wide distribution of the source material does not rule out glaciation by Welsh ice from the north-east. There is no such obvious local source for the basal facies. If this is also till, then it may well be derived from the floor of Cardigan Bay to the north-west where substantial thicknesses of Mesozoic strata have been proved since the pioneering work of Dixon. The incorporation of Jurassic or Lower Cretaceous material would account for both the presence of Ostrea and the physical properties.

Unit 2. In the central part of the section Unit 1 is succeeded by a bed, approximately 0.5 m thick, iron-stained and cemented and containing pebbles in a sandy matrix. Although recorded as "raised beach" by John (1969) and Bowen (1974), this is not well exposed, being usually concealed by the modern storm beach, and in view of its thickness and elevation cannot safely be interpreted as evidence of a sea level higher than the present. Indeed, the limited extent of the exposure would make it difficult to distinguish from a washover fan produced, possibly, by a single storm event. On the present day coast, in locations such as Freshwater West, the upper limit of storm waves is marked by fans of this type along the base of the dunes and the exposure of iron-stained sands banked up against the cliff face at the extreme southern end of the West Angle section may well be a relic of former dunes in just such a situation.

Unit 3. The pebble bed is succeeded by a series of light grey (5GY7/1) sandy silts, horizontally-bedded and approximately 2.5 m thick. These fill a valley form, overlapping the clays of Unit 1 at the northern end of the section and the sands of Unit 2 to the south. They contain a few, thin, gravel layers and a few discrete layers containing woody detritus. Stevenson and Moore (1982), who carried out detailed pollen analysis of a monolith through this part of the section, referred this wood to Alnus. This unit has generated much of the interest in this site as previous workers (John, 1969; Bowen, 1974; Stevenson and Moore, 1982) have interpreted this unit in terms of a marine phase requiring a HWM at least 4 - 5 m O.D. and have argued that it provides evidence of deepening water and therefore a marine incursion during the Ipswichian (Oxygen Isotope Stage 5e). However, no marine indicators have been recorded.

In order to make a detailed re-examination, a series of 1.0 kg samples was collected from representative and apparently undisturbed sections of the face during the summer of 1995. One thin gravel layer was sampled and proved to contain angular rock fragments of local type but no shell fragments nor any indication that deposition took place in a marine or estuarine environment. The rest of the material was prepared for examination using standard micropalaeontological techniques. It consisted predominantly of silt with minor medium-fine sand containing a high proportion of well-rounded grains. The material had clearly not been decalcified since it contained calcareous grains which could be leached out with acid. Of the six samples subjected to detailed examination, four were barren, while only two contained distinguishable shell fragments as a minor proportion of the 250μ fraction. All shell material was finely comminuted and rounded with no fragments large enough to be retained on a 500μ mesh. The same two samples also yielded a total of eleven tests of common foraminifera (all well preserved) including *Quinqueloculina seminulum*, *Ammonia beccarii*, *Elphidium* sp. and two planktonic forms. Bearing in mind that the samples were relatively large, and that all size fractions were exhaustively searched, it seems likely that the presence of a relatively small number of foraminiferal tests associated with sand-size shell material can be attributed to windblow and that they do not represent an indigenous fauna. The presence of well-rounded (quartz) sand grains and the high degree of sorting supports the view that this material was introduced by spasmodic reworking from local dunes. Equally significantly for the interpretation of the local environment Stevenson and Moore (1982) recorded the aquatic taxa, *Sparganium*, *Potamogeton*, *Typha*, *Nuphar*, *Nymphaea* and *Polygonum amphibium* together with *Valeriana* officinalis, indicating the presence of areas of open, fresh, water bordered by a tall herb-marsh community. Their data also indicate a regional flora with the trees and woodland species characteristic of a temperate (interglacial) environment and they tentatively suggest a "Hoxnian" age for the deposit. Since estuarine muds deposited in a temperate environment typically contain a substantial fauna with forams, ostracods and small gastropods, as well as larger bivalves etc. the lack of marine fossils makes an estuarine origin for this unit appear unlikely and the earlier interpretations should be questioned. It seems more reasonable to interpret Unit 3 as an alluvial deposit characterised by pools of fresh water. Other taxa present, *Hippophae*, and *Plantago maritima*, could be derived from a surrounding dune community. Stevenson and Moore (1982) also noted a record of *Ruppia maritima* by Turner, but the presence of a species which is usually associated with brackish pools does not conflict with this interpretation as a marshy valley among coastal dunes.

Unit 4(i). This forms a prominent buttress about 4.0 m high in the middle of the section extending the full height of the cliff and breaking the lateral continuity of Unit 3. It is composed of reddish-brown gravel (7.5YR7/6), poorly sorted, with coarse angular clasts in a sandy matrix. Clasts are of local red marl and red sandstone together with substantial quantities of rhyolite and dolerite. Igneous rocks do not outcrop south of Milford Haven and glacial transport is a likely agent for their delivery from north Pembrokeshire. The material is massive and structureless in parts but there are finer units that show crude bedding with a dip of about 10° towards the centre of the feature. This bedding is cut by a set of parallel, small-scale, faults that dip steeply outwards with displacements of 30 cm or so, giving some lateral extension of the beds. These faults do not extend into the surrounding silts which are weakly consolidated and show no sign of tectonic disturbance. Minor faults of this type in porous, friable, materials probably develop while the material is frozen and are typical indicators of permafrost. There are signs of differential movement between the gravel fill and the surrounding silts and the faulting must have occurred as a result of settlement or landslipping before the movement of the mass to its present attitude was completed and before the deposition of the "upper head" of Unit 4(ii). John (1969) interpreted this material as till but the presence of crude bedding together with a degree of sorting and a weak fabric leads the author to support the view of Bowen (1974) that it is head. The presence of far-travelled erratics may indicate that this incorporates till from an earlier glaciation as suggested by Mitchell (1972). This unit appears to be the fill of a steep-sided depression, possibly a channel, cut into Unit 3. Again, in view of the weakly consolidated nature of the silts of Unit 3, this would be consistent with a phase during which the ground was deeply frozen. A similar section is well exposed in the bay north of West Angle where a depression has been excavated along a crush-zone in the Lower Limestone Shales.

Unit 4(ii). This is widely distributed as a thin layer capping the whole section. It is composed of reddish, poorly-sorted gravel (10YR7/6) with coarse, angular clasts of local Red Marl and sandstone in a matrix of sandy silt. Access to locations near the clifftop is difficult but, in contrast with Unit 4(i) no far-travelled erratics of igneous material were obtained from this unit. In the bay north of West Angle the unit is up to 1.0 m thick and there is a clear uncomformity, marked by an erosion surface and by a colour change, between Unit 4(i) and the overlying Unit 4(ii). A similar unconformity is recorded for the main bay by John (1969) but this was less clear at the time of writing. This hiatus indicates that Unit 4(ii) should be interpreted as a distinct upper head recording a period of erosion followed by a final phase of solifluction. The absence of far-travelled erratics of igneous material suggests that, unlike Unit 4(i), the material available at this stage was of purely local derivation. At the base of Unit 4(ii) there is a layer of finer material that lacks clasts and which may be analagous to Unit 5 indicating a period of weathering and soil development separating the two events. This has not yet been investigated but it is worth recording that at other sites, for example Frenchman's Bay (SM 801 307), there seems to be a similar division between an upper and lower head so that the feature is widely established.

Unit 5. The head of Unit 460 grades upwards into the ubiquitous orange silty layer (10R6/3) that is widespread throughout Pembrokeshire and South-West England and generally described as "Sandy Loam" by previous workers. This deposit is up to 0.5 m thick and forms the parent material for the modern soil profile. It has been much disturbed by agriculture and by the activity connected with the former brickworks and lime kilns and was not investigated in detail during the present study.

SUMMARY

It has proved possible to re-examine all of the lithological units described by the previous workers cited in this paper and the proposed sequence of events outlined below takes note of their observations. There seems to be general agreement on the reality of an early glaciation. Two distinct glacigenic facies are present but it is not possible to say whether they represent a single event. There is no evidence to support the views of John (1969, 1970), and Bowen (1974) that the section at West Angle records a subsequent interglacial sea level substantially higher than at present, nor is there support for the suggestion of John (1969, 1970), that Unit 4 is in part a till of Devensian age, although it may contain recycled glacigenic materials. There is no new direct evidence for the dating of the events described but, if Unit 3 is of Ipswichian (Oxygen Isotope Stage 5e) age (John, 1970; Bowen, 1974), the whole of the complex sequence of events following the deposition of Unit 3 must have taken place within the Devensian. The suggestion by Stevenson and Moore (1982), that the palynological evidence fits better with a "Hoxnian" age, offers a much longer time scale.

The picture that has emerged from this work is that of a valley excavated in bedrock during the Early Pleistocene and subsequently filled by till (Unit 1) during an early glaciation which transported igneous material and both Mesozoic and Westphalian sediments from the north and west. Later the buried channel was partially re-excavated, probably by stream action. During a subsequent interglacial, sea level reached approximately the same level as at present (Unit 2) and drainage was impeded by the build-up of a dune belt at the coast. Alluviation (Unit 3) took place in a slack behind the dune belt and it is some of this material that has been preserved. Subsequent cold cycles were marked by a phase of gully erosion and by two phases of solifluction, the first of which re-worked tills and re-distributed erratic material to fill depressions (Unit 4(i)), during episodes in which soils were frozen to a depth of several metres. There is also evidence for landslipping or subsidence involving partially frozen ground, perhaps following erosion of the coastal dune belt. The final phase of solifluction represented by Unit 4(ii) appears to follow a period of erosion and soil development.

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