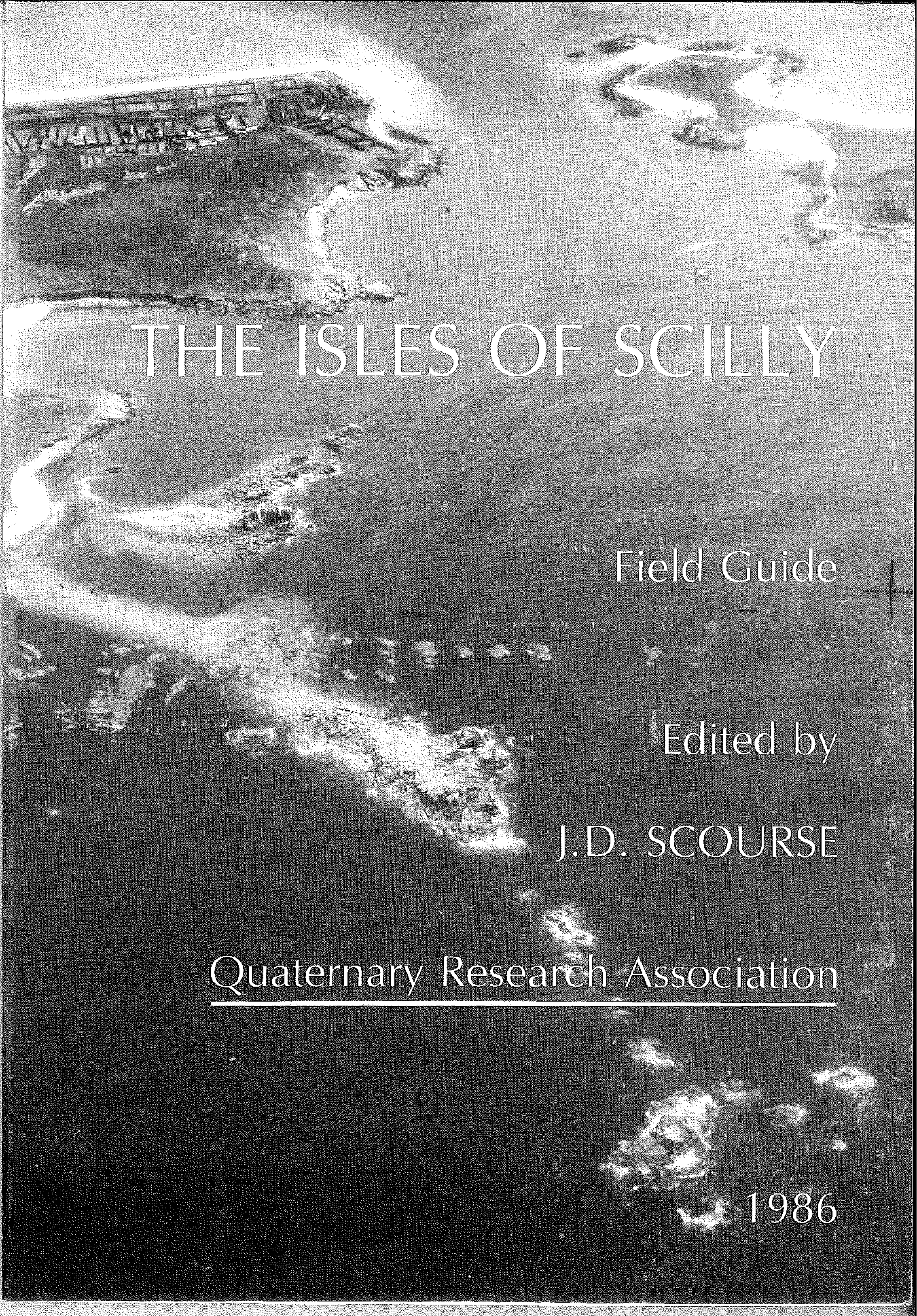

THE ISLES OF SCILLY

Field Guide

Edited by

J.D. SCOURSE

Quaternary Research Association

1986

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QUATERNARY RESEARCH ASSOCIATION

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Cover photograph: oblique aerial photograph of White Island, St. Martin's and Tean taken from the north-north-east, showing Chad Girt, White Island Bar, Pernagie Bar and Porth Seal (see pages 90-99).

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FIELD GUIDE TO THE ISLES OF SCILLY

6 - 8 SEPTEMBER 1986

Field Meeting Organiser and Field Guide Editor: J. D. Scourse

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PREFACE

Along with Fremington in North Devon and Trebetherick in North Cornwall, the Isles of Scilly have, since the 1960's, featured as one of the critical points in the extrapolation of the limit of the Wolstonian glaciation along the northern shores of the South West Peninsula. As such their position must be familiar to many students of the British Pleistocene. Despite the significance of the evidence preserved on the Scillies, which arises directly from the work of Mitchell and Orme (1967), this is the first excursion to the islands to be organised specifically to review Quaternary features. The islands are also particularly rich in archaeological material, much of which has a bearing on the recent sea level history of the area (Fowler and Thomas, 1979; Thomas, 1985).

All this, combined with the beauty of the islands themselves, would seem to be justification enough for an excursion. However, a number of factors make early September 1986 a particularly auspicious time for this visit. Much evidence has recently accumulated which tends to contradict the conclusions of Mitchell and Orme (1967) concerning the Pleistocene stratigraphy of the islands and the age of the sedimentary units present (Scourse, 1985). The excursion will provide a valuable opportunity for discussion and interpretation of this contradictory and conflicting evidence on site. Secondly, new evidence has recently been published concerning the Flandrian vegetational history of the islands, from both mire sites (Scaife, 1980; 1983) and archaeological soil sites (Dimbleby, 1977, Greig and Keeley, 1978: Dimbleby et al., 1981, Evans, 1983). The relevance of such palaeoecological studies to island biogeography is always significant, especially so in this case given such major problems as the possible existence of glacial refugia on the continental shelf (Huntley and Birks, 1983), and the location of early Flandrian land bridges to Ireland (Devoy, 1985). Thirdly, Professor Charles Thomas's major synthesis of thirty years of archaeological field work and research in the islands, "Exploration of a Drowned Landscape : Archaeology and History of the Isles of Scilly" was published in 1985; the weekend of 6th-7th September coincides with a particularly large tidal range* which will hopefully enable the examination of the significant submerged features which he describes.

* The spring tidal range (MHWS) as St Mary's is 5.0m, the neap tidal range (MHWN) 2.3m. On 6th September the tidal range is predicted at 4.6 m.

The Field Guide is divided into two main parts. The first part presents reviews of the three major themes covered by the excursion, the Pleistocene stratigraphy, Flandrian vegetational history, and archaeology. The second part deals with the individual sites to be visited on the excursion and is divided into three reflecting the respective islands visited on the three days of the excursion, the first part dealing with St. Mary's, the second St. Martin's and Nornour, and the third day Tresco and Samson. The excursion routes and stops are given in Figures 1 - 4. The first day on St Mary's will deal with the Pleistocene stratigraphy outside the glacial limit (i.e. sediments of colluvial, littoral and aeolian origin), Flandrian vegetational history and archaeology. The second and third days will concentrate on the Pleistocene stratigraphy inside the glacial limit

The recommended Ordnance Survey map is the 1:25,000 Special Sheet covering the Isles of Scilly.

ACKNOWLEDGEMENTS

James Scourse would like to thank all his colleagues in Cambridge, and in particular his supervisor, Professor R.G. West, for constant help, encouragement, advice and field assistance. For assistance in the preparation of this Guide, he would also like to thank Dr J.R. Hawkes (BGS, Keyworth) for current information on the solid geology, including permission to quote freely from the Guide to the Scillies prepared for the IMM Conference (September, 1985), Dr J. Catt (Rothamsted Experimental Station, Harpenden), Dr J. Dowdeswell (Scott Polar Research Institute, Cambridge) for computer analyses of fabric data and Dr J.R.M. Allen (drawing and general assistance), Joan Lewis (typing) and Bill Rowntree (photography) for technical assistance. For financial support he would like to acknowledge NERC and Girton College, Cambridge.

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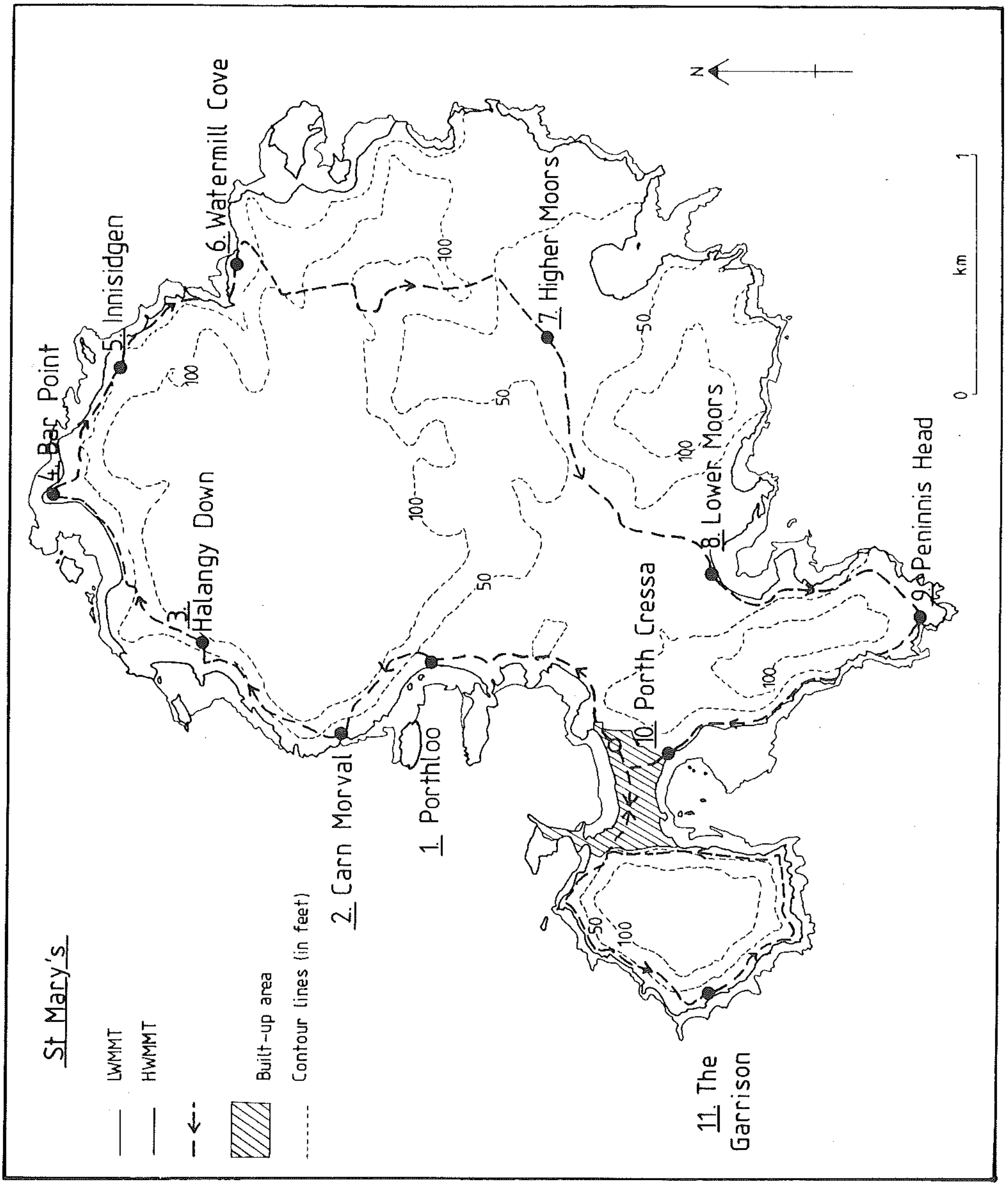


Figure 1. St.Mary's - excursion route

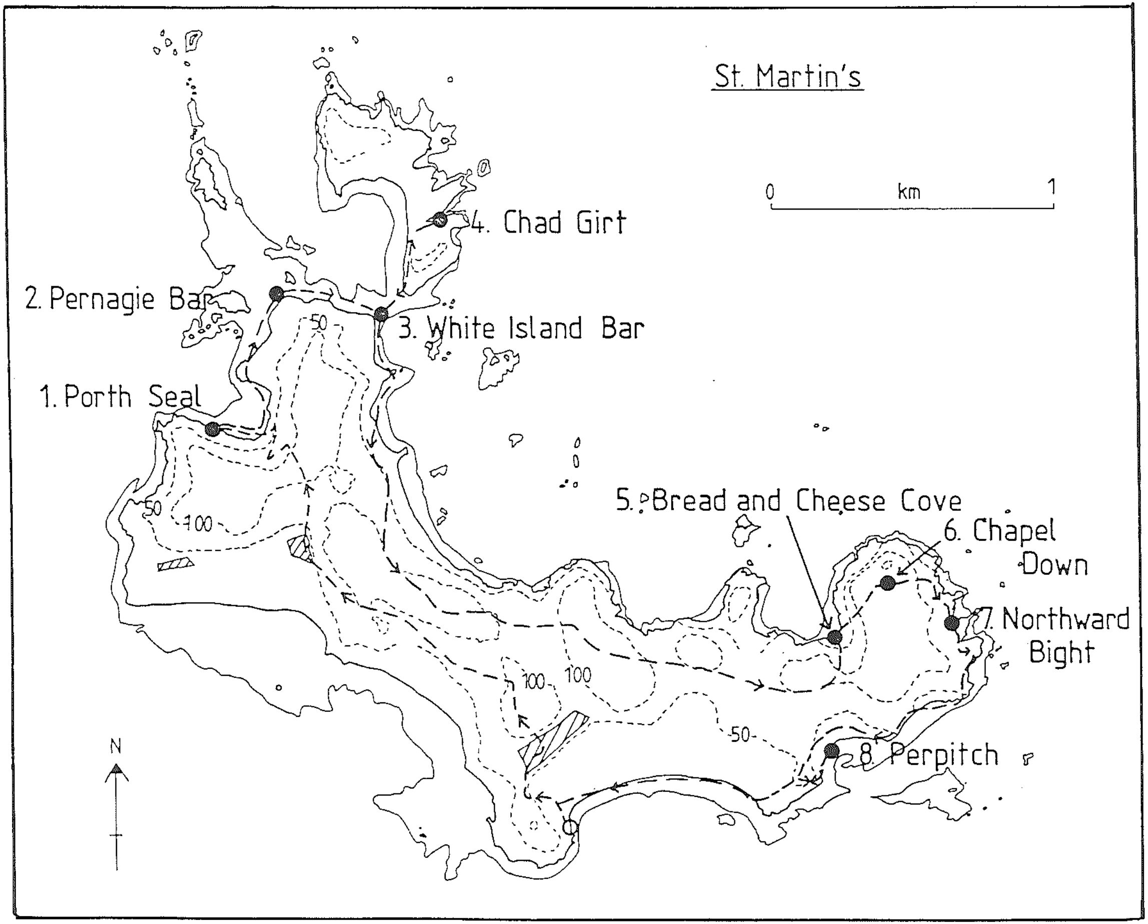
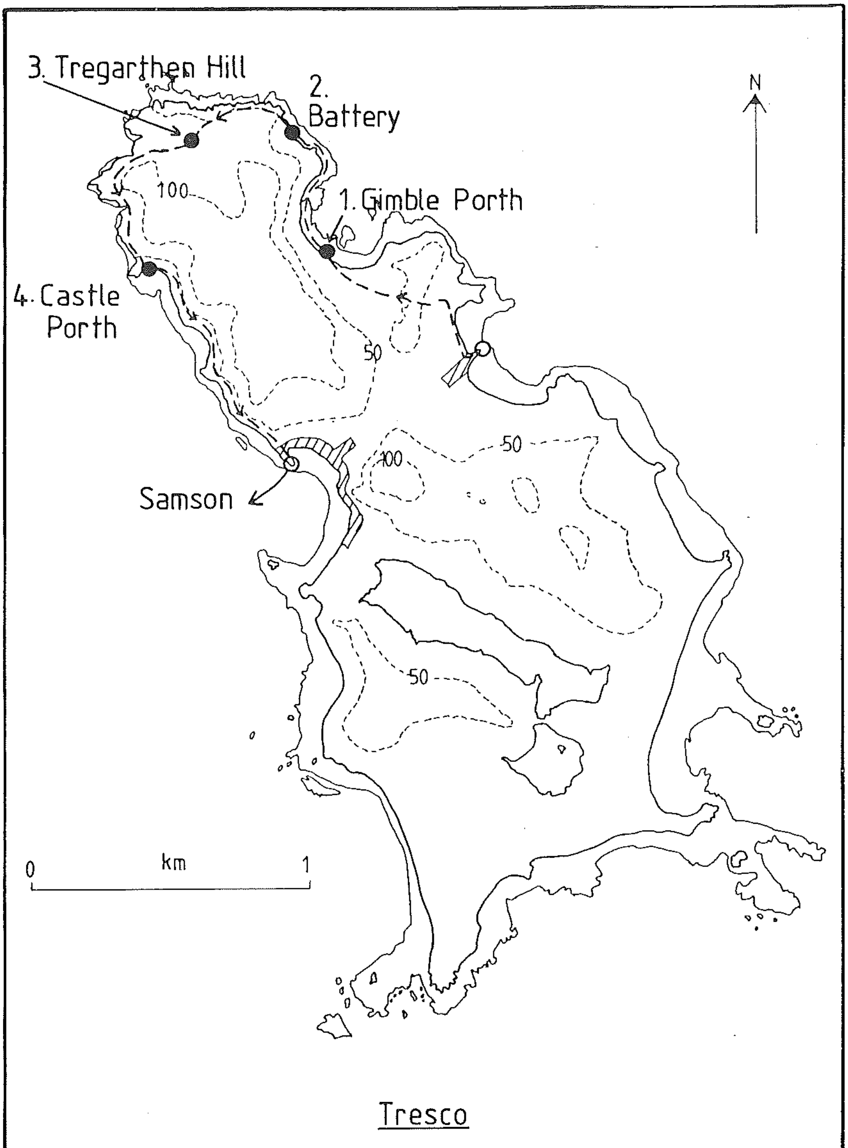


Figure 2. St.Martin's - excursion route



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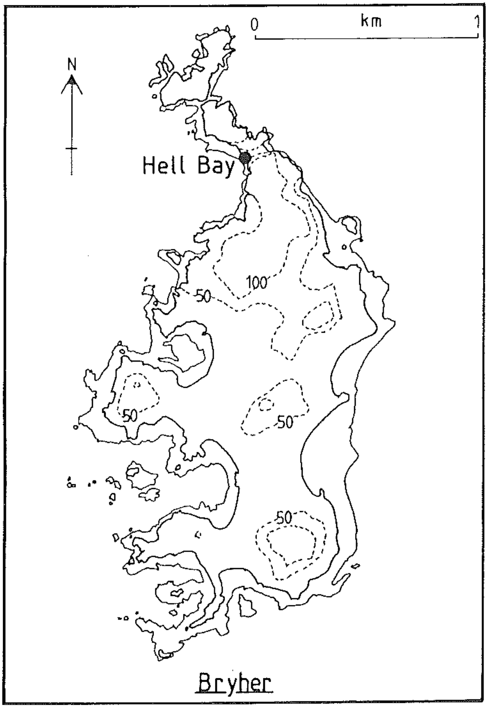


Figure 5. Bryher - site location

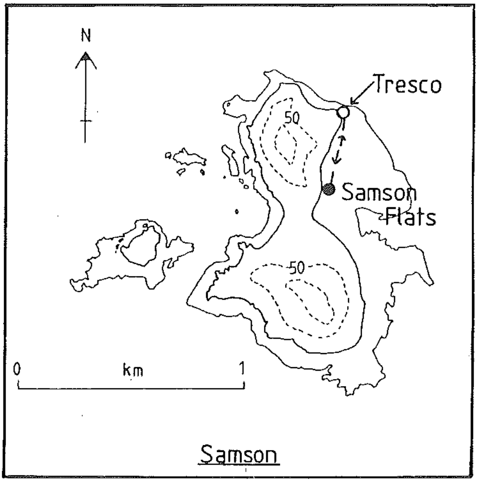


Figure 4. Samson - excursion route

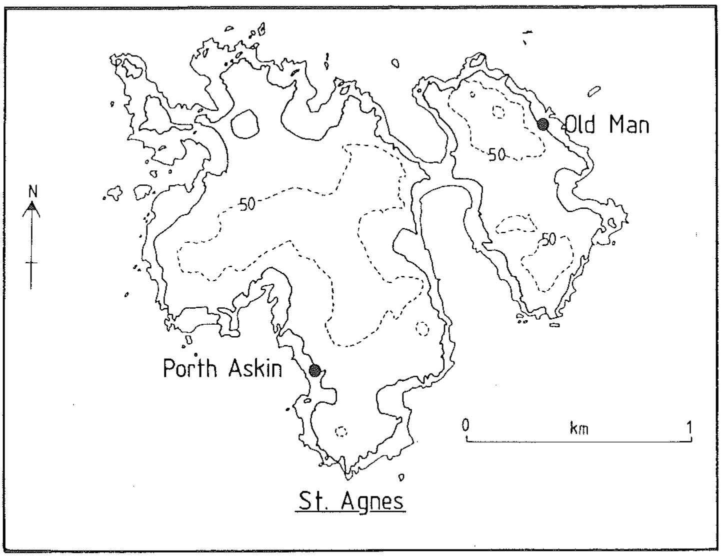


Figure 6. St.Agnes - site locations

INTRODUCTION

The Isles of Scilly lie some 40 km west-south-west of Land's End (Fig.7). At the present time, assuming sea level at OD, there are over two hundred islands in the Scilly archipelago, though the vast majority of these are devoid of terrestrial vegetation and soil, and project only a few metres above high water. The five largest islands are permanently inhabited: St. Mary's, St. Martin's, St. Agnes, Tresco and Bryher (Fig.7). The largest island of St. Mary's measures approximately 4 x 3.5 km and can be comfortably walked around in one day. The highest point of the group is Telegraph Hill on St. Mary's at 41.16m.

The solid geology of the islands is dominated by granite, a unifying influence that has assisted in the identification of foreign and erratic material. The intrusion of the granite and consequent metamorphism of the country rock occurred during the closing stages of the Armorican (Variscan) orogeny and a single large batholith is now exposed as six cupolas, five on the mainland, including Bodmin Moor and Dartmoor, and one, largely submerged, forming the Isles of Scilly; a seventh, Haig Fras, forms a submarine outcrop some 100 km to the west-northwest (Fig.9). These cupolas, and the mineral veins associated with them, appear to follow the north-east/south-west trend typical of the Caledonian fold axes (Edmonds et.al.,1975). Seismic data and dredged samples suggest that the islands and reefs represent only the north-western two-thirds of a roughly oval granite pluton approximately 200 km in surface area. The SE portion suffered downfaulting during Mesozoic and Tertiary tectonic movements associated with the development of the English Channel and Irish Sea. Although broadly Variscan in age, K/Ar and Rb/Sr isotopic data from various of the Cornubian plutons have yielded a spread of ages from 310 to 265 Ma (Dobson and Rex, 1971).

Though Cornubia is one of the most heavily mineralised districts on the earth, the Scillies themselves lie only on the fringe of this district. Nevertheless, there are four exposures of elvan (quartz-porphyry) dyke (on St. Mary's, St. Agnes and Annet), and abundant thin zones of greisening (Fig.8), many of which have been emphasized by denudation. Cassiterite has been recorded from some associated thin quartz-tourmaline veins. Isotopic information suggests that this mineralisation occurred during the early Permian (280-270 Ma), but hydrothermal processes are thought to have been active into the Tertiary.

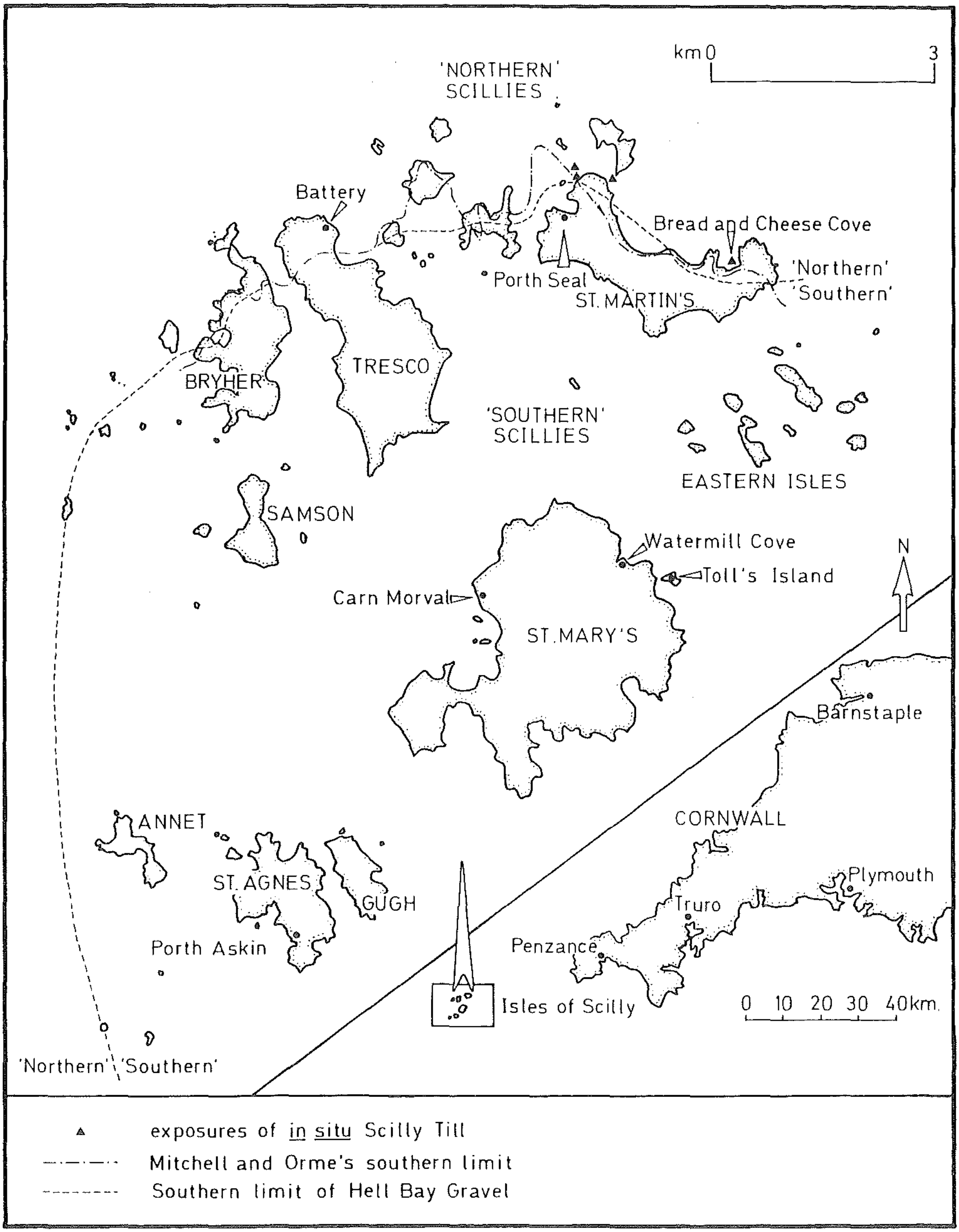


Figure 7. The Isles of Scilly - location map, critical sites and the southern limit of the Hell Bay Gravel

Barrow (1906) divided the granite into coarse and fine grained facies, the latter occupying a roughly central position and intrusive into the former (Fig.8). Though Barrow believed the only existing exposure of country rock to be the highly altered tourmalinised slates, 'killas', which occur on White Island, St. Martin's, recent workers have reinterpreted this material as either sheared or greisened granite (J.R.Hawkes, pers. comm. 1985). However, one small and previously undescribed exposure of phyllitic country rock containing sporadic perthite megacrysts does occur on Shipman Head, Bryher (J.R.Hawkes, pers. comm. 1985).

The coarse granite is volumetrically dominant and consists of abundant white orthoclase-perthite megacrysts set in a matrix of quartz, plagioclase, biotite and muscovite. The fine granite is very similar mineralogically to the coarse facies but contains only sporadic perthite megacrysts.

No in situ Mesozoic sediments occur on the Scillies, but Barrow identified Eocene (?) gravels on the summit of Chapel Down, St. Martins (1906). The gravel, which consists largely of flint and greensand chert, Barrow correlated with the Eocene fluvial gravels capping the Haldon Hills in Devon. In 1957 Dollar attributed these gravels to the Pliocene, and Mitchell (1960) to Lower Pleistocene fluvial aggradation. However, Mitchell and Orme (1967) later interpreted these gravels as glacial outwash; they will be examined on Day 2 of the excursion. Other almost identical gravels occur on Bryher and Tresco, and these will be examined on Day 3.

Despite the lack of Mesozoic and Tertiary sediments onshore, there are thick and important sequences related to this interval offshore (Fig.9). These are particularly relevant to the Pleistocene of the Scillies in that they represent, in part, the source material for the foreign glacigenic sediments. A wedge of Permian sandstone outcrops to the north-west of the Scillies between the Variscan sediments and the Upper Chalk. The latter constitutes one of the most widely distributed rock types on the continental shelf and is bounded on all except the landward side by Tertiary sediments. The eastward limit of the Upper Chalk is situated at 6°W, and the Lower Chalk is only known to outcrop much further to the north-east midway between Pembrokeshire and Hartland Point. An offlapping sequence of Palaeogene, Miocene and Early Pleistocene sediments extends southwestwards from the Upper Chalk as far as the continental shelf break (Fig.9; Evans and Hughes, 1984).

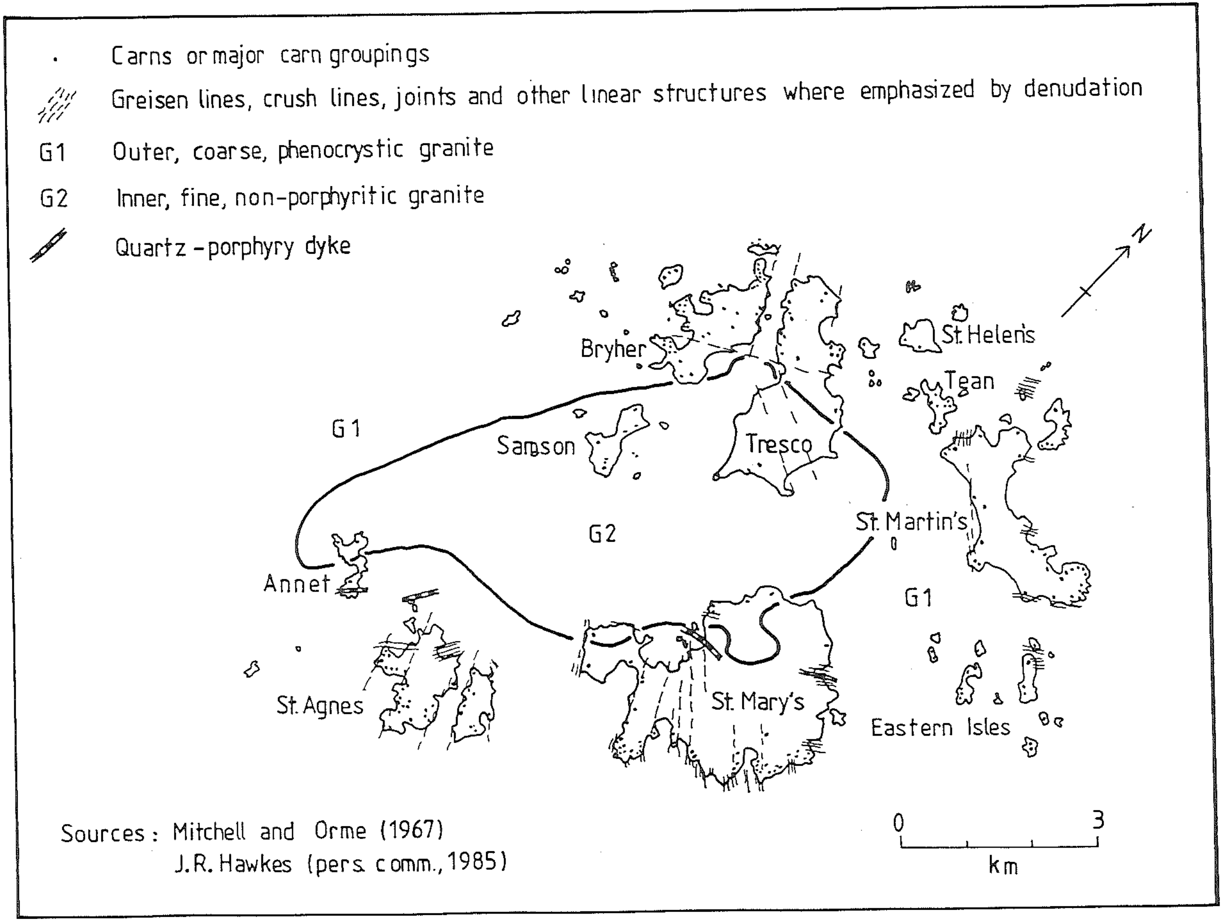


Figure 8. The Isles of Scilly - solid geology and structural geomorphology

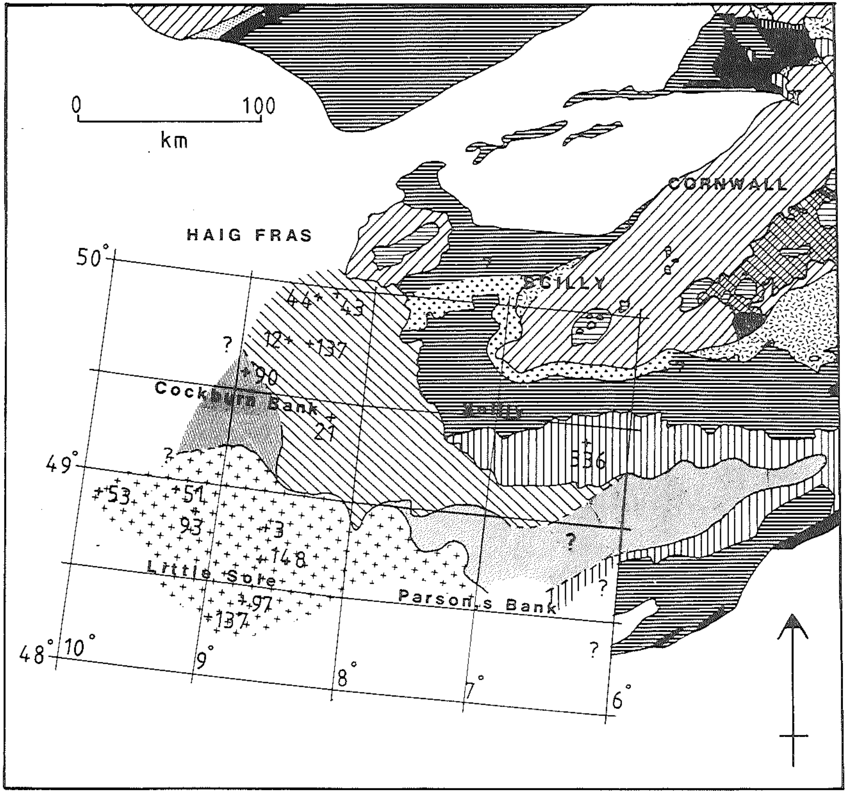


Figure 9. South central Celtic Sea - solid geology

(Sources: Evans and Hughes, 1984; BGS offshore maps)

PART I : THEMATIC REVIEWS

A. PLEISTOCENE STRATIGRAPHY (JDS)

Early Workers

The horticulturalist incumbent of Tresco Abbey, Augustus Smith (1858) first recorded the occurrence of foreign stones (chalk-flints and greensand) on the Isles of Scilly; his samples were collected from Castle Down, Tresco. A contemporary account of Smith's lecture to the Royal Geological Society of Cornwall records, "the flints and greenstones varied little in size, ranging from that of a hen's egg to that of a blackbird - how they got to Scilly was a mystery which it was for gentlemen of more scientific knowledge than he professed to explain" (Bishop, 1967). Statham (1859) produced the first comprehensive description of the geology of the islands, including the succession of superficial deposits. However, it was Nicholas Whitley who was the first, in 1882, to interpret the foreign stones found by Smith as glacial in origin. Barrow exhibited a striated boulder from the islands to the Geological Society in 1904, and in 1918 Hinch considered that the foreign stones might have been emplaced by a glacier which flowed down the Irish Sea.

The most important early statement of the entire geology, including the Pleistocene succession, was produced in 1906 by Barrow in the Geological Survey Memoir on "The Geology of the Isles of Scilly". Barrow defined four main lithostratigraphic units in the Pleistocene succession, 'raised beach', 'head', 'iron-cement' and 'glacial deposit'.

Barrow recognised the conglomerate of an old beach, now raised above the level of the present beach and resting upon an old shore platform. He regarded the beach as being formerly much more extensive but having been largely eroded away leaving the old platform exposed in many places. Barrow applied the term 'head' to the "accumulation of angular or subangular fragments of granite in an advanced state of decomposition". This 'head' had reoccupied the position of the eroded beach, and, resting on the old platform, had a terrace-like contour imparted to it. Barrow believed the true stratigraphic position to be fixed on White Island (Fig.10) where it rests on the bare granite and underlies the 'main head', "a glacial deposit in turn reposing on the latter".

Barrow was able to divide the head in certain localities into two parts, an 'Upper' and a 'Lower' or 'Main' Head. He believed this to be well demonstrated at the foot of Beacon Hill, St. Martin's, where the two units were separated by a "curious glacial deposit". Barrow cited Porthloo, St.Mary's, as the type location for the Head. He noted that the highest portion of the Lower, or Main, Head often consists of very fine materials. This, because of its high content of silica and iron oxide, he termed the "iron cement", and because of its distinctively different nature he thought it had a different origin from the head. Barrow remarks that "the origin of this curious deposit is by no means clear" although he was able to point out that in many places the iron-cement and glacial deposit are associated.

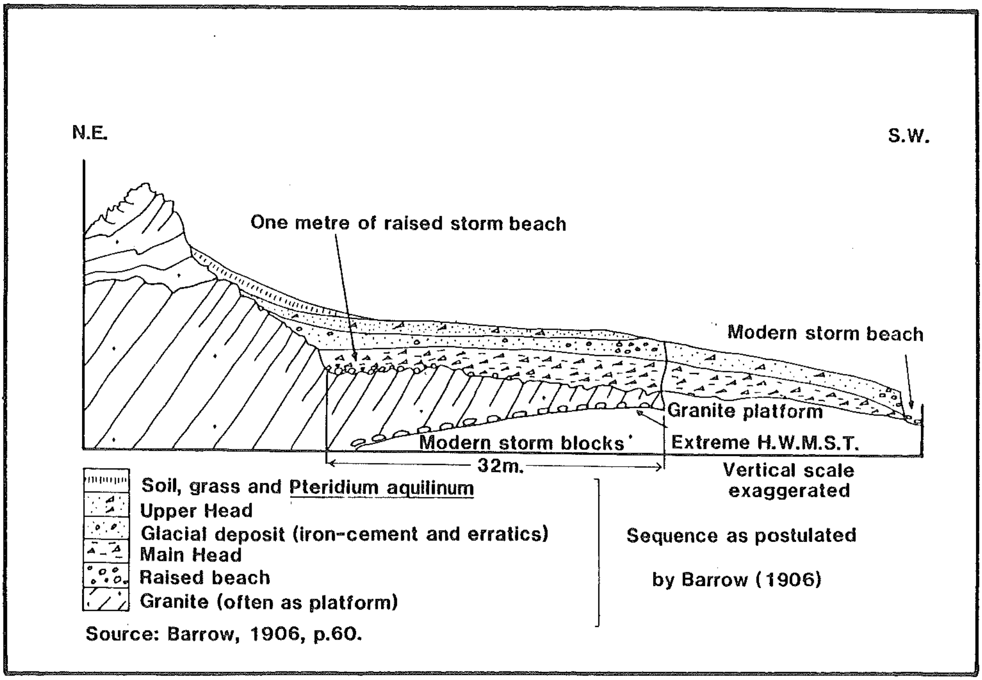


Figure 10. Sequence at Chad Girt, White Island (Barrow, 1906)

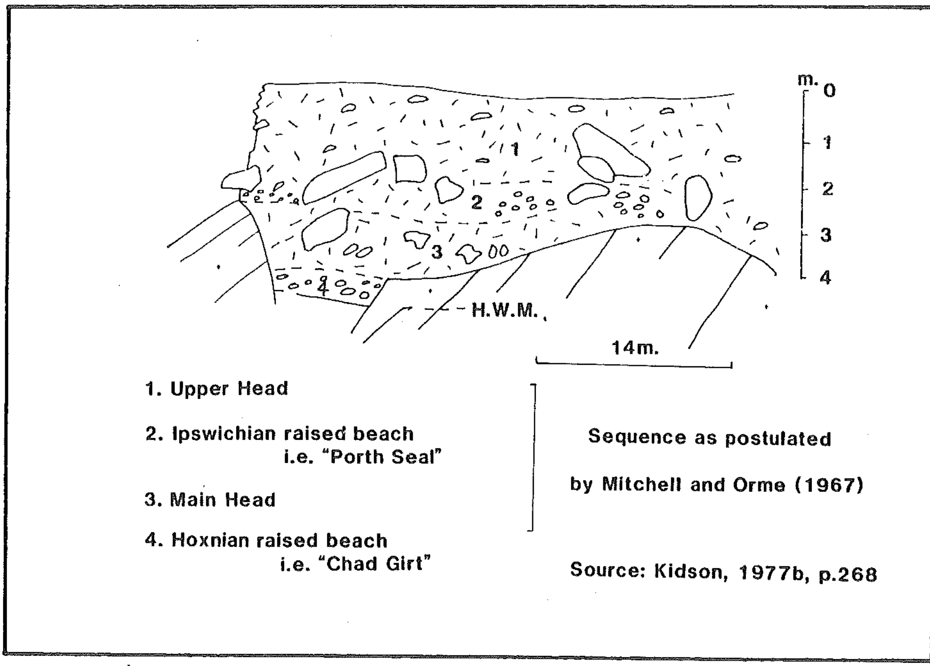


Figure 11. Sequence at Porth Seal, St.Martin's

Barrow noted that within this ferruginous matrix foreign stones occur in lenticular patches. This he termed a "glacial deposit". He collected a series of the foreign stones from the glacial deposit in St. Martin's Bay, St. Martin's. He argued that "a portion of them must have been derived from an older deposit, as many of them are too well rounded to leave any doubt that they were derived from some gravel and not directly from the parent-rock".

In his discussion on the origin of the glacial deposit and foreign stones, Barrow was quite certain that they had been carried by ice: "that these stones have been brought into their present position by ice admits of little doubt". He believed their "curious distribution" to be unintelligible except by invoking some other means of transport than water. Further, "it is quite clear that they (the foreign stones) must have been carried by floe-ice".

Barrow believed that type-site for the entire Scillies Pleistocene sequence to be displayed at the head of a deep marine gully Chad Girt, on the eastern coast of White Island, St. Martin's. He interpreted the following succession (in descending order):-

1. Upper, or Recent, Head
2. Iron-cement, or Glacial Deposit
3. Main, or Lower, Head
4. Old Beach
5. Sloping surface of the granite (Fig.10)

Very little work was published on the Pleistocene of the Scillies between 1906 and 1965. In his paper on Trebetherick, Arkell (1943) writes, "in the Scilly Isles, the main head is covered by loess identical with the limon of Brittany", and later quotes W.B.R. King in a personal communication on the loess of Brittany, Normandy, the Channel Isles and Scilly Isles. This is the earliest reference to loess in the region, and makes the absence of any discussion of loess in Mitchell and Orme (1965; 1967) conspicuous.

Mitchell and Orme (1967)

In 1965 Mitchell and Orme published a preliminary account of their findings, the major work appearing in 1967. Their interpretation of the stratigraphy differs in four respects from Barrow's:

1. Till and Outwash Gravel

Mitchell and Orme divide Barrow's "curious glacial deposit" into two separate units, till and outwash gravel. The till they regard as being restricted in occurrence, but well exposed at Bread and Cheese Cove on St. Martin's (Fig. 2). The outwash gravel they found to be more widespread in occurrence, forming the basis for their ice limit on Scilly (Fig.7). Mitchell and Orme reinterpret Barrow's "Eocene (?)" gravel on St. Martin's as part of this spread of outwash gravel.

2. Raised beaches

Mitchell and Orme identify a second, higher, raised beach than that reported by Barrow at Chad Girt, resting stratigraphically between his Glacial Deposit and Upper Head. They term the raised beach observed by Barrow on White Island, the 'Chad Girt Raised Beach', to distinguish it from the higher, younger, raised beach. This younger beach they identified at Porth Seal, St. Martin's (Figs. 2 and 11) and therefore they term it the 'Porth Seal Raised Beach'. Nowhere can the complete sequence they interpret be seen in one section. Their succession is as follows:-

1. Upper Head
2. Raised Beach (Porth Seal)
3. Glacial Deposit
4. Lower Head
5. Raised Beach (Chad Girt)
6. Shore platform

The chief criterion used by Mitchell and Orme for the differentiation of the two beaches where they do not appear in section is a qualitative assessment of the lithologies of the contained clasts. Prior to the glacial event, they argue, the beaches could only incorporate local material, whereas afterwards glacial debris rich in erratics would be readily incorporated into subsequent beach sediments. It is important to note, however, that Mitchell and Orme accept that a few erratics do occur in the lower, Chad Girt, raised beach.

3. Ice limit

By mapping the distribution of the till and outwash gravel, Mitchell and Orme suggested an ice limit running through the northern islands in the group (Fig.7). South of this line, the glacially-derived sediments are not found.

4. Chronostratigraphy

Comparing the basic stratigraphic sequence with similar sections in South West England and in Ireland, Mitchell and Orme claim a Gipping (Saale or Wolstonian) age for the glaciation responsible for the deposition of the glacial material. Comparing the Scilly stratigraphy with that at Trebetherick in North Cornwall, they equate the 'solifluction pebbly bed' described by Arkell (1943) with the Scilly Till (Mitchell and Orme, 1967), and with the glacial deposits at Fremington in North Devon (Stephens, 1966), and in County Cork, Southern Ireland. They date the events as follows: "in Ireland, opinion favours a Saale or Gipping age for this till because the southern limit of the last glaciation is drawn in Wexford and Caernarvonshire (Mitchell, 1960). The authors place the till and outwash gravels of the Scilly Isles in the Gipping sequence. There is evidence that during the preceding Hoxne interglacial, sea level was at least 100 ft. above the present, and it is possible that, following Mitchell (1960), the Chad Girt beach was deposited during this warm period". They therefore interpret the Upper, Porth Seal Raised Beach as being Eemian (= Ipswichian) in age, and the Upper Head as Weichselian (= Devensian).

Regional Syntheses

A number of regional syntheses of the Pleistocene stratigraphy of the Southern Irish Sea Basin as a whole have been published which relate directly to the Pleistocene stratigraphy of the Scillies (John, 1971a; Mitchell, 1972; Bowen, 1973a, Kidson, 1977a). These reviews either incorporate the interpretations of Mitchell and Orme, or reject them and place alternative interpretations on their stratigraphy. Until the 1980's opinion concerning these chronologies could be broadly classed into two camps, the 'Irish' school and the 'Anglo-Welsh' school (Kidson, 1977b).

The interpretations of the Irish school are exemplified by Mitchell (1960; 1972), Mitchell et al. (1973), Stephens, (1966; 1971) and Synge (1971). The attitude of the Irish school is based around the argument that the 'main raised beach' of the area as at Courtmacsherry in southern Ireland, on the Gower coast of South Wales, around Barnstaple Bay in North Devon and in the Scillies (Mitchell and Orme, 1967) could be dated as Hoxnian. The basis for this dating is not the deposit itself, but the dating of the deposits overlying the raised beach. Wherever glacial deposits are found overlying the beach they have been regarded as Wolstonian if they lie outside the proposed limit of the Devensian glaciation. Thus the limit of the Devensian glaciation becomes a critical factor in the stratigraphy (Fig. 12). In this way, the 'main' raised beach in Scilly and West Cornwall has been regarded as Hoxnian, and the glacial deposit in Scilly as Wolstonian. Mitchell and Orme (1967) therefore date the 'Scilly Till' as Wolstonian and correlate it with the Fremington till of North Devon.

A problem for the Irish school workers has been the lack of recognition of Ipswichian interglacial high sea levels in the coastal stratigraphy, and the lack of Ipswichian equivalent sites throughout Ireland. Mitchell thus comments, "it is to be regretted that the shores of the Irish Sea are so reluctant to reveal deposits stretching in time over most of the Ipswichian Warm Stage, and containing fossils such as Carpinus in quantity which would place the identity of the warm stage beyond doubt...
It seems very likely that the extensive raised bogs must have occupied the Irish Midlands during the Ipswichian, just as they have done in the Littletonian (= Flandrian), and it seems curious that erratics of Ipswichian peat, though sought for, have not been found in glacial deposits of Midlandian (= Devensian) age" (Mitchell, 1972). Thus, sites such as Porth Seal and Northward Bight on Scilly (Mitchell and Orme, 1967), Westward Ho! (Stephens, 1966), Gower (Mitchell, 1972) and Shortalstown in southern Ireland (Colhoun and Mitchell, 1971) which the Irish school interpret as Ipswichian equivalent marine units become crucial to their arguments.

As a result of the dating procedure outlined above, the 'main raised beach' emerges as a stratigraphical marker of some importance (Bowen, 1981). The Anglo-Welsh school resolve the difficulty of the lack of Ipswichian sites by regarding this raised beach as Ipswichian in age. This view has been put forward by Bowen (1971; 1973), Kidson (1971) and Kidson and Wood (1974). The major problem for this school to resolve is therefore not the Ipswichian raised beach, but the age of the glacial deposits overlying the beach. Two sites of crucial interest to the Anglo-

Welsh school have been Fremington in North Devon, and the Isles of Scilly, where tills have been interpreted as stratigraphically superposed to the beach. Bowen (1969; 1973) has reinterpreted the Scilly stratigraphy in the light of this problem. He cannot accept that the glaciation which influenced these sites was the Devensian, though the till is stratigraphically superposed to the beach as he regards the orthodox Devensian limit to be further to the north. Once again, the last glaciation limit is seen as stratigraphically crucial. In his interpretation (1969) he proposes that the lenticular mode of the glacial material and its geomorphic association with coastal valleys is more consistent with a solifluction origin than deposition by glacier ice. He therefore regards the till as originally deposited during the penultimate glaciation, then redeposited as a 'solifluction lithofacies' during the last cold stage. Bowen rejects the evidence for two raised beaches in the southern Irish Sea. He writes "recent work in Gower tends to confirm the unitary nature, and Last Interglacial age, of the raised beach adduced ... as a critical stratigraphic marker. At Minchin Hole Cave, two marine units occur (Bowen, 1977), an inner beach ... and an outer beach ... The outer beach (Patella) correlates, by amino-stratigraphy, with other Last Interglacial beaches in South West England (Andrews, Bowen and Kidson, 1979) ... An attempt to recognise two interglacial beaches elsewhere ... is invalid: in Gower because the evidence is incorrectly described, and the method stratigraphically inadmissible (Bowen, 1973a; 1973b): and on St. Martin's, Isles of Scilly, because the critical stratigraphy is inferred, and superposed, and granite corestones have been interpreted as a marine deposit" (Bowen, 1981).

Evidence from the amino acid racemization of marine molluscs in raised beaches in the southern Irish Sea Basin has provided, since the late 1970's, further information relating to the relative ages of raised beaches (Andrews et al., 1979; Davies, 1983). Bowen writes, "a system of aminozones has been established, numbered in accordance with the marine isotope record (to facilitate comparison) which calibration by independent dating (U-series, TL) has partly converted the relative aminostratigraphic scale into a geochronological one" (Bowen, 1984). The method has enabled the division of the 'Inner Beach' at Minchin Hole from the outer 'Patella Beach' and 'Nerotoides Beach' (Sutcliffe and Currant, 1984), U-series dates on travertine at Bacon Hole (Schwarz, in Stringer et al., 1984) enabling the outer beaches to be correlated with 'oxygen isotope stage 5e', the inner beach possibly with 'stage 7' (Bowen, 1984).

From this work, therefore, a pattern of raised beaches of different ages but at similar heights is emerging from the shores surrounding the Irish Sea as already suggested by workers of the Irish school, but for different reasons.

A further hypothesis, unallied in its thinking to either the Irish or Anglo-Welsh schools has been provided by Kellaway et al.(1975). In this work, several lines of evidence for a former glaciation of the English Channel are considered. The glaciation is postulated to have covered the Isles of Scilly and impinged upon the present day coastline of West Cornwall.

As evidence, they point to geomorphological features on the floor of the English Channel and deposits including the 'outwash gravels' of Scilly (Mitchell and Orme, 1967) which they regard as indicative of the last glacial phase, while the erratics in the 'main raised beach' may denote the former presence of a more extensive cover. They believe that the outwash deposits may correlate with the Fremington till (Edmonds, 1972) or perhaps with the 'glacial deposits' of Somerset (the Burtle Beds) or the 'boulder bed' of Trebetherick (Arkell, 1943; Clarke, 1965). They attribute the distribution of erratics on the channel floor and in the modern and raised beaches of its coasts to widespread Saalian glaciation (= Wolstonian).

Glacial Limits

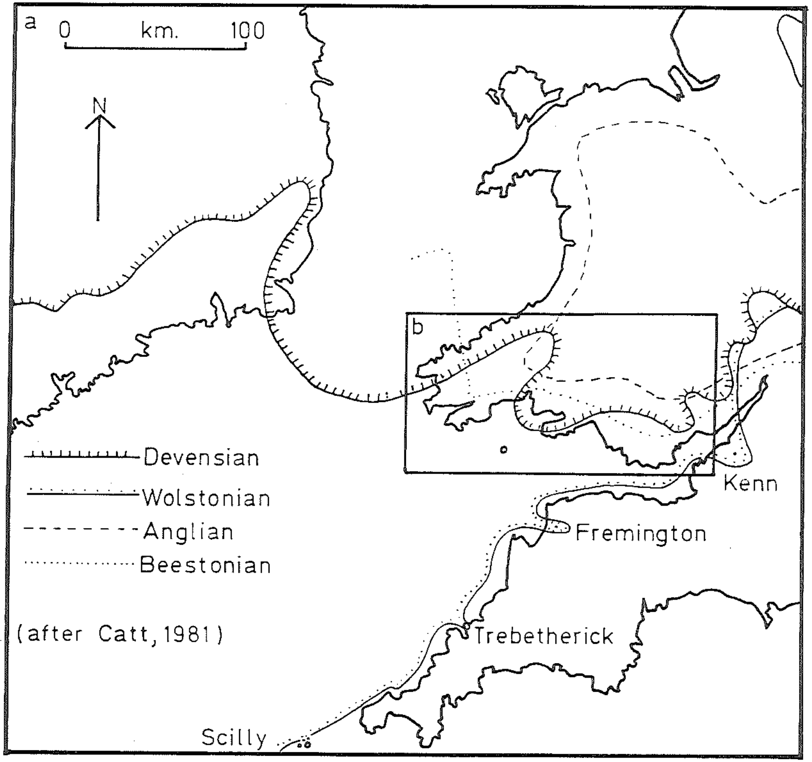
1. Devensian

It has been noted that the limit of the Devensian glaciation is stratigraphically crucial in the southern Irish Sea Basin for both Irish and Anglo-Welsh schools in terms of dating till and head in the region (Fig.12). The two classic papers originally dealing with this question were produced by Charlesworth (1928; 1929). Charlesworth's 'end-moraines' in both Ireland and Wales have been substantially modified by subsequent workers. Mitchell's 1960 Weichselian (= Devensian) ice limit followed a line running from the Lleyn Peninsula in North Wales to Wexford on the Irish side, but his revised 1972 limit lay much further to the south, between Mathry on the Pembrokeshire coast and just north of Carnsore Point on the Irish Coast.

Bowen has published extensively on the Devensian limit in Pembrokeshire and South Wales. There have been many local elaborations of the Devensian limit in this area (Fig.12), reviewed by Bowen (1981).

The question of these limits in the context of this Field Guide is important only in that most workers regard the Devensian limit as lying well to the north of the Scillies. Therefore, all glacial deposits on the Scillies have to be regarded as Wolstonian or earlier (Fig. 12). Apart from the views of Kellaway *et al.* (1975) considered above, there are a number of other studies which have questioned the orthodox views on the limits of the Devensian glaciation.

In Pembrokeshire, John (1971a) demonstrated that the coastal stratigraphic succession was identical on both sides of Charlesworth's (1929) line, thus rendering it redundant as a significant ice margin (Fig. 12). Using radiocarbon dates of derived Mollusca and by correlating the Pembroke stratigraphy with that in Devon and the Isles of Scilly, John (1971a) suggested that Late Devensian ice covered Pembrokeshire and the Bristol Channel, thus challenging the orthodox view that the tills in the South West are Wolstonian, though he subsequently revised his limit, placing it immediately south of Milford Haven (John, 1971b).



Wolstonian limit mainly from Mitchell and Orme (1967) and Mitchell (1972)

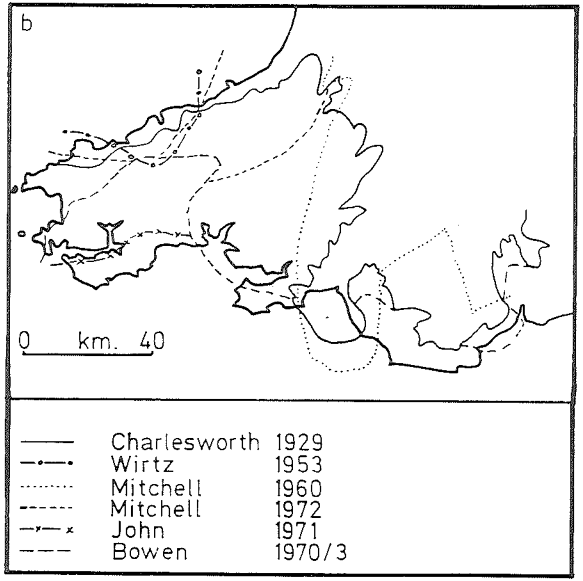


Figure 12. a - Postulated glacial limits in the southern Irish Sea Basin
b - Attempts to define the extent of the Last Glaciation in South Wales (Bowen, 1981)

Prior to his untimely death in 1983, Synge (1977; 1985) revised his views concerning the Devensian limit. In 1977 he argued that under the influence of high glacial sea levels during the Devensian maximum an ice shelf advanced down the Irish Sea as far as the Isles of Scilly, also reinterpreting the Courtmacsherry raised beach as Middle Devensian rather than Hoxnian in age. In 1985 he raised the possibility that the Scilly till could be Early Devensian in age.

2. Wolstonian

After Mitchell and Orme's work of 1967, most authorities have placed the limit of the penultimate glaciation, the Wolstonian, along the northern shores of North Cornwall and the Isles of Scilly (Fig.12). Catt (1981) has intimated, however, that the Scilly till could conceivably be Anglian in age. If the Scilly till is soliflucted as Bowen (1969) suggests and the Fremington till not tied stratigraphically to the Hoxnian raised beach (Kidson and Wood, 1974), then the date is simply pre-Devensian. This could mean either Wolstonian or Anglian, or even earlier.

Suggested dates for the glaciation influencing the South West therefore vary from the Devensian (John, 1971a; Synge, 1977; Kellaway et al. 1975) through the'orthodox' Wolstonian (Mitchell, 1972; Bowen, 1973a; Kidson, 1977b) to conveivably Anglian or even earlier (Catt, 1981).

The defining of glacial limits carries within it the danger of a circularity of argument as a product of negative evidence. Workers of both the Anglo-Welsh and Irish schools have stated that the till outcrops in the south of the region must be Wolstonian in age because the Devensian limit lies further to the north. Thus Mitchell and Orme (1967) state "In Ireland, opinion favours a Saale or Gipping age for this till because the southern limit of the last glaciation is drawn in Wexford and Caernarvonshire". Essentially, the argument is as follows: the limit of a certain till is last glaciation in age, and any till occurring further to the south cannot be of the same age because the limit lies further to the north.

Offshore Sequences

Any consideration of the Pleistocene stratigraphy of islands must include reference to the offshore sequences which surround them. The most relevant publications which concern the southern Irish Sea Basin and the south-central Celtic Sea are Garrard and Dobson (1974), Delantey and Whittington (1977), Garrard (1977) and Pantin and Evans (1984). The general picture revealed by the Institute of Geological Sciences in the early 1970's was of two units of Irish Sea till separated by thick sequences of temperate marine interglacial sediments of possible Ipswichian age. Garrard and Dobson regarded the upper till sheet as being Devensian in age, and proposed limits for this upper till sheet in the vicinity of the southern entrance to St. George's Channel (Fig. 13). The underlying marine sediments they regarded as Ipswichian. During the deglaciation of the Late Devensian, they believe the shallower regions of the Irish Sea underwent an intensive period of erosion which produced a number of meltwater channels. These subsequently acted as traps for the deposition of estuarine sediments associated with the early stages of the Flandrian transgression. Garrard (1977) reports on small and isolated outliers of glacial drift found as far south as the Bristol Channel. These 'lag gravels' consist mainly of small patches of erratic pebbles and cobbles with the fines winnowed out by strong tidal currents. Garrard (1977) also suggests more definite limits for the upper Devensian till in the vicinity of St. George's Channel (Fig. 13).

Delantey and Whittington (1977) argue that the 'Neogene' deposits of the south Irish Sea and Nymphe Bank are in fact glacial in origin, and accordingly reinterpret Dore's (1976) Neogene-Pleistocene boundary as the limit of Devensian deposits (Fig. 13).

Pantin and Evans (1984) have identified two main Quaternary formations in the central and southwestern Celtic Sea, the late Pliocene/early Pleistocene upper Little Sole Formation and the late Devensian/early Flandrian Melville Formation. The Melville Formation consists mainly of tidal deposits, but at a number of sites also contains glacigenic sediment. This material has been analysed in detail by Scourse and others (Scourse, 1985); a summary of the results are presented in Appendix 1. In addition, occasional small mounds of possible glacigenic material and scattered boulders on the sea bed, revealed by sidescan sonar, indicate "ice rafting" (Pantin and Evans, 1984). The occurrence of scattered boulders has also been noted by Hamilton et al. (1980). These sediments occur between 300 and 500 km. to the southwest of the suggested limits of Devensian material in the St. George's Channel area (Fig.13).

Scourse (1985)

In order to establish a local lithostratigraphic framework independent of the raised beach-tied stratigraphies erected in southern Ireland and Wales, Scourse (1985) mapped the extant sections on the sixteen largest islands. Absolute dating has helped to provide a chronology of events, consisting of twenty-nine ^{14}C determinations and two pre-existing thermoluminescence (TL) dates (Wintle, 1981). Local inter-site correlations have been strengthened by detailed palynology which has also assisted palaeoenvironmental reconstruction.

The defined units (Scourse, 1985) have been incorporated into two lithostratigraphic models, for the 'southern' and 'northern' Scillies respectively (Fig. 14). The southern limit of the Hell Bay Gravel defines the boundary between these two areas.

Overlying the raised beach sediments of the Watermill Sands and Gravel in the southern Scillies is the Porthloo Breccia, a unit of variable soliflucted material derived entirely from the weathering of the granite bedrock. Organic deposits are found towards the base of this unit at five sites (Fig. 7), Carn Morval (SV905118), Watermill Cove (SV925123), Toll's Island (SV93119), Porth Askin (SV882074) and Porth Seal (SV918166). These are thought to represent the inflings of small ponds or lakes formed during active solifluction. Radiocarbon

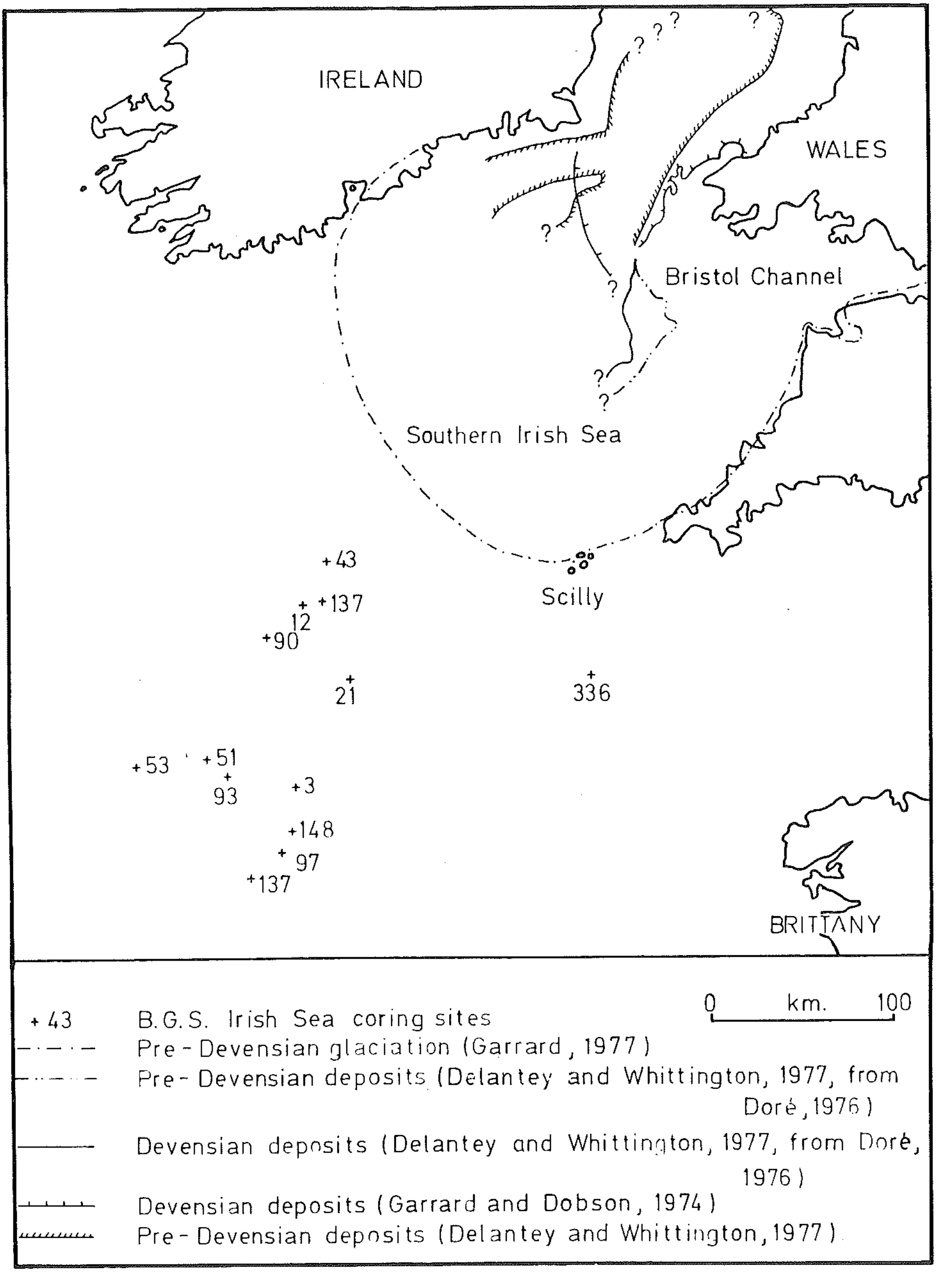


Figure 13. Glacial limits in the Irish Sea from offshore evidence

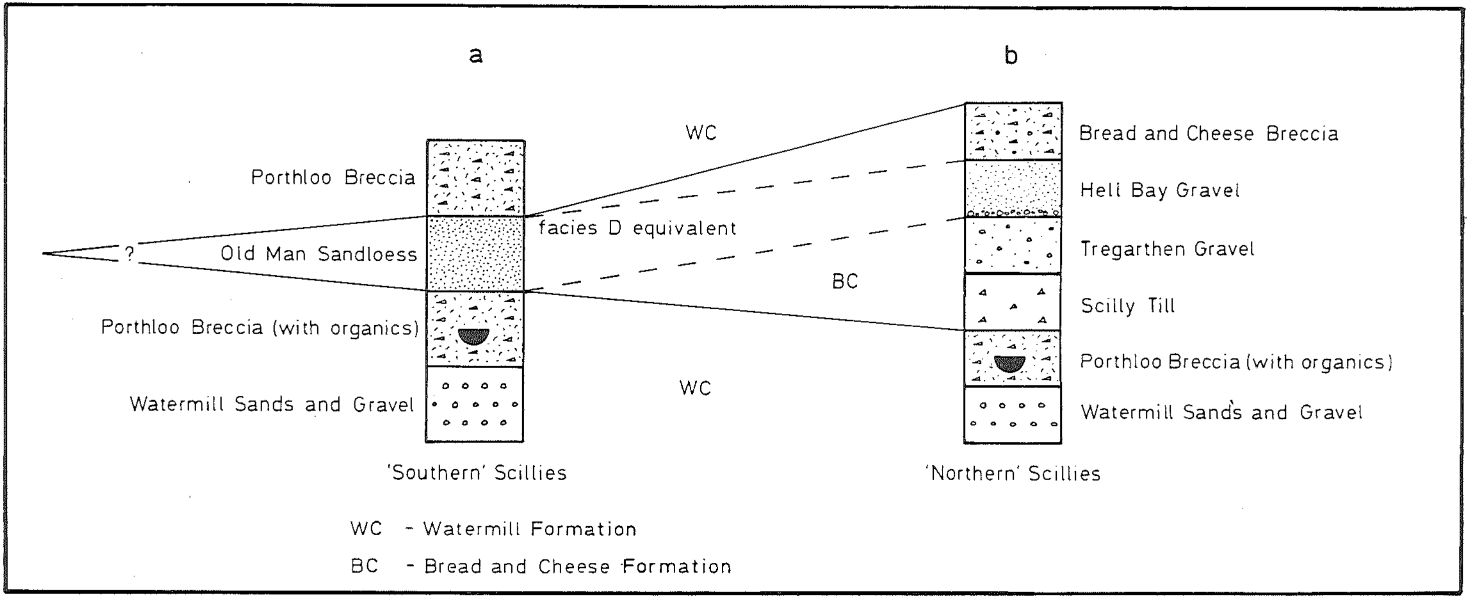


Figure 14. Lithostratigraphic models for the southern and northern Scillies, and their correlation (Scourse, 1985)

determinations from these organic sequences are critical since the organic sediments are interpreted as pre-dating the units related to the glacial advance, the Scilly Till, the Tregarthen Gravel, the Hell Bay Gravel and the Old Man Sandloess. If accepted as reliable these dates therefore provide maximum ages for the glaciation (Fig. 14).

All the organic sites are permanent open sections thus increasing the potential for contamination of the ^{14}C samples by modern rootlets and groundwater infiltration. After thorough cleaning samples were taken from two locations within most of the organic units at specific levels, from the open cleaned face ('external samples', Table 1), and from a horizontally bored sample up to 3m within the unit ('internal samples', Table 1). The humic alkali extracts were measured in addition to the solid plant detritus residues permitting a degree of mutual control which assists in the identification of the extent and sources of contamination. The reliability of the individual dates are discussed under the respective sites in Part II of the Guide.

The pollen diagrams from the organic sites are all very similar in recording tundra grassland vegetation and represent the earliest vegetational record for the Scillies. If the ^{14}C determinations are accepted as reliable they appear to indicate deposition of the organic sediments between 34,500 $^{+885}_{-800}$ (Q2410) and 21,500 $^{+890}_{-800}$ (Q-2358) years B.P. ; the pollen diagrams are broadly similar to other spectra of this age from elsewhere in NW Europe (Bell et al. 1972, Morgan 1973, West 1977). The individual pollen diagrams are presented and discussed under the respective sites in Part II of the Guide.

In the southern Scillies the Porthloo Breccia is overlain by the Old Man Sandloess, a coarse aeolian silt (Catt and Staines, 1982) with subdominant fine sand and minor amounts of clay, from which two TL dates, both of 18,600 (QTL 1d and 1f) years BP, have previously been published (Wintle, 1981). The unit occurs as four facies related to different modes of reworking (Scourse, 1985). One of these, facies D, is much less well sorted and contains structures clearly indicative of downslope movement.

In the northern Scillies the Porthloo Breccia is overlain by three units which are interpreted as all related to one glacial event. At four sites a massive, very poorly sorted, clast and clay-rich pale brown diamicton, defined as the Scilly Till, is thought to represent an in situ till unit unaffected by post-depositional downslope movements; it may be basal in origin. At Bread and Cheese Cove (Figs. 2 and 7) this material occurs in association with a matrix-supported sandy gravel, the Tregarthen Gravel, which has an erratic assemblage consistent with the underlying Scilly Till. This material also occurs in isolation elsewhere. Aeolian loessic sedimentation in association with the glacial advance may have been responsible for the deposition of the Old Man Sandloess in the southern Scillies. The relative coarseness of this unit is perhaps a function of proximity to its glacially-derived source material. The mineralogy of the Scilly Till is very similar to the Old Man Sandloess, suggesting a genetic association (Catt, Appendix 2). A coarse silt/fine sand matrix supported gravel containing a wide variety of glacially-derived striated erratics with a considerable proportion of ingested local material is very widespread in the northern Scillies. Defined as the Hell Bay Gravel, this material is thought to represent a period of solifluction postdating the glacial advance, in which the Scilly Till, Tregarthen Gravel and Old Man Sandloess were mixed and transported downslope. In situations where these sediments were totally stripped from the land surface, weathered granite was once again soliflucted, this constituting the Bread and Cheese Breccia. In the southern Scillies this post-glacial period of solifluction is represented by the upper Porthloo Breccia.

If this evidence is accepted it indicates that ice advanced as far as the northern Isles of Scilly during the Dimlington Stadial (Rose, 1985) of the Late Devensian Substage around 18,600 $^{+3,700}_{-3,700}$ (QTL 1d and 1f) years BP (Wintle, 1981).

The evidence which supports this model of a Devensian glaciation clearly conflicts in a number of important respects with Mitchell and Orme's (1967) scheme of events. The major differences include:-

1. Recognition of only one raised beach unit stratified with other sediments.

2. Recognition of widespread loessic sediments in the Scillies, and their relationship with the glacigenic unit.

3. Revised sedimentological interpretations of the defined units.

4. Independent radiometric dating rather than relative dating based on the inferred ages of raised beach units.

As with all interpretations in historical geology, this model of the Devensian glaciation of the Isles of Scilly is but a working hypothesis. The evidence on which it is based is clearly far from unequivocal, and the resultant interpretations are open to challenge and ultimate modification. However, the evidence outlined in this Guide is impossible to reconcile with a Wolstonian age for the glaciation of the Scillies; therefore either this evidence is unreliable, as with the ^{14}C and TL dates, or misinterpreted, as with the identification of in situ till, or both, or the glaciation was indeed Devensian in age.

The fundamental points in the argument are:-

1. The reliability of the ^{14}C and TL dates

2. The demonstration that the Scilly Till is in situ, and not slumped or soliflucted.

3. The validity of the lithostratigraphic correlations between sites and islands.

SITE	BED	SAMPLE LOCATION	SAMPLE FRACTION	^{14}C DATE yr BP	LAB.NO. CAMBRIDGE(Q)
Carn Morval	2b	external	extract	19.860+220 -210	2357
Carn Morval	2b	external	residue	24,490+960 -860	2356
Carn Morval	2f	external	extract	19,300+120 -120	2359
Carn Morval	2f	external	residue	21,500+890 -800	2358
Carn Morval	2b	internal	extract	21,640+270 -260	2446
Carn Morval	'lowest layer'	external	bulk sample	26,550+700 -650	2176
Carn Morval	'middle layer'	external	bulk sample	20,630+480 -450	2177
Watermill Cove	3a	external	extract	23,250+1720 -1420	2361
Watermill Cove	3a	external	residue	27,800+1770 -1450	2360
Watermill Cove	3c	external	extract	23,030+1275 -1100	2363
Watermill Cove	3c	external	residue	24,900+430 -410	2362
Watermill Cove	3a	internal	extract	31,770+850 -770	2447
Watermill Cove	3a	internal	residue	33,050+960 -860	2408
Watermill Cove	3c	internal	extract	28,870+590 -550	2406
Watermill Cove	3c	internal	residue	26,680+1410 -1200	2407
Porth Askin	1a	external	bulk sample	25,920+590 -550	2178
Porth Askin	1a	external	extract	20,960+180 -180	2371
Porth Askin	1a	external	residue	23,980+1400 -1200	2370
Porth Askin	1a	internal	extract	22,960+625 -580	2413
Porth Askin	1a	internal	residue	24,550+500 -470	2412
Porth Seal	4b	external	extract	16,440+120 -120	2365
Porth Seal	4b	external	residue	18,780+260 -250	2364
Porth Seal	4d	external	extract	11,200+1550 -1300	2367
Porth Seal	4d	external	residue	15,450+120 -120	2366
Porth Seal	4b	internal	extract	34,500+885 -800	2410
Porth Seal	4d	internal	residue	25,670+560 -530	2409
Bread and Cheese Cove	1a	external	extract	7,880+180 -180	2369
Bread and Cheese Cove	1a	external	residue	9,670+65 -65	2368
Bread and Cheese Cove	1a	internal	extract	7,830+110 -110	2411

Table 1. Radiocarbon determinations on organic sediments within the Porthloo Breccia

The reliability of the individual ^{14}C dates is discussed in Part II. Taken as a group, however (Table 1), it is suggested that the determinations form a fairly consistent group given the problems of analysing pre-Flandrian material. Both the sediments and the pollen spectra from the organic sequences are clearly cold-stage, and probably periglacial, in their affinities; they are not interglacial or Postglacial. If the organic sequences were deposited during a cold stage earlier than the Devensian, such as the Wolstonian, but then contaminated with modern carbon, surely a wider spread of dates would have resulted with perhaps an occasional infinite date? It was a recognition of the dangers of contamination at sites such as these that resulted in both humic extracts and solid residues on repeated samples from the same sites being analysed. If some form of independent evidence ultimately reveals all these samples to be extremely badly contaminated, and thereby falsifies the hypothesis of a Devensian glaciation, doubts must be shed on the reliability of all radiocarbon dates from bulk organic sediments such as these. However, if the organic sediments were deposited earlier in the Devensian than the dates suggest, a Devensian age for the glaciation can still be sustained.

The reliablity of the TL dates has already been discussed and accepted by Wintle (1981).

Discussion of the in situ status of the Scilly Till is considered in Part II. However, even without the existence of the Scilly Till, the consistency of the stratigraphic relationship between the Porthloo Breccia and the Hell Bay Gravel at many sites in the northern Scillies would perhaps indicate primary glacigenic deposition and subsequent solifluction or slumping within one cold stage postdating organic sedimentation, a conclusion consistent with the Devensian model.

A false argument concerning the stratigraphy of reworked till has bedevelled thinking concerning the chronology of events in the southern Irish Sea Basin. Bowen (1984) has stated concerning the stratigraphy in South Wales 'superposition of diamicton (recycled glacial beds) as part of a laterally continuous formation of head, on top of raised (Patella) beach showed that in most of south Gower the last local glaciation occurred before the raised beach event". The statement implies that all reworked material was originally emplaced prior to the unit over which it lies; there is no reason why this should be a general truth. Taking the case of the Hell Bay Gravel and the Porthloo Breccia, there is no reason why glacigenic sedimentation should not have occurred postdating the deposition of the Porthloo Breccia, and then recycled within one cold phase. This is indeed a simpler hypothesis.

It is possible to question the between site and island lithostratigraphic correlations. There is only one organic deposit which directly underlies the Scilly Till anywhere, at Bread and Cheese Cove (Figs. 2 and 7). This is also a very unsatisfactory site in that it has provided clearly aberrant ^{14}C determinations. It could therefore be argued that the Porthloo Breccia in the northern Scillies correlates with the upper Porthloo Breccia in the southern Scilles, thereby completely overturning the stratigraphic relationship between the radiometric dates and the Scilly Till. Not only would this controvene Occam's razor in being unnecessarily complicated but it would also imply:

1 An extremely complicated depositional history e.g. two major periods of loess deposition.

2. Extremely steep gradients in depositional environments over very short distances.

3. Conflict with the mineralogical association between the Scilly Till and Old Man Sandloess (Appendix 2).

In western Britain Quaternary lithostratigraphic correlations have to be achieved without the luxury of the widespread and continuous lateral extent of sedimentary bodies, as in parts of East Anglia. In such situations correlations have to be achieved on the basis of the evidence to hand in the simplest possible way until additional evidence is able to justify a more complicated scenario.

It is suggested that the evidence presented to support a model of the Devensian glaciation of the Scillies, though equivocal, is nevertheless more substantial than the evidence presented to support a Wolstonian age for the glaciation. It is hoped that this excursion will provide a forum for the discussion of these critical points.

B. FLANDRIAN PALAEOBOTANY (RGS)

In spite of their small area, the Isles of Scilly have yielded a substantial number of pollen data. These are largely soil pollen analyses carried out in response to the extensive archaeological interest of the Scillies. The highly equable character and diversity of the present flora is well known (Lousley, 1971). The fact, however, that today these islands are devoid of indigenous woodland has posed questions as to the character of the natural vegetation and to the effects of prehistoric occupation in the islands.

Early macrofossil records attest to the presence of Postglacial woodland. Lousley (in correspondence) noted the records of oak trunks in submerged forest situations around the coastline and there are numerous old records of stumps (mostly Quercus), having been dug out of the ground of St. Mary's, St Martins and Tresco. Augustus Smith recovered the latter prior to his tree planting activities.

Dimbleby (1977) provided the first pollen evidence that the Scillies had been dominated by deciduous woodland. Although no means of dating were possible, his soil profile from Innisidgen (SV919128) showed conclusively that Quercus and Corylus were present in open canopy woodland with Gramineae and Pteridium ground flora. That forest clearance took place is also seen in this profile. The truncated lower soil levels which continue the evidence of deciduous woodland are overlain by a zone of dominant Gramineae and Pteridium prior to burial by blown sand.

Clear evidence of post-forest clearance agriculture comes from three soil profiles which provide very localised data from adjacent to archaeological sites of the Halangy Down Iron Age settlement (excavated by P. Ashbee 1965-70),Nornour in the Eastern Isles (Butcher, 1970,1971,1972,1974) and Bar Point, St. Mary's (Evans, 1983). At the former, Dimbleby (Dimbleby et al, 1981) points to the striking absence of tree pollen in the soil profile of the cliff section immediately adjacent to the Iron Age settlement and the nearby Bronze Age Bants Carn passage and entrance grave. Pollen taxa present in the spectra were characterised largely by types indicative of pastoral and arable agriculture and perhaps evidence of sea weed manuring. At Nornour, pollen analysis by Greig (Greig and Keeley, 1978; Dimbleby et al, 1981) was carried out on a soil profile buried by blown sand adjacent to a later prehistoric and Romano British site (SV9441481). Although not radiocarbon dated the lower section of the profile was thought to correspond broadly with the period of occupation. As in Dimbleby's analysis of Halangy, evidence of cereal cultivation and pastoralism was present. Balaam (in Evans, 1983) has studied the soil profiles underlying some Iron Age (c190-70 bc) field boundaries and lynchets excavated at Bar Point (SV916128). In each case his pollen assemblages are again indicative of an open landscape with some evidence of cereal cultivation. Although in relatively close proximity to Dimbleby's earlier section at Innisidgen similar high arboreal pollen values were not found although one section produced small quantities of Quercus, Alnus and Corylus at its base.

Analyses of peat accumulations might be expected to provide both a longer record of vegetation and environmental change and enable some correlation of the individual soil profiles noted above. Pollen diagrams from the two remaining relatively extensive peat areas of Higher Moors nature reserve (SV923109) and Lower Moors (SV913106) have been constructed (Scaife, 1980a, 1983; Scaife, in Dimbleby et al., 1981). Radiocarbon dating of Higher Moors peats shows that their growth was initiated during the mid-Atlantic period at 6330+-100 bp (HAR-3695). This sequence therefore provides data on the Flandrian climax vegetation of the area and of subsequent effects of prehistoric deforestation. Lower Moors has not yet been dated but is seen to be a younger deposit developing from an originally shallow pool or lagoon during the later prehistoric period. Both mires have been extensively cut for fuel in the past and are currently being rapidly degraded through water extraction, earlier land drainage and scrub regeneration. The ecological character of these areas has changed substantially from the period of the earlier botanical records with areas of more acid bog now almost non-existent.

A Flandrian climax forest comprising Quercus, Betula, Corylus and Fraxinus was present (Higher Moors and perhaps Innisidgen). The earliest evidence of agriculture (cereal) is seen at Higher Moors. It is thought that this was Neolithic and was followed by some late Neolithic or early Bronze Age woodland regeneration. During the Bronze Age and probably associated with the widespread agricultural activity, is the almost total clearance of remaining woodland and the establishment of arable and pastoral and plagioclimax communities. It is this openness which is evidenced in the soil pollen profiles associated with the Iron Age and Romano British settlements. To clarify some of the dating and environmental problems, further work is being carried out on the peat and soil profiles underlying dated archaeological structures. It is hoped to obtain (through diving) some of the submerged peats variously noted around the islands which may yield data on the character of early Flandrian environments.

C. SCILLY IN PREHISTORY : A CONCISE VIEW (CT)

To a prehistorian Scilly offers a study area of quite exceptional attraction. The arena is finite. The sea boundaries minimise any casual cultural contamination. The physical extent is compact enough to allow very detailed exploration. At its greatest (pre-Man) limit the entire laccolith was not much bigger than modern Jersey, and at the time of the first settlement it was not much smaller than modern Guernsey. Geology, and geomorphology, are both relatively straightforward, though leaving plenty of room for debate, and there are no extreme vertical contours. Natural resources can be identified and, more to the point, are distinguishable in their natural state from exotics and in any man-altered state from imports. Most aspects of Scillonian biology have been properly reported, including a good sub-recent faunal record. Soils are less acid than one would expect, and the state of preservation of the archaeological finds is often better than in mainland Cornwall. Lastly, in recent years a disproportionately high (and highly funded) attention has been given by regional and national archaeologists to the field remains of Scilly; in many classes of monuments, we can now probably locate eighty per cent or more of true totals.

The clear physical termini are matched by a temporal one. Prehistory here starts with a postulated farming-hunting-gathering colony, almost certainly drawn from the Land's End area. Their material culture, always in a rather uncertain balance with environment and resources, was not significantly modified nor enlarged until a pre-Roman phase perhaps as late as the 3rd century BC - indicated by Early Iron Age innovations, and presumably by the introduction of a spoken Celtic (British) that continued until its demise as Late Cornish in the 16th/17th centuries.

Before this change, it is pointless to talk about any 'Early, Middle or Late Bronze' period. Both Ashbee (1974) and the present writer prefer to use the term 'Early' for the whole era. But how early did 'Early' begin? Here we are less positively informed through radiocarbon assays than we are through analogies and comparanda, but at the moment the most likely basis for a first, full, settlement is one involving transfer of a local Late Neolithic economy from the nearest mainland. Diagnostic pottery, and a range of flint and other lithic objects, as well as a restricted livestock (<u>Bos</u>; <u>Ovis</u>; somewhat later, <u>Sus</u>) show where we are in terms of Cornish prehistory. Considerably later than such major sites as Carn Brea (mid-4th millennium, calendar BC), the horizon is contemporary with the Beaker phase and not much earlier than Cornwall's first barrows of the developed Early Bronze stage. In calendar time, the initial settlement occurred - using present reckoning - a century or so either side of 2000 BC. It might have been preluded by an occasional stopover visit in the previous half-millennium, judging by a few sherds of some form of Middle Neolithic pot from Samson and perhaps St. Mary's, but the evidence for the principal colonisation is consistent.

During the 4th, 5th and perhaps later 6th millennia Cornwall was characterised by a local Mesolithic, Jacobi's (1979) 'Later Early Flandrian Hunters of South-Western Type', to give them this rather cumbersome label. They are well in evidence from a host of finds but may in reality have constituted only a few migratory bands. When these finally appear in the Land's End, Scilly was severed from the mainland by many miles of the Atlantic. Discovery of the odd artefact of Mesolithic type in Scilly cannot weigh against the sheer improbability that these folk, if able to paddle to offshore rocks, ever made such a crossing; one that deterred much stouter small craft until the 19th century. The developed Neolithic of Cornwall had a strong remnant Mesolithic element seen in flintwork from Carn Brea onwards. There are no clearly recognisable Mesolithic facies, floors or middens in Scilly, despite prolonged search. For the idea of a general late settlement of islands so far out in the Atlantic, one might look at the case of Hebridean outliers. St Kilda (the Hirta group), for example, was first reached at a very similar 'Late Neolithic and post-Beaker' time.

After this beginning, exploitation of Scilly proceeded within a terrain that can now be modelled in outline. Accepting a relative sea/land rise here at a present estimated rate of about .24 metre per century, levelling out over the last 3 or 4 millennia from an earlier steeper curve of Postglacial transgression (cf. Hawkins, 1971), the mean sea level around 2000 BC stood at (Chart datum) minus 8 metres, with low spring tides around minus 10.2 m. or 33.5 feet below today's. This implies a main-island area of the order of 26 miles^2 (66.5 k^2) - a considerable bloc. Palaeobotanical evidence, to which we can add present distributions of certain woodland species like Wood Spurge or the uncommon Wood Dock (Rumex sanguineus L.), hints at a central mixed-oak forest of at least 5000 acres, the remainder being divided between open scrub or natural heath, some sand-dune belts and several small marshy basins draining to margins. The forest or its surrounds supported - if faunal evidence is correct - a viable population of Red Deer, C.elaphus, that may not have been eliminated until late Roman times. Whether it arose from a nucleus breeding stock deliberately introduced (as juveniles) from Cornwall, or whether like the curious little Scilly Shrew - not Sorex, but Crocidura - and the now extinct Pallas's Vole, Microtus oeconomus Pallas, these deer descended from a pre-severance stock, is not yet clear.

Field-work, field survey and even the occasional excavation since the 1940s have given us a tentative picture of expansion followed by over-exploitation. To this we can, cautiously, apply models of island population behaviour drawn from distant and more recent studies. In short, it is argued that the colony outgrew, not so much its potential food resource, as its ability to manage and to renew that resource. It can also be guessed that during the early 1st millennium BC a balance was regained through less profligate use of the not very good soils, and better management of forest clearance. Manuring - that is, dressing with sand, seaweed, ash and organic waste - may have been one empirical solution. Throughout the Early period in Scilly the small circular stonewalled huts, clearance mounds, and elaborate little field systems exactly parallel those known, in greater detail, over most of Cornwall's uplands and granite moors.

The well-known entrance graves or supposedly megalithic tombs of Scilly - their true total about 90 to 100 (chambered) among a very much greater series of unchambered and usually smaller cairns and mounds - have to be interpreted in the broader context of Middle and Later Neolithic Britain and western Europe. It is unnecessary to repeat suggestions of 'megalithic missionaries' arriving by sea from Iberia, Brittany or any other region. On a mainland chronology, Scilly's cairns are Early and Middle Bronze age and, though morphologically within the overall Passage Grave series, the earliest were probably constructed nearly millenium and a half after (say) Newgrange. The prototype of the entrance grave occurs in, and was probably developed within, the Late Neolithic of west Cornwall. In the Isles, the nature of these bun-shaped kerbed cairns with their low slab-walled, slab-roofed chambers - and indeed their careful placing in the Early landscape - makes it far from certain that their primary function was funerary. Today, they are interpreted as some kind of shrine or territorial marker; permanent temples, dedicated to the Ancestors, of detectable family or extended family agricultural settlements. Depositions in the narrow, unblocked, chamber passages have included 'fertility' material (midden contents) and occasionally token human cremations. But the dead were otherwise disposed of in small rectangular slab cists of mainland Cornish type, or possibly (for the less important) under little, low, cairns concentrated in a series of marginal cairnfields like Shipman Head Down on Bryher.

In this long-lived, isolated and culturally static society, its materiel enlivened only very occasionally by the odd bronze tool or weapon from the mainland, great use was made of the abundant flint and chert to be found on most beaches, derived ultimately from glacial deposits. Waste is extensive, and scrapers were the commonest product. Use was also made of the finer granite for bowls, saddlequerns, pounders, rubbers, and hammers; and apparently of an isolated vein of greisen in the Eastern Isles. Organic artefacts have not survived. Bone and antler, however, do. To the domesticated fauna, which by the Iron Age had embraced goats(?) and a small pony, we can add remains of Red Deer, Grey Seal and a wide assemblage of bird and fish types, let alone almost every kind of edible mollusc. Clearly conventional farming had spread into fishing, fowling, gathering and collecting. No doubt fishing in particular was specialised at an early date as to seasons, locations, equipment and species taken.

The hazards of estimating (frankly, guessing) population totals from site distributions in prehistory are obvious. If however one has to make a guess, then simply as a guide to informed thinking one might talk about an initial settlement of about 50 persons in the first decade; a rise to the order of 600 to 1,000 in the first three to five centuries; and an eventual contraction and levelling of the order of 300 to 500. This last estimate can with more conviction be argued for Roman, Early Christian and medieval Scilly, and it may be a genuine optimum. Its rise to about 2500, levelling again to around 2000 (as now), took place only after the 16th century AD. All these figures are maxima. By contemporary standards the field archaeology of Scilly is now fairly thoroughly explored and recorded, and that record will not support any argument for markedly larger Early populations.

As far as Scilly's inter-tidal archaeology or 'submerged remains' are concerned, they are mostly field walls, or parts of field-systems and settlement components, with occasional isolated huts and even a few burial cists. Some huts, presumably very early ones, are totally submerged and little can be said of them. Only the stone endures; granite walls, granite querns, scatters of flint tools and waste in situ or in a secondary context like a midden spread on some former plot. The precise vertical fixes of some remains may give a relative indication, vis-a-vis a graph of sea-level rise, of the last possible date of any dry land (i.e., above HWT) use. The form and shape of the odd monument may suggest its most probable archaeological date - a rectilinear house with quern on a Tresco beach is not likely to be older than Iron Age and is in fact near HWT. On the whole, these indications match up and were in part used to check the rate of sea-level rise. Most major inter-tidal remains have been fully planned. New examples continue to emerge or to be reported, just as the known sites are from time to time cloaked by shifting sand or fresh seaweed beds. Important of course are the few cases where a wall is visible now on dry land (perhaps as part of a larger site), goes below a shingle bank or low cliff around HST and amazes the observer by emerging again on a sand beach above or near the low water mark. There is no doubt that most of these remains represent land-use in the Early period; a former 'fish-trap' explanation has long been discredited. In the course of our excursion it is hoped to observe instances of these remarkable monuments, but it is safer to wait and see rather than to predict with confidence which ones will be visible!

D. THE SCILLY ISLES IN THE QUATERNARY (GFM)

I try to set out in a few short paragraphs my current view of Quaternary events in Scilly. I am quite prepared to change this view if convincing evidence is presented during the field-trip for a new interpretation of the deposits. Much ice has flowed by since the publication of the Geological Society's Special Paper in 1973, but here I use the terms Devensian and Wolstonian as used in that paper. I take four sites only.

St. Martin's: Bread and Cheese Cove I consider that the till here is of Wolstonian age, but that it has been moved downslope by freeze/thaw processes during the Devensian, probably Late Devensian.

St. Martin's: Northward Bight I consider that the sequence here reading downwards is:

Head with erratics	Devensian
Unconsolidated beach with large cobbles	Ipswichian
Head without erratics but with shattered beach cobbles	Wolstonian
Consolidated beach with small cobbles	Hoxnian
Rock	

St. Martin's; Porth Seal I consider that the sequence here reading downwards is:

Head with erratics	Late Devensian
Organic material	Intra Devensian
Unconsolidated beach with large cobbles	Ipswichian
Head without erratics	Wolstonian
Consolidated beach with small cobbles	Hoxnian
Rock	

Samson: Samson Flats I consider that the intertidal walls here are the remains of fish-traps, and are not field-walls.

PART II : SITE DESCRIPTIONS

Saturday 6 September

St. Mary's

1.	Porthloo	SV908115
2.	Carn Morval	SV905118
3.	Halangy Down	SV910124
4.	Bar Point	SV915130
5.	Innisidgen	SV921127
6.	Watermill Cove	SV925123
7.	Higher Moors	SV925107-921115
8.	Lower Moors	SV913105
9.	Peninnis Head	SV912093
10.	Porth Cressa	SV905105
11.	The Garrison	SV898105

PORTHLOO (SV908115) JDS

Barrow (1906) cited the exposure of the 'Main Head' at Porthloo as typical for this material, and Scourse (1985) has informally designated Porthloo as the type-site for the Porthloo Breccia member of the Watermill Formation (Fig. 14).

Two units are exposed at Porthloo. Up to 5m of coarse granitic breccia overlies occasional large rounded granite cobbles. The upper unit is the stratotype for the Porthloo Breccia, and the lower unit may represent a fragment of raised beach deposit. The clasts within the Porthloo Breccia are all extremely angular, vary in size from pebbles to boulders, and are exclusively granite in lithology. The deposit is for the most part clast supported, with approximately 300-600 granules (2-4 mm) and 20-400 pebbles 74 mm per 100g. sediment . The matrix is extremely poorly sorted. The material is in places stratified and occasionally displays lobate structures with clast concentrations along the margins of the lobes. The clast fabric is consistently orientated parallel with local slope, but with a predominant dip into the flow direction. The source material for the sediments is entirely weathered local granite, though local lenses of loess occur within it which are derived by aeolian processes from a wider source (Appendix 2). The sedimentology of the Porthloo Breccia is considered in more detail in Appendix 3. It is most satisfactorily interpreted as a product of solifluction within a periglacial regime. The Porthloo Breccia is by far the most ubiquitous unit found in the Scillies, most of the other units being interbedded within it, or underlain or overlain by it.

CARN MORVAL (SV905118) JDS

A succession of organic deposits can be seen at this site at the head of a deep gully in the solid granite (Fig. 15). The gully is orientated roughly parallel with the local slope direction towards the south-west, the section having been eroded normal to this direction. Further to the north, towards the Carn Morval headland, a raised beach (Watermill Sands and Gravel) consisting of small rounded pebbles can be seen resting on the solid granite at 4.52 m. OD the upper parts of which interdigitate with a silty sand which coarsens upwards into a coarse granite breccia (Porthloo Breccia). Another raised beach(Watermill Sands and Gravel) consisting of very coarse granite boulders set in a granular sandy matrix, can be seen a few metres to the south of the gully section. The base of this raised beach lies at 4.73 m. OD. The precise stratigraphic relationship of the organic sequence to these raised beach exposures is not entirely clear, lacking direct superposition or lateral extension (Fig. 15). However, lenses of the Porthloo Breccia interdigitate with the organic sediments so it seems likely that the raised beaches lie stratigraphically below the organic sequence. The microstratigraphy of the organic sequence, unit 2, is illustrated in Figure 16 and described in the sediment column on the percentage pollen diagram Figure 17.

This site was originally investigated by Wintle as part of a programme of research calibrating TL with ^{14}C dates. Traced laterally towards the southwest the Porthloo Breccia is overlain by a well-sorted sandy silt, interpreted by Wintle as being loessic in origin. For this material she obtained a date of 18,600 $^{+3,700}_{-3,700}$ (QTL1f) using the TL method (Wintle, 1981), the organic beds described having been dated by ^{14}C to 26,550 $^{+700}_{-650}$ (Q21176; 'lowest layer') and 20,630 $^{+480}_{-450}$(Q2177; 'middle layer'). Granulometric analysis of this material indicates that it has dominant modal classes in the very fine sand and coarse silt fractions, is composed of 57% silt, 38% sand and 5% clay, and has the peaked distribution characteristic of aeolian sediments. It can be lithostratigraphically correlated with the Old Man Sandloess.

The organic deposits are black in colour, contain abundant micaceous silt and sand and form two distinct beds within the unit (2b and 2f), each overlain by a less organic dark brown sandy silt (2c and 2g). Organic bed 2b is underlain bu a cream-white sand with some clay, 2a, which on contact with 2b becomes more clay-rich; 2a bottoms onto the rockhead. Above 2c is a thin layer of granite breccia, 2d, which is continuous with the Porthloo Breccia on both sides of the gully, and this is overlain in turn by a bed of brown silty clay, 2e. Organic bed 2f, like 2b, is underlain by a cream-white sand with clay. The top of 2g interdigitates with the overlying Porthloo Breccia. Though post-depositional contortion and slumping has taken place the original stratigraphical relationships between the beds have been retained. Large granite clasts are found throughout the sequence. All the contacts are gradational.

The sediments are interpreted as having accumulated in a small pool ponded within a rock gully in the solid granite, the base of which lies at 4.5 m. OD. The presence of water at this site in the past is explained by the spring which rises today in the gully a few metres towards the west. The sediments themselves and the pollen indicate deposition during a cold stage, and under these conditions the gully may have been closed to form a basin by an icing or naled (Brown, 1967), into which the sediments accumulated.

The beds forming the sequence are distinct and to each can be attributed a specific genesis: the pollen washings and loss on ignition diagram, Figure 18, assists in their interpretation. Granulometric analysis of bed 2a indicates that it contains 66% sand, 31% silt and 3% clay. It is rich in quartz and mica indicating derivation from the granite, and probably represents the initial fairly rapid deposition of poorly sorted largely minerogenic material into the basin at a time of active solifluction. Amorphous humus is estimated to contribute up to 90% of the organic content of beds 2b and 2f, the remaining 10% being made up by macroscopic carbonised plant detritus, highly decomposed Coleoptera (see below), pollen and spores. Two hypotheses may be invoked to explain this high percentage of humus:

1. Slow accumulation rates, in the same way that 'recurrence surfaces' occur in peat bogs (Aaby and Tauber, 1975). Since the accumulation rate is partly dependent on hydrological conditions, humified beds 2b and 2f may relate to periods of drying and exposure during which humus-forming biological processes were able to operate. This humus can be regarded as autochthonous.

2. Inwashing of mor humus from surrounding slopes. The erosion of mor humus from podsol profiles and blanket bog on British

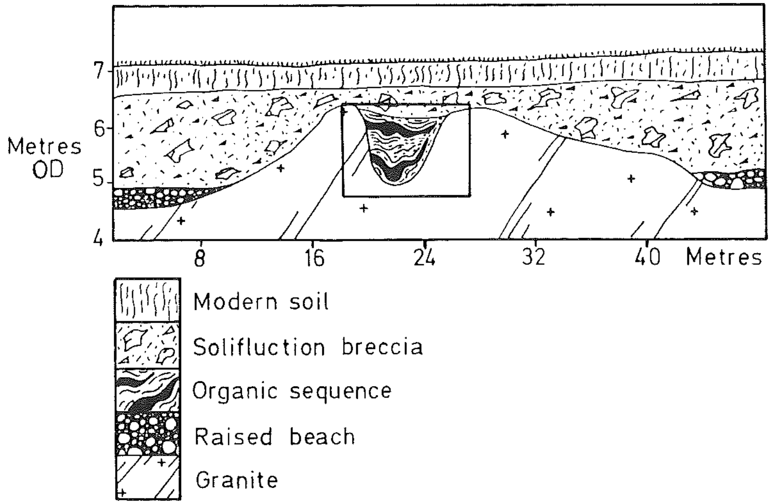


Figure 15. Carn Morval - stratigraphy

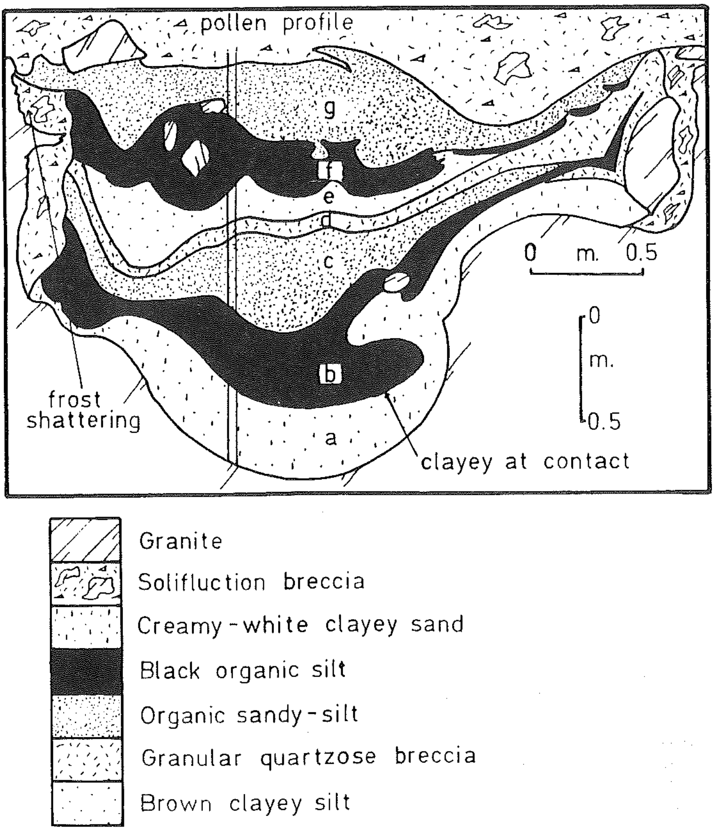


Figure 16. Carn Morval - microstratigraphy

uplands produces a deposit striking in its similarity to beds 2b and 2f. This humus can be regarded as allochthonous.

Beds 2c and 2g are less humified and by analogy with the respective hypotheses above may represent either faster accumulation rates or the reduced inwash of mor humus. Bed 2d represents a period of solifluction from the surrounding slopes directly into the pool. Bed 2e has a dominant model class in the very fine sand fraction and consists of 50% sand, 37% silt and 13% clay. This suggests an aeolian origin, but compared with the Old Man Sandloess it contains a fairly high clay percentage and is relatively poorly sorted; this may perhaps be explained in terms of deposition in standing water.

The main features to note from Figure 18 are the occurrence of unidentifiable carbonised organic detritus in beds 2b and 2f, and the high organic content of these two beds as indicated by the loss on ignition analysis at 550° C. Organic content is greatest in beds 2b and 2f, reaching 30% in 2b and 22% in 2f. As expected, organic content is lowest in beds 2a and 2d, reaching a minimum of around 1% in both. The loss at 950° C. results are surprisingly high, though fluctuating, reaching a maximum of 10% in bed 2b; the removal of clay lattice water is thought to be the most likely explanation for this loss (Dean, 1974), perhaps with the additional minor removal of organic material which was not combusted at 550° C.

The post-depositional contortion and slumping of the sediments can be attributed to two processes, solifluction over the surface of the basin, and the melting out of a basal ice body perhaps related to the naled referred to above. Loading may be an additional factor.

A detailed pollen sampling programme was undertaken, samples being taken by tube from the base of bed 2a at 5 cm. intervals to the base of the Porthloo Breccia as indicated in Figure 16.

It was noted during sampling that the organic sediments had been recently bored by solitary bees. This was clearly an important potential source of contamination. In an attempt to avoid contamination, therefore, the face of the section was carefully cleaned as far as was possible, without totally removing the organic beds. The face was cut back by about 0.75 m., and this seemed to have penetrated beyond the zone of contamination. However, when pollen counting commenced it quickly became apparent that some levels were contaminated with modern pollen. Some objective method was therefore required to separate the 'bee pollen' from the fossil pollen. The following factors were found to be likely indicators of bee contamination at any particular level:

1. the presence of bee tunnels at a particular level prior to cleaning.

2. anomalous pollen assemblages, the vertical homogeneity broken by periodic influxes of new taxa

3. very high pollen concentrations compared with neighbouring levels, and

4. the presence of large numbers of pollen clumps.

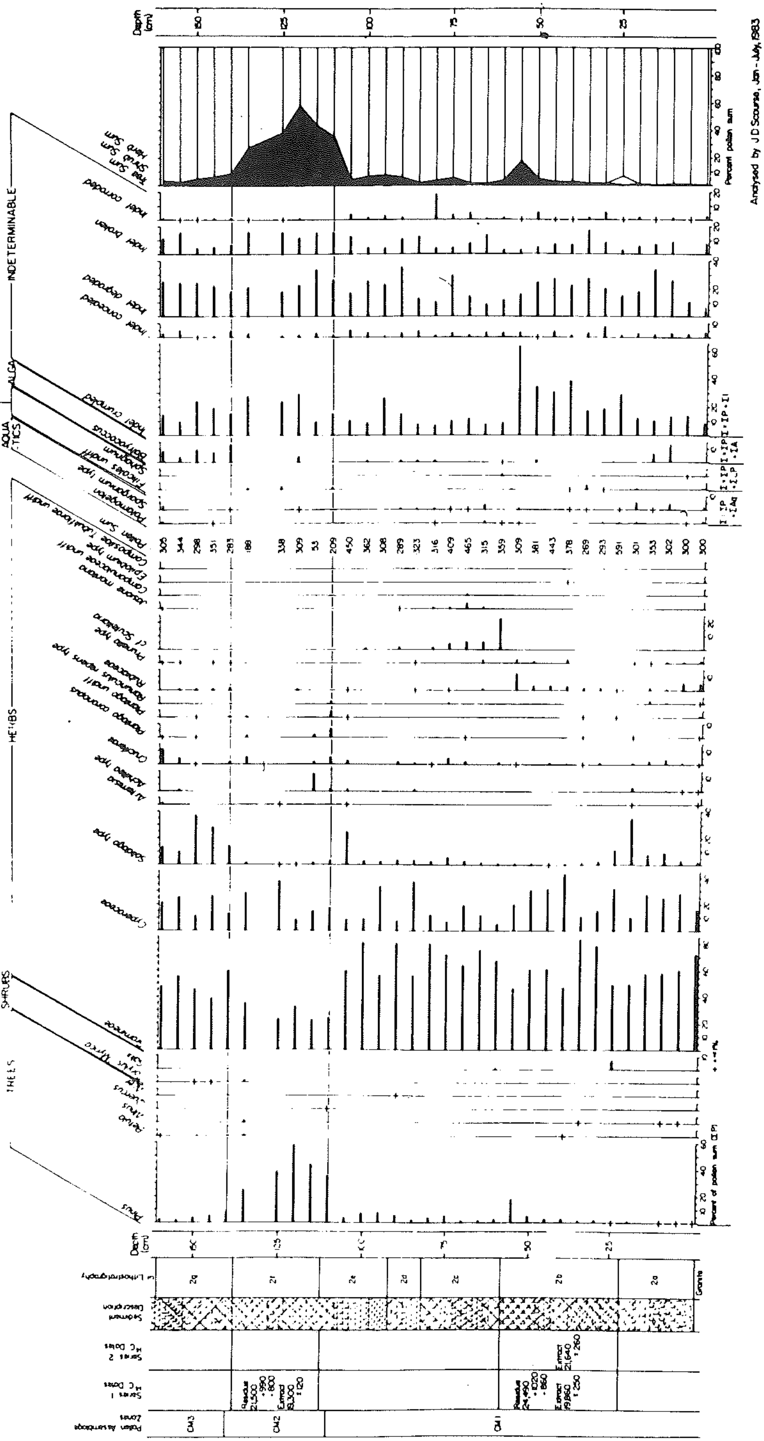


Figure 17.

CARN MORVAL · Corrected Percentage Pollen Diagram

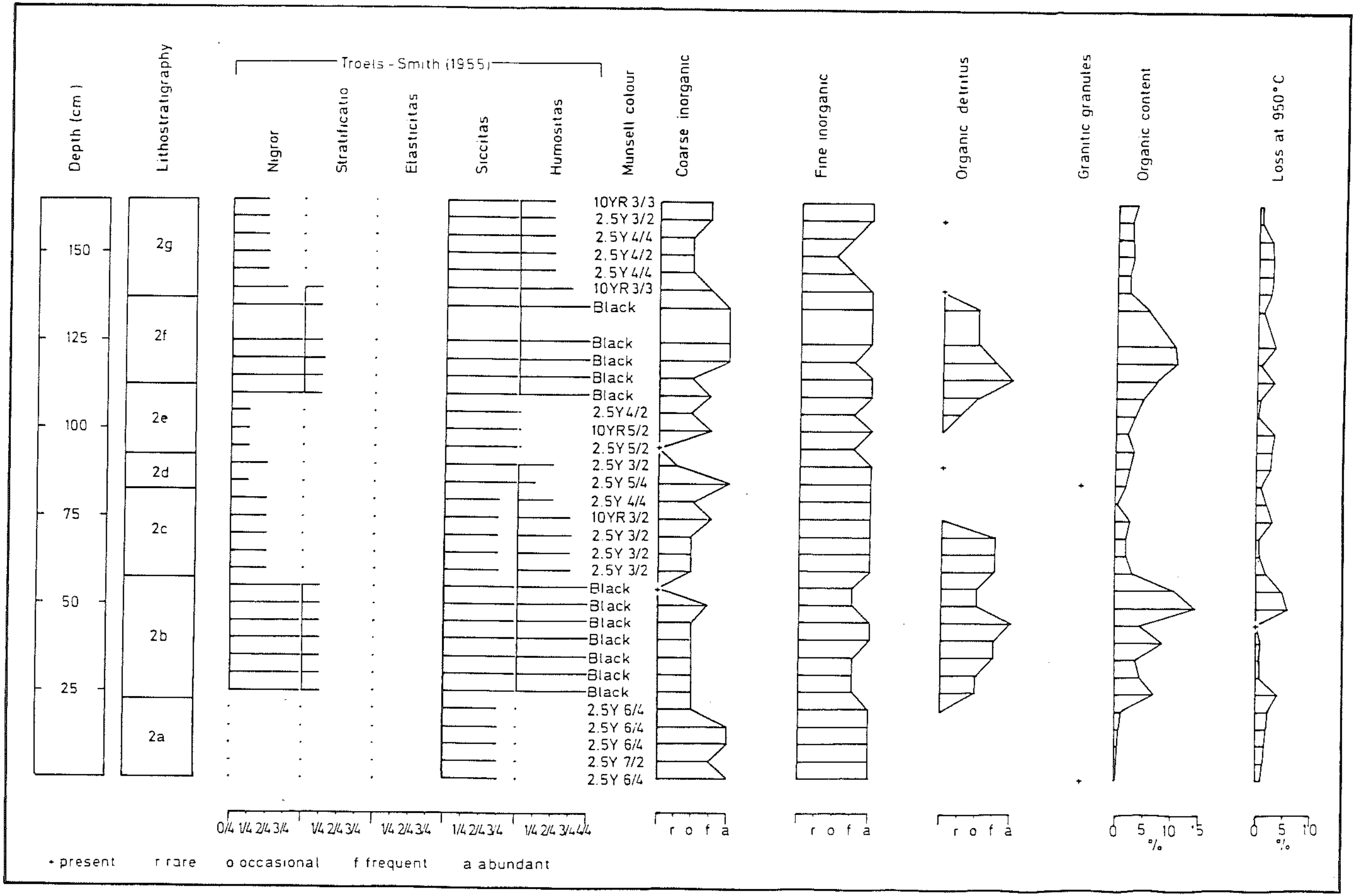


Figure 18. Carn Morval - loss on ignition and pollen washings diagram

If a level was suspected of contamination on the basis of these factors, taxa were critically examined in the light of the following two criteria:

1. insect (entomophilous) rather than wind (anemophilous) pollination, and
2. state of preservation; bee pollen was in an excellent state of preservation in comparison to the fossil material.

If the taxa was indeed from an insect-pollinated plant and was in an excellent state of preservation, combined with one or more of the initial four criteria, it was regarded as a contaminant, and excluded from the 'fossil' diagram accordingly. The only major separation problem occurred when a single taxon was, in terms of preservation, clearly made up of both fossil and bee pollen. This applied particularly to the Compositae.

On the basis of these criteria, three pollen diagrams have been prepared, one 'total' percentage diagram, including fossil and bee pollen (Fig. 19), one 'fossil' percentage diagram (Fig. 17), and one concentration diagram which includes both fossil and bee pollen (Fig. 20).

Of the 33 levels prepared, 32 contained countable pollen, only the top level of bed 2g being barren, all the levels containing pollen therefore being continuous.

The taxa regarded as being bee contaminants can be seen in Figures 19 and 20. By far the most important of these are Rubus fruticosus and Compositae Liguliflorae. In level 115 cm. Rubus fruticosus reaches a concentration of 348,000 and Compositae Liguliflorae 146,000 grains per $cm.^3$. Level 85 cm. was also badly contaminated. Only levels 0 to 25 cm., 60 cm., 75 cm., 95 cm., 100 cm., and 130 cm. were totally uncontaminated, though the remaining levels were only slightly affected.

Taxa thought to have been harvested and introduced by the bees apart from Rubus fruticosus and Compositae Liguliflorae include Angelica Type, Bidens Type, Caryophyllaceae, Chenopodiaecae, Ranunculaceae, Liliaceae, Cirsium/Carduus, Allium Type, Empetrum, Armeria/Limonium, Rosaceae, Leguminosae, Ononis Type, Silene maritima Type, Herniaria and Umbelliferae. Plants contributing to these taxa all grow locally and are known to be entomophilous.

The solitary digger bees at Carn Morval have shown a marked preference for soft, easy excavatable, sediment; therefore, beds 2b and 2f seem to be their favourite digging sites. These beds are also the richest in organic content and therefore the most suitable for radiocarbon dating. Along with rootlets, and percolating groundwaters charged with modern humus, solitary digger bees have to be regarded as an additional potential source of contamination for radiocarbon dating at this site.

Before fossil pollen assemblage zones (p.a.z.) and vegetational history can be discussed, pollen taphonomy must be considered. In small basins such as this, most pollen would have been washed in by the small streams draining the immediate

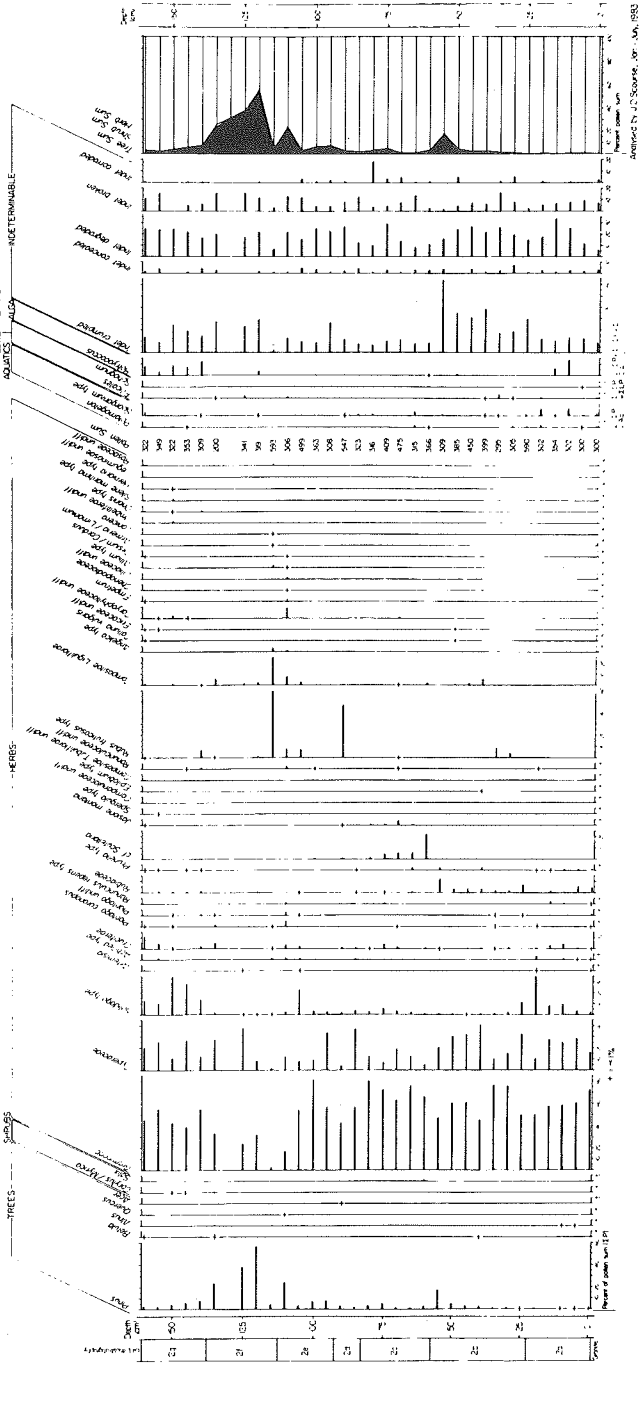


Figure 19. CARN MORVAL - Total Percentage Pollen Diagram

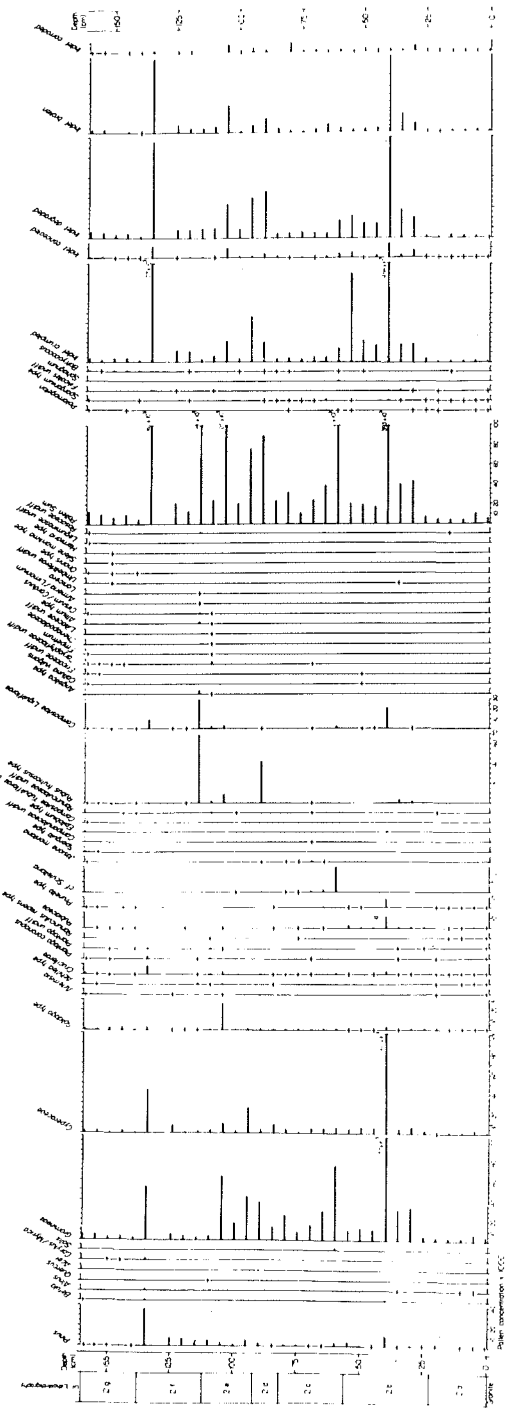


Figure 20. CARN MORVAL - Concentration Pollen Diagram

slopes, and would therefore represent local vegetation. This local component would be further complemented by aquatic and helophytic vegetation living within, or surrounding, the pool, but diluted by a small long-distance airborne component landing on the water surface. The most important airborne taxon in this context is Pinus, and it is this which provides the only real change in the diagrams.

Just as the different beds can be attributed a specific genesis, so the taphonomy of each bed is different. The 'micro-taphonomy' of the site is summarised in Table 2. The main features to note from this Table are that local sources predominate throughout the sequence, that bed 2d probably consists of reworked pollen from lower levels, and that bed 2e, having an aeolian origin, may well consist of a larger regional component than the other beds.

The change in the Pinus frequencies enables the diagrams to be divided into three pollen assemblage zones as indicated in Figure 17. These zones have been confirmed using the numerical ZONATION program (Gordon and Birks, 1972).

0-110 cm. Zone CM1 Gramineae-Cyperaceae p.a.z.

This zone is totally dominated by herb taxa. Gramineae frequencies are consistently high, ranging from 47% (55 cm.) to 82% (35 cm.) while Cyperaceae occur consistently but at lower frequencies, ranging from 5% (60 cm.) to 42% (40 cm.) Other important herb taxa include Solidago Type, which reaches two distinctive peaks at 20 and 105 cm., Cruciferae, Plantago undiff., Rubiaceae, Prunella Type, Jasione montana and cf. Scutellaria. The aquatic taxa Sparganium Type and Potamogeton are sporadically present through the zone, but are particularly concentrated within beds 2a and 2c. Similarly the freshwater algae Botryococcus reaches a peak at 10 cm. within bed 2a. Pinus values are very low in the basal sediments, but rise gradually from 20 cm. to reach values of 8% towards the end of CM1. The only major correlation between pollen concentration and sediment type is the contrast between beds 2a and 2b. Concentrations are very low in 2a, between 8,000 and 18,000 grains per $cm.^3$, rising rapidly to 905,000 grains per $cm.^3$ in the basal level of 2b. Concentrations of this order are very high indeed, even by comparison with temperate limnic sediments (C. Turner, pers. comm., 1984). Percentages of indeterminate pollen are consistently high through CM1, but with an increase in bed 2b.

110-140 cm. Zone CM2 Pinus-Cyperaceae p.a.z.

This p.a.z. covers the top of bed 2e and bed 2f and is defined by a rapid rise in the Pinus frequencies from around 8% at the top of CM1 to 56% at 120 cm., and a corresponding decrease in the Gramineae frequencies. Cyperaceae frequencies, however, continue at the same levels as in CM1, reaching a poorly defined peak of 37% at 125 cm. Other herb taxa include Solidago Type, Cruciferae, Achillea Type, Plantago undiff., Plantago coronopus and Ranunculus repens Type. Aquatic taxa frequencies are low in this p.a.z., whilst indeterminate percentages continue at similar levels as in CM1.

The concentration diagram through this zone is again very erratic; the Pinus peak appears as a distinct feature but is less impressive than on the percentage diagram. The Gramineae

Unit	Description	Genesis	Pollen Taphonomy		
			Local source pond itself and slopes	Extra-local source	Regional source airborne component
2g	Organic sandy silt	Lacustrine - fast sedimentation rate	Strong	Weak	Weak
2f	Black organic silt	Lacustrine - slow sedimentation rate	Strong	Moderate	Weak
2e	Brown silty clay	Waterlain sandloess	Moderate	Weak	Strong
2d	Granular quartz breccia	Solifluction	Reworking of underlying sediments		
2c	Organic sandy silt	Lacustrine - fast sedimentation rate	Strong	Weak	Weak
2b	Black organic silt	Lacustrine - slow sedimentation rate Possible inwashing of pollen	Strong	Moderate	Weak
2a	Creamy-white sand with clay	Fluvial/colluvial minerogenic inwash	Strong	Moderate	Weak

Table 2. Carn Morval - microtaphonomy of organic sequence

decrease and the stability of Cyperaceae appear not to be mere artifacts of the percentage calculations.

140-160 cm. Zone CM3 Gramineae-Cyperaceae p.a.z.

This p.a.z. covers bed 2g and is essentially a repeat of CM1 with very low Pinus, high Gramineae, stable Cyperaceae frequencies and a similar array of herb taxa. Botryococcus percentages rise in the zone, but comparison with the concentration diagram shows this to be an artifact of the percentage calculations.

Many of the changes seen in the diagram can be attributed to sedimentary conditions, taphonomic variations, or secondary weathering. In particular, the possible drying of the pool during 2b times inferred from the humification of the sediment is supported by the increase in indeterminate weathered pollen in 2b. The rapid increase in total pollen concentration at the base of 2b can be attributed to a dramatic decrease in the sedimentation rate associated with this drying.

All the herb taxa are characteristic of arctic tundra vegetation, the grasses dominating but with sedges in favourable, perhaps wetter localities. Much of the sedge pollen may be from plants which were living in the pool itself, and thus reflect very local fluctuations. The other herb taxa are common colonisers of the disturbed minerogenic soils of the periglacial zone (Godwin, 1975).

Undoubtedly the most interesting feature of the diagram is the Pinus peak of CM2. Six hypotheses can be invoked to explain this increase:

1. Vegetational change. The Pinus peak may indicate an actual increase in Pinus growing near the site.

2. Change of wind direction. This may have altered the source of the long-distance pollen introducing larger amounts of wind-pollinated Pinus into the basin.

3. Sedimentation rate. A constant long-distance Pinus component. indicated by the stable but low frequencies of Pinus in CM1 and CM3, combined with a much lower sedimentation rate would have the effect of increasing Pinus concentrations.

4. Differential weathering. Resistant Pinus grains are often found in partially oxidised sediment in high percentages because other less resistant grains have decayed. This is also a result of differential recognition, Pinus being an easily identified grain even in an advanced state of destruction (Kerney, Preece and Turner, 1980).

5. Bee contamination. Faegri (1961) has noted the important presence of anemophilous pollen adhering to bumble bees. In view of the importance of other bee contaminants at this site, it is possible that the anemophilous Pinus peak is a function of similar contamination.

6. Differential pollen influx rates. A low but consistent long-distance Pinus component combined with a reduction in the pollen productivity of the locally growing herbs would have the effect of increasing both Pinus percentages and concentrations.

These hypotheses can be discussed in turn:

1. An increase of Pinus growing near the site, representing interstadial conditions, is thought to be fairly unlikely. Other tree taxa, such as Betula, show no such increase during CM2. In addition, no macrofossils of Pinus have been found at the site, nor were any Pinus stom atal guard cells (Bennett, 1983; Kerslake, 1983) counted in the pollen preparations.

2. The lack of other tree taxa mentioned above supports this hypothesis, for bisaccate Pinus grains can be carried thousands of miles by wind, whereas the pollen of other tree taxa is less successful in this respect (Birks and Birks, 1980; Nichols et al., 1978). This hypothesis has the disadvantage of being largely untestable.

3. Though it is possible to demonstrate the likelihood of reduced sedimentation rates in 2b and 2f, the lack of a concomitant Pinus peak in 2b, and the fact that the Pinus peak is more well developed in the percentage rather than in the concentration diagram indicates that this hypothesis is unlikely to be responsible for the feature. An increase in the concentrations of Pinus without an increase in the percentages would support this hypothesis; the opposite is, however, the case.

4. Two introduced species of pine are the only widespread trees today growing on the Scillies. Pinus radiata (Monterey Pine), planted since the beginning of the century, and Pinus contorta (Lodge Pole Pine), planted from 1964, are used as windbreaks (Lousley, 1971). Solitary bees probably pick up pollen grains from these species and may well have deposited small numbers in the Carn Morval deposit along with the other recent contaminants. It is thought extremely unlikely, however, that values as high as 56% (120 cm.), or that the 'rounded', continuous, Pinus curve over seven levels to be seen in Figure 17 could have been produced in this way. All well preserved intact grains resembled Pinus sylvestris.

5. During severe climatic deterioration the pollen productivity of local herbs would be restricted, thus emphasising a long-distance Pinus component in both concentrations and percentage diagrams. The overall character of the pollen spectra taken with the stratigraphy of the site and the radiocarbon dates (see below) argue strongly in favour of this hypothesis.

These hypotheses are not mutually exclusive. It is probable that two or more of these hypotheses may have operated at the same time to produce the Pinus peak. The favoured explanation on the basis of the above discussion is that the feature is the result of a relatively small long-distance Pinus component being exaggerated in both percentage and concentration terms by the oxidation of other less resistant pollen and a decline in the pollen productivities of local herbaceous plants caused by desiccation of the basin and climatic deterioration respectively.

Despite extensive sieving, no identifiable plant macrofossils have been discovered at this site. Dr G.R. Coope of the Department of Geology, University of Birmingham has analysed samples of beds 2b and 2f for Coleoptera, but has only found decomposed weevils. Weevils are the most resistant of the beetles to chemical decay, adding supporting evidence to likely weathering during 2b and 2f times caused by drying out of the pool.

In terms of radiocarbon dating three sources of potential contamination by modern carbon can be identified at the Carn Morval site:

1. rootlet penetration of the organic material

2. percolation through the organic material by groundwaters rich in modern humus and

3. tunnelling by solitary bees introducing recent pollen, faeces, dead bees and cocoon secretions.

Contamination by ancient carbon is also a possibility in view of the likelihood of the deposition of eroded mor humus in the basin as discussed above. This contamination, can, however, be regarded as minimal, as such material would have been only slightly older than autochthonous carbon in the basin, especially considering the resolution of the radiocarbon method on deposits of this general age.

The beds selected for dating were 2b and 2f because of their high organic content. The radiocarbon dates were completed as two series: these are referred to as the 'first' and 'second' series.

1. Sampling - First series

At least the outer 0.5m of material was removed to minimise contamination. Following the counting of these samples, and of pollen counting from the respective levels, a number of sources of contamination, mainly by younger carbon, were identified. Contamination was identified as being most severe at the section face, becoming less severe with distance into the section away from the face. Accordingly, the second series dates were sampled using an alternative method.

2. Sampling - Second series

For the field sampling of the second series dates, a Dutch-type wing auger was used to penetrate the face of the section horizontally. Core samples from between 1.00 and 3.5 m. into the section along the same beds as dated in the first series were obtained. In order to obtain at least 1 kg. of sediment, it was occasionally necessary to core the section twice at juxtaposed points (Fig. 21).

3. Pretreatment

Samples were first broken up and scanned for any visible modern rootlet penetration. Roots, if detected, were removed. In view of the fact that 70% of the modern carbon introduced by rootlets consists of dead cell material in the root walls

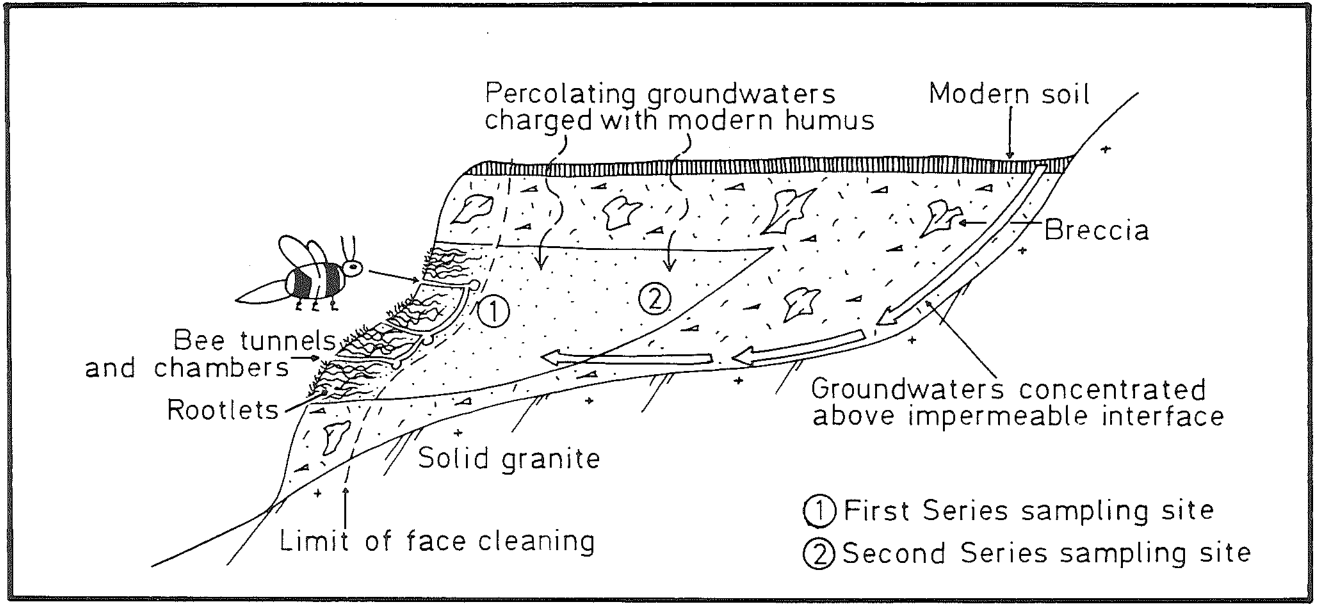


Figure 21. Organic sites - sources of contamination and radiocarbon sampling sites

which cannot be detected by the naked eye, samples with a major rootlet problem were discarded. If minor rootlet penetration appeared to be an important potential source of contamination, the sample was mixed thoroughly with distilled water and then left to settle. The rootlets then floated to the surface and could be skimmed off. Rootlets were only observed in some of the first series samples. Not a single rootlet was observed in any of the second series samples.

The samples were then mixed to a pulp in a liquidizer and diluted with a buffer solution made up from sodium pyrophosphate ($Na_4\ P_2\ O_7$) and sodium hydroxide (N_aOH) in order to extract the humic materials. This mixture was then heated to 60° Centigrade and stirred continuously for 12 hours. The supernatant was then decanted and centrifuged, the resultant residue being added to the original; more buffer solution was then added and the process repeated. The supernatant was then acidified with 10% hydrochloric acid (HCl) to a pH of about 2, causing the humic material to precipitate out. After repeated settling and decanting of the supernatant, the humic precipitate was neutralised with distilled water to pH6, after which it was dried at 80° Centigrade. The resultant black solid was then combusted.

If they contained sufficient carbon, the solid residues of the samples were dated as a control. Following the removal of the supernatant the residue was mixed with distilled water and left to settle, whereupon the supernatant was decanted and the fine residue, containing both organic and silt-sized inorganic particles, separated manually from the coarse, mainly inorganic residue. The fine residue was then mixed with very dilute HCl in order to acidify the sample in preparation for combustion. The sample was returned to pH6 by repeated washing with distilled water, and then dried at 80° Centigrade.

The first series dates are as follows:

	Residue	+	-	Extract	+	-	Q number
2b	24,490	960	860	19,860	220	210	2356/7
2f	21,500	980	800	19,300	120	120	2358/9

These dates are stratigraphically consistent, bed 2f being younger than bed 2b. The extract dates are younger than the residue dates by between 4,630 (2b) and 2,200 years (2f). This suggests that modern humus has been introduced at the face of the section, this contamination being most severe at the base*. As not all the humic fraction was extracted from the residues, it is therefore likely that the residue dates are slightly too young.

* A number of studies have demonstrated that humic extract dates are usually younger than solid residue dates (Olsson, 1974; Matthews, 1980; de Gans and Cleveringa 1983; Caseldine, 1983) These have been consistently interpreted in terms of contamination by groundwaters charged with modern humus.

All contamination sources identified are more likely to have penetrated inward from the face of the section than downwards through the overlying strata because of the induration of the Porthloo Breccia above. Therefore, the recovery of a 'second series' samples was attempted, as described above (Fig. 21). However, bed 2f was found to extend laterally into the section only a few centimetres following its removal for the first series samples, and was therefore not sampled. The second series sample of bed 2b was pretreated, but on combustion, the residue was found to contain insufficient carbon for dating. Therefore, the second series programme on the Carn Morval site only consists of one date, the humic fraction of bed 2b.

The date is as follows:

Extract +	-	Q number
21,640 20	260	2446

This humic extract date is older than the first series humic extract dates by nearly 2000 years, suggesting that it is less contaminated by modern humus than the first series samples. Because no residue date was possible there is unfortunately no control on the amount of contamination in the first series 2b residue date. It is suggested that the first series residue dates are the most reliable, deposition of the organic material probably having occurred between about 24,500 and 21,500 ^{14}C years B.P. All seven ^{14}C dates from the Carn Morval site are well grouped noninverted and the differences between residue and extract dates are explainable.

HALANGY DOWN (SV910124) GWD

The Iron Age settlement of Halangy Down was excavated from 1964 onwards by Ashbee (1964-1970). No clearly defined palaeosols could be found beneath any of the structures on this site from which soil pollen profiles might have been studied. In the hope of obtaining a soil pollen profile that might cover the period of occupation of the Halangy site, a series of samples was taken in the marine cliff lying some 150 yards downslope from the site. The cliff section showed about four feet of unconsolidated deposits, possibly hillwash, overlying a ten foot depth of unmodified 'head'.

Contiguous samples at one inch intervals were taken through the unconsolidated deposits at the top, and also in a loamy layer, possibly a weathered soil, immediately beneath the 'head'. This latter proved to be devoid of pollen. The pollen diagram obtained from the upper layers (excluding a few 'casuals') based on total pollen plus fern spores, is shown in Fig. 22 and alongside it the stratification of the deposit.

The most striking feature of this pollen profile is the virtual absence of tree pollen. This means that there is no means of dating the different layers by tree species. The only date indicator is a piece of 14th century pottery found at ten inch depth, in the surface layer of loose grey sand. This probably implies, though it does not prove, that the layer below this in the profile is of earlier date.

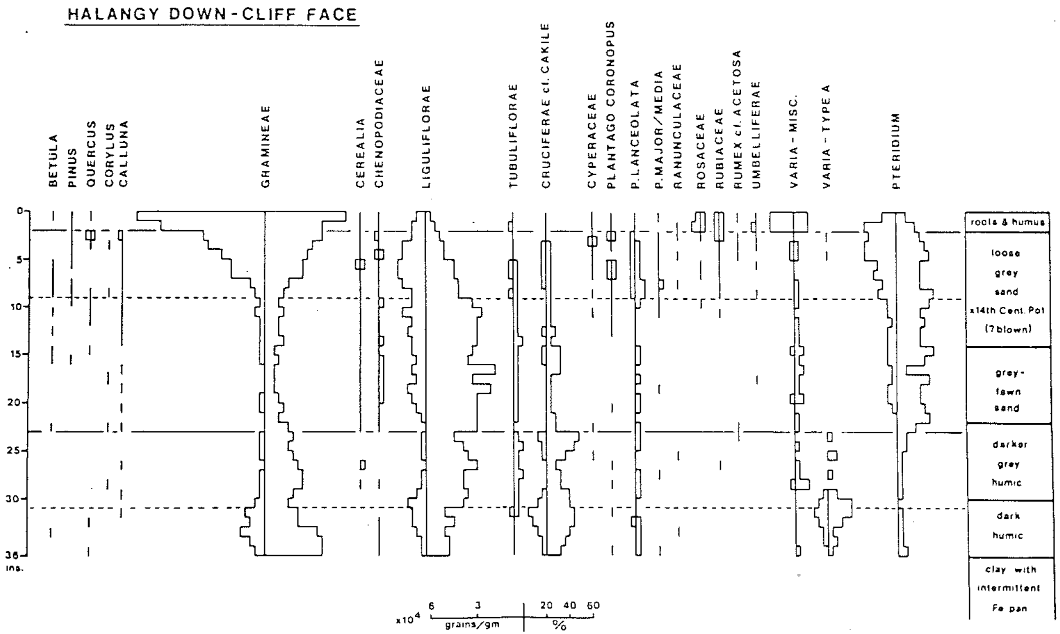


Figure 22. Halangy Down - cliff face pollen diagram (Dimbleby et al., 1981)

The pollen diagram falls into five distinct layers, indicated by horizontal lines across the diagram. The topmost layer, only two inches deep, is characterised by a high proportion of grass pollen, and particularly of the group described in the diagram as Varia-Miscellaneous. These are pollen types which could not be identified (though well preserved) and probably represent aliens associated with the present use of the land for commercial flower growing. The pollen of Pittosporum, an introduced evergreen shrub used today as a windbreak, was found only in these two samples.

From two to nine inches, the profile is dominated by grass, Liguliflorae and ruderal pollen, together with abundant bracken spores. The fact that the main curves show distinct trends implies that pollen is being carried down into this layer, so that despite the loose nature of this material it had not been added to in recent times but had developed a stable surface from which a sequence of pollen spectra has developed.

This is in marked contrast to the underlying layer, in which the pollen is evenly distributed both in frequency and percentage. It would be reasonable to regard this as a layer of accumulating top soil, probably hillwash from the fields above. The pollen suite is poor in species and is largely dominated by Liguliflorae and bracken. As both of these pollen types are relatively resistant to decay, we may be seeing here the relic of a richer assemblage. At 23 inches, a sudden change occurs, marked by higher percentages of grass pollen and much less bracken. The most conspicuous feature, however, is the sudden increase in the pollen of Cruciferae, of a type which could not be identified for certain, but had a close resemblance to Cakile maritima. The grains are smaller than modern specimens, but this is commonly so with pollen preserved in mineral sediments. The Cruciferae, of course, include crop plants such as cabbage or charlock, so the significance of this pollen type must remain in doubt. However, I know of no parallel for high concentrations of the pollen of this family, which is entomophilous, and its presence must mean the presence of quantities of flowering material. Possible explanations are that either a flowering crop was being grown as a green manure of that local coastal vegetation was being brought on to the fields for the same purpose.

Whatever the explanation, the distribution of this pollen type in this layer suggests that at 23 inches there is an old surface subsequently buried under hillwash. This layer itself, however, is clearly not a primary soil, for at 31 inches another apparent surface appears, also showing high values of Cruciferae pollen but characterised by a new pollen type, so far not identified. Re-examination of this pollen type suggests that it is also a crucifer, possibly Cochlearia anglica another coastal plant. However, it clearly distinguishes the lowest of the five layers. This has all the indications of a pollen profile developed in a soil in situ, which is confirmed by the description of the lowest two layers shown at the right-hand side of Fig. 22. It seems unlikely that this soil was covered by deposits from close by, for the samples above it give mirror images of the pollen curves, especially the Cruciferae and the Varia-Type A.

It is apparent that though this level of 29 to 36 inches is the lowest polleniferous horizon, there is no greater representation of tree pollen in it than in any of the layers above. In this sense, it contrasts with the Nornour profile which is both somewhat earlier and on a small island. However, the bog evidence from Higher Moors and the palaeosol evidence from Innisidgen, neither of which is more than a mile from Halangy Down, clearly establish the previous presence of woodland in this area of St. Mary's. It therefore has to be assumed that Halangy Down itself was once wooded. Though it is not possible with certainty to equate the lowest buried levels of the cliff face pollen profile with the Iron Age occupation above, in the absence of any other archaeological settlements in the vicinity this would be a likely explanation. If so, not only were the environs treeless at this time but apparently all traces of a primary soil have disappeared, presumably by hillwash or wind erosion. The palaeosol at Innisidgen indicates truncation of the primary soil profile and the superimposition of blown sand associated with agricultural land use.

BAR POINT (SV915130) NDB/HCMK

During excavations of prehistoric field walls at Bar Point in 1979 and 1980 (Evans, 1984) a number of samples were taken for pollen analysis, and some soil profiles buried by blown sand examined by Macphail (1981).

The pollen samples came from cultivation soils, field boundaries and lynchets. One small group of samples was taken from a humus rich stabilisation horizon in the body of the sand dune. Other samples were taken from the present dune surface and from the clean grey sand that made up the bulk of the dunes. These latter samples were taken to assess the degree to which the buried soils might have been contaminated by more recent pollen washed down through the loose sand of the dunes. Because of the lack of variation between samples (both vertically and from one profile to another) and the small number of samples in which pollen was present in quantity, no pollen diagrams have been prepared.

In all cases the pollen assemblages are indicative of open land, with no trees or shrubs. At the base of only one profile were there very small quantities of _Quercus_, _Alnus_ and _Corylus_. The pollen that has survived gives little indication of the exact nature of the vegetation when the fields were in use, although the presence of cereal pollen suggests cultivation of cereals on the site at some time. The main groups are: Gramineae and Liguliflorae, with subsidiary amounts of Tubuliflorae and Cruciferae. _Plantago lanceolata_ pollen is in consistent but low abundance.

A feature of both the lynchet profiles and those beneath the north-south banks is that higher frequencies occur in the lower parts of the profiles. In the case of the lynchets this may be due to pollen-rich layers having been buried by topsoil which then continued to be cultivated and aerated, consequently becoming pollen-poor. In the case of the north-south banks it is suggested that the high frequencies indicate buried horizons.

The standstill horizon in the blown sand contained, in addition to Gramineae and Liguliflorae, pollen of Calluna and other Ericaceae, suggesting that after inundation of the site by sand a substantial change in vegetation took place with heathland being more widespread.

The soils were shallow podzols and humoferric or ferric podzols formed in head (generally indurated and granitic in character) and blown sand. The pre-cultivation soils underlying the main North/South wall were shallow ferric podzols and an example is described below:

0-20cms. (Ah): Black (5YR2.5/1) moderately weak medium sand with coarse blocky structure; common fine roots present. Clear, smooth boundary to:

20-39cms. (Ea): Pinkish grey (7.5YR6/2) to dark brown (7.5YR3/2) moderately weak to weak sand, structureless, containing many small stones and rare roots. Gradual, wavy boundary to:

39-42cms. (Bs): Strong brown (7.5YR5/6) moderately firm loamy sand, massive, many small stones, rare roots and containing a weak iron pan. Clear, wavy boundary to:

42-62+cms. (Bsx): Strong brown (7.5YR5/8) moderately strong sandy loan, massive (to platy?), 5% pores, few small and common very large stones, roots absent. Diffuse, irregular boundary to:

62+cms. (Cx): Cemented layered head.

After the construction of the North/South wall a plough soil was formed, thus homogenising the A and upper parts of the B horizon. After the building of the East/West walls the depth of the plough soil increased and an example (Humo-ferric podzol) is described below:

0-12cms. (Ap): Very dark grey (5YR3/1) moderately weak sandy loam with coarse blocky structure, containing few stones, 0.5% pores, many fine roots and with a clear smooth boundary to:

12-17cms. (Ap 2): Black (5YR2.5/1) moderately weak sandy loam with coarse blocky structure, few stones, 0.3% pores, many fine roots and a clear, smooth boundary to:

17-27cms. (Ea): Brown (7.5YR4/2) weak sandy loam with coarse blocky structure, 0.1% pores, few medium roots and a clear, smooth boundary to:

27-27.5cms.(Bf): Brown (7.5YR4/2) weak to strong iron pan.

27.5-42cms. (Bs/Bhs): Both yellowish red (5YR5/6) and dark reddish brown moderately firm sand with coarse subangular blocky structure, including iron pans and merging with the head.

INNISIDGEN (SY921127) GWD/HCMK

At Innisidgen, on the north coast of St. Mary's close to Innisidgen Carn, a small sandpit provided a section of a stabilized sand-dune which extended down to a buried soil profile beneath the dune. There was also a narrow but clear-cut humus band higher up the dune which probably represented a one-time stabilized surface of the dune. Pollen analysis of these two buried levels was carried out in order to establish the ecological conditions associated with their formation.

The old land surface was clearly visible as a dark humus horizon about 8 cm thick. Lying above this at a variable height in different faces of the sandpit was a dark humus horizon about 2 to 3 cm thick. At the point sampled it lay 1½ m above the old land surface. This upper humus horizon was set in silver sand which showed no clear profile development, but there was a series of similar bands at lower levels, apparently associated with the stratification of the dune. About 25 cm above the old land surface the colour of the sand changed to a light brown.

Below this light brown sand there was an indurated iron pan, approaching a centimetre in thickness at some points. It was clearly derived by the leaching of the body of the dune. In places it ran above the old land surface, but at some points it cut through the surface or coincided with the surface.

The soil associated with the old land surface was wet and of a heavy texture. The presence of stones in it confirmed that it was the original ground level and not part of the dune.

The profile was somewhat irregular, but may be described as follows:

0.1cm	Compressed raw humus
1.12cm	Humus-stained A horizon
12-13cm	Narrow bleached horizon
13.20+cm	Light brown heavy loam, merging irregularly into:
	Light brown heavy loam with stones and small black nodules.

An interpretation of this profile could be that podzolization of gleying was taking place in the upper layers of a deeper brown earth soil.

The upper humus layer, lying about 1½ m above the buried soil, offers no problems and can reasonably be seen as a surface of the dune that was stabilized under a heathland vegetation and then after a short lapse of time overwhelmed by further shifting sand.

The buried soil is more complex and more informative about the past vegetation history of St. Mary's. There are three layers which show distinct differences in their pollen analysis (Fig.23):

Sample 200 Overlying the old land surface. This sample is moderately rich in pollen and therefore is derived from topsoil. Heather pollen predominates.

Samples 199-197 These samples are dominated by grass pollen and bracken spores. Sample 199 has a very high pollen frequency and is clearly the surface humus of the buried soil.

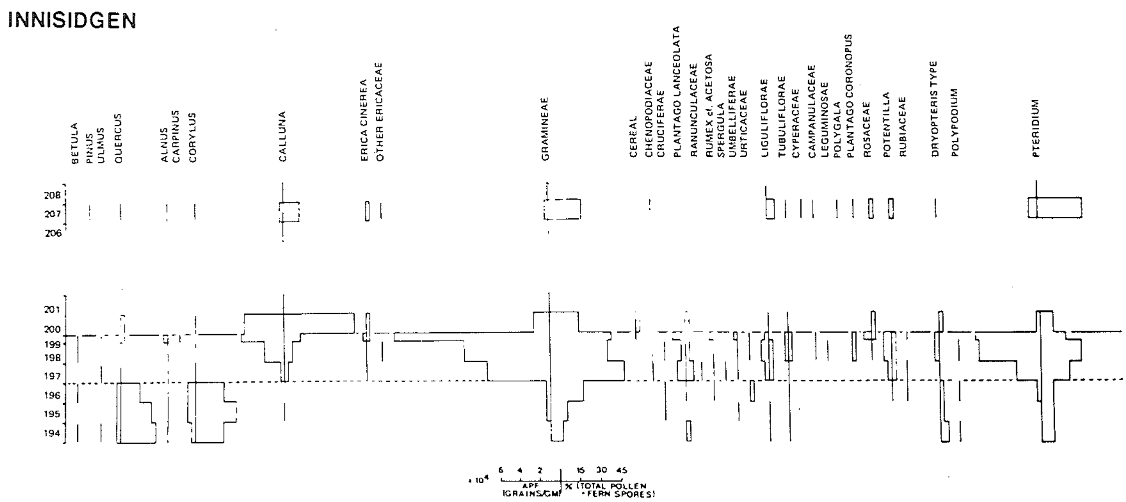


Figure 23. Innisidgen - pollen diagram (Dimbleby, 1977)

Samples 196-194 These samples are dominated by oak and hazel pollen. The frequencies are low, suggesting that they do not represent a soil surface.

To take the last layer first, the likely explanation of this is that it represents the lower part of a forest profile which has been truncated by the removal of the pollen rich surface layers. The possible reasons for such truncation will be discussed below. This layer seems to provide good evidence of the one-time presence of deciduous woodland at this coastal site. It is not possible to say much about the nature of this woodland, though the abundance of hazel and the consistent presence of grass pollen may suggest that the canopy density was such that enough light penetrated to allow the flowering of these species.

The middle of these three layers, sharply delineated from those above and below it, has a pollen suite strongly reflecting open country. It could represent material transported, possibly by wind and dumped on the surface of the truncated old forest soil. It cannot be told with certainty whether it was initially pollen-rich, but the form of the frequency curves suggests that the pollen in it has been derived from a stabilized surface represented by the humic sample No. 199.

What could have been the cause of the ecological changes which these analyses seem to indicate? A possible cause is suggested by the pollen types which are associated in small proportions with the dominants mentioned. Some of these are plants like those in the upper humus horizon which may be expected in open situations in such an area. Others, however, are to be regarded as indicators of agriculture, such as Cerealia, Plantago lanceolata, Rumex cf. acetosa, Urticaceae and Spergula. It is clear that the middle layer has much richer representation of such taxa than the adjacent layers. Nevertheless, there are some of these plants in the truncated forest soil, and also some in the overlying dune base (sample 200).

A possible sequence, therefore, is that a forest environment existed on this sandy parent material, and that this was then exploited for agriculture, removing the tree cover and eventually leading to windblow, so truncating the forest soil. Soil instability continued in the area and at some later date (chronology unknown) a thin covering of sand (samples 197, 198) blew back on to the truncated profile. As there is no pollen accumulation on the surface of the truncated soil, it may be that the time lapse was very short, but the possibility of repeated episodes of denudation must be allowed for. Eventually the new surface was stable long enough for a humus layer to develop and for pollen to become incorporated into the underlying sand. This pollen was from open country in which farming was being practised, this actual site itself was under grass and bracken and probably not cultivated, as the pollen frequency curves show no sign of disruption. This period of stability was finally destroyed with a new sand blow resulting in the dune. The lowermost layer of the dune (sample 200) was apparently topsoil from an adjacent area of heath, and though it is unlikely that this itself was being cultivated, it also contains a few agricultural weeds and some cereal pollen, showing that arable agriculture was still being practised locally.

It is impossible to ascribe any firm dates to any stage of this suggested sequence, but the ecological changes are plausibly explained by an incoming and continuing agricultural presence possibly in the prehistoric period. Other factors than cultivation may have been involved, of course the development of heathland, for instance, may have been due to the associated use of fire.

A humo-ferric podzol (for which there is no dating evidence) has been noted in the cliff section, buried by blown sand. This differs slightly from the profile beneath the sand dune described above. The podzol was described by Macphail (1981) as follows:

0-3cms. (Ah): Black (5YR2.5/0) weak medium sand with medium blocky structure, abundant roots and a clear, wavy boundary to:

3-45cms. (Ea): Pinkish grey (5YR7/2) weak to loose sand, structureless, with few roots and a gradual smooth boundary to:

45-61cms. (Ea2): Brown (10YRS5/3) weak sand, structureless, with few roots and a gradual, smooth boundary to:

61-71cms. (bAh): Black (2.5YR2.5/0) mderately weak moist sandy loam with coarse blocky structure, common roots and a clear, smooth boundary to:

71-83cms. (bEa): Reddish brown (5YR4/2 - 5/3) weak sandy loam, structureless, roots absent, wet and with a clear smooth boundary to:

83-88cms. (bBh): Very dark grey (5YR3/1) firm sandy loam, massive, wet and with a clear wavy boundary to:

88-98cms. (bBs/Bf): Yellowish red (5YR5/6) firm to strong sandy loam, massive, with an irregular, brittle thin iron-pan, Bhs lamination, wet and with an abrupt, irregular boundary to:

98-118cms. (bB): Strong brown (7.5YR5/6) firm to strong loamy sand, massive and with a gradual, irregular boundary to:

113+cms. (bCx): Cemented head.

WATERMILL COVE (SV925123) JDS

This section can be found to the south-east of Watermill Cove proper. Above the wave-cut platform and modern beach a section, about 3 m. thick at its greatest extent, runs normal to the local slope direction dip towards the north-east. Lying below 1-2 m. of coarse granite breccia, unit 4, there is a fairly undisturbed unit of black organic humic material, unit 3, between 1 and 1.5 m. thick and extending laterally about 20-25 m. along the base of the section which lies at around 4.4 m. OD (Fig.24) . Underlying the organic deposit, as revealed by pits, is a fairly homogeneous unit of coarse to medium light brown sand, unit 1b, but immediately between the sand and the organics is a thin layer of coarse cemented granite breccia, unit 2; the sands underlying are uncemented, and appear to rest on solid granite, though this granite may be part of a raised beach cobble. The contact between units 1 and 2 is erosional. Units 2, 3 and 4 can be correlated with the Porthloo Breccia.

Sand unit 1b has a dominant mode of 1.0 ϕ on the coarse to medium sand boundary, moderate to good sorting and contains only 1% silt and 1% clay. The overall constitution of the sediment is quite fine, plotting close to samples that are without doubt littoral dune sediments from West Cornwall, suggesting a possible aeolian origin, but the distribution lacks the very high kurtosis characteristic of such sediments. It may therefore be a backshore sand.

At SV924123, along the southern shore of Watermill Cove itself, a raised beach consisting of both cobbles and sand is exposed. The beach sand, unit 1b, therefore provides a stratigraphic link between the two sections, and, as such, forms part of the type-exposure of the Watermill Sands and Gravel.

This sand bed is overlain by a thin granite brecia, interpreted as a solifluction deposit which must have spread over the exposed beach, and this passes upwards into the organic unit. This can be divided up into four beds, a, b, c and d. 3a is a brown to black organic silt, highly humified, containing some quartz granules. 3b is a fawn to light brown sand, largely inorganic compared with 3a, again containing quartz granules; the junction between 3a and 3b is gradational, so that the definition of the lithological boundary is somewhat arbitrary. 3c is a black, richly organic, highly humified silt; the contact between 3b and 3c is sharp though not unconformable. 3d is very similar lithologically to the upper parts of 3b.

The microstratigraphy of unit 3 is given in the sediment column of the percentage pollen diagram, Figure 25, and is confirmed by the pollen washings/loss on ignition diagram,Figure 26. The main features to note from Figure 26 are the occurrence of unidentifiable carbonised organic detritus in beds a and c, and the more organic nature of these two beds as indicated by the loss on ignition analysis at 550° C. Organic content is greatest in the basal level of bed a, the basal unit of the organic sequence, and in the centre of bed c, reaching about 15% at both levels. Otherwise the organic content is very low, reaching a minimum of 1.5% towards the upper part of bed b. There is an abundance of fine inorganic detritus through all

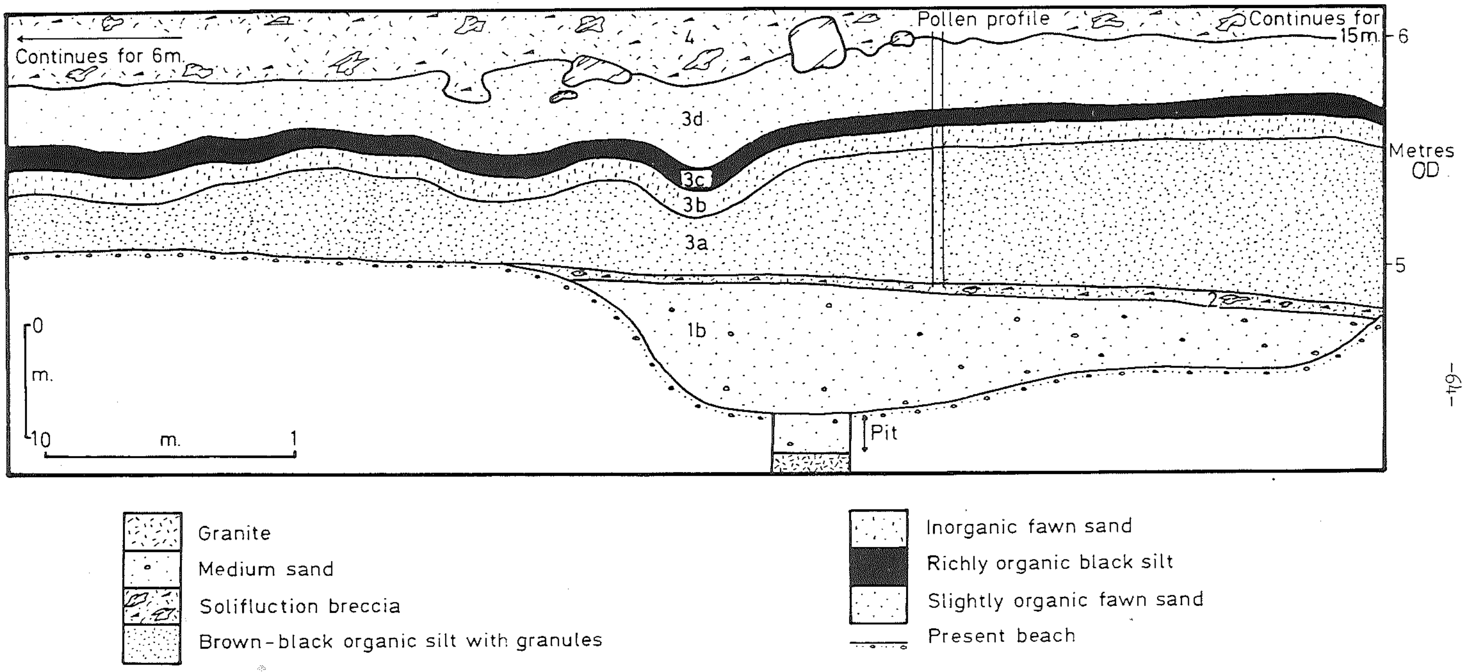
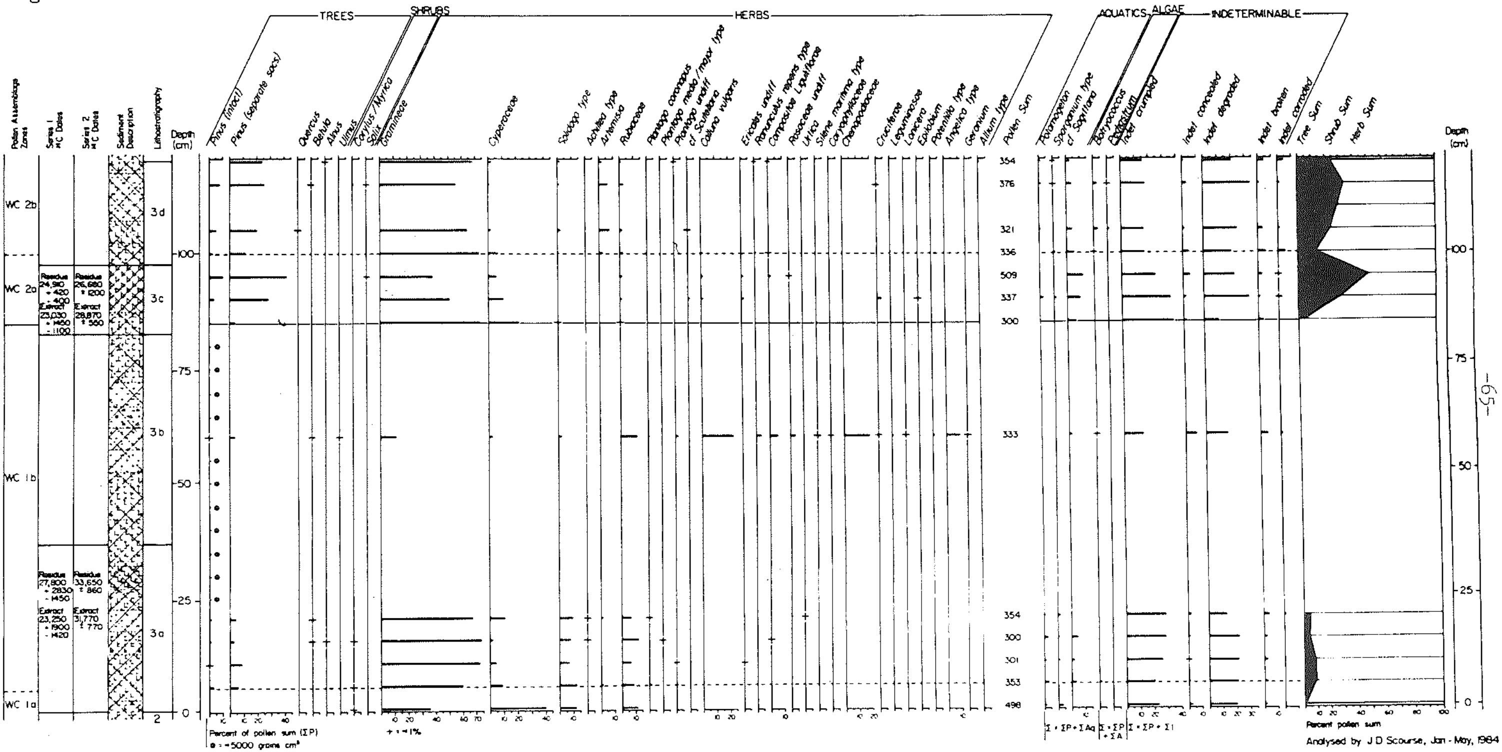


Figure 24. Watermill Cove - stratigraphy

Figure 25. WATERMILL COVE - Total Percentage Pollen Diagram



beds; coarse inorganic detritus levels are also high, declining only where the organic content reaches its highest levels. The organic material is estimated to consist of 90% humus, the remaining 10% consisting of pollen, spores and macroscopic unidentifiable plant fragments.

The coarse breccia, 4, overlies the entire sequence. Only the very uppermost parts of bed 3d have been deformed by the overlying solifluction. To the north-west of the organic sequence a quartz-porphyry dyke (elvan) crosses the shore platform from south-west to north-east (Fig. 8). Clasts derived from this dyke can be found in the breccia, unit 4, indicating that the dominant direction of solifluction was from the east, north-east, or north, in response to the local slope morphology.

Such solifluction is thought to have been responsible for the accumulation of the organic sequence at Watermill Cove. Solifluction down the slopes of neighbouring headlands would perhaps have the effect of ponding a small lake or large pond into which the sediments accumulated. The varying sediments represented by unit 3 would therefore represent inwashings of coarse minerogenic sediment, probably associated with active solifluction, contrasting with periods of more organic sedimentation. The same hypotheses as invoked to explain the high degree of humification of the organic material at Carn Morval can be erected here. The main obligate aquatic taxa at Watermill Cove are Sparganium Type, Potamogeton, cf. Sagittaria and the algal forms Botryococcus and Pediastrum. These are represented with quite high frequencies in beds 3a and 3c, and it is perhaps significant that two taxa, Pediastrum and cf. Sagittaria are recorded here and not at Carn Morval. This may indicate the increased importance of allochthonous as opposed to authochthonous humus at Watermill Cove in comparison with Carn Morval. This is supported by the high amounts of Indeterminate: Crumpled and the relatively low amounts of Indeterminate: Corroded pollen in beds 3a and 3c. This suggests that at these times the basin contained standing water and was receiving eroded mor humus and penecontemporaneous pollen from the catchment.

All the sediments in the organic sequence can be regarded as lacustrine, the variations between beds being caused by the influx of different materials within the catchment. Thus beds 3a and 3c represent the deposition of eroded mor humus, and beds 3b and 3d the deposition of coarse minerogenic material associated with active solifluction within the catchment.

A detailed pollen sampling programme was undertaken, samples being taken by tube from the base of bed 3a at 5cm. intervals to the base of unit 4 as indicated in Figure 24.

As at Carn Morval, it was noticed during sampling that the organic sequence was in a few places penetrated by small holes. It was assumed that these had been excavated by solitary bees until an examination revealed woodlice occupying the ends of the burrows. One or two woodlice were found occupying disused bee holes at Carn Morval, and it is thought that solitary bees were originally responsible for the holes at Watermill Cove. The sampling programme therefore followed the pattern developed at Carn Morval. During pollen counting, however, it became apparent that contamination of the pollen samples from this

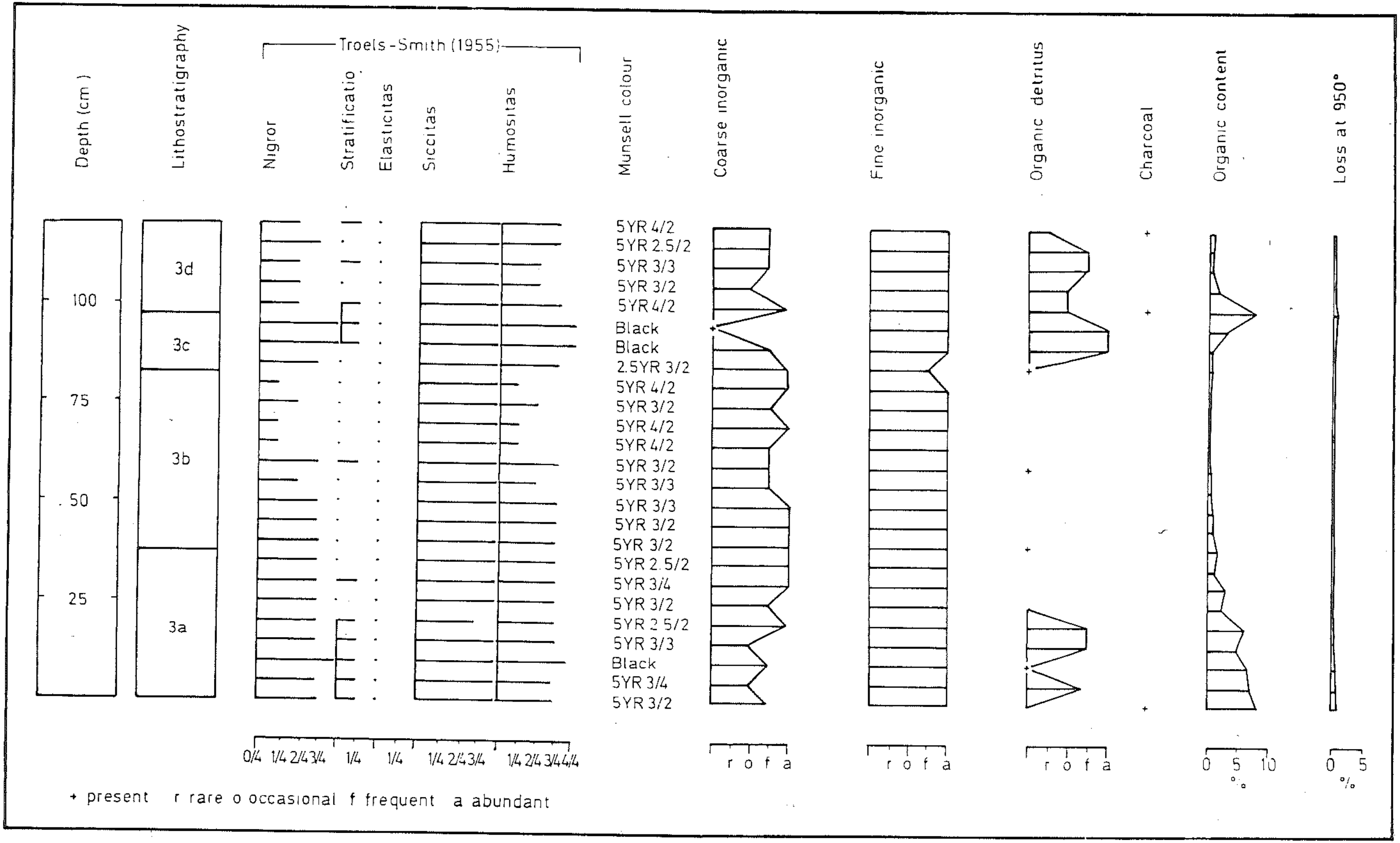


Figure 26. Watermill Cove - loss on ignition and pollen washings diagram

Figure 27. WATERMILL COVE - Concentration Pollen Diagram

source was minimal, only one level (60 cm) being affected. This level occurs within the most inorganic part of the sequence, in bed 3b (Fig.24), and is juxtaposed to levels containing pollen concentration below the countable threshold of 5000 grains per cm^3.

At this level, taxa thought to have been harvested and introduced by the bees include Ranunculus repens Type, Compositae Liguliflorae, Calluna vulgaris, Silene maritima Type, Caryophyllacae, Chenopodiaceae, Cruciferae, Leguminosae, Rosaceae (cf. Rubus fruticosus), Angelica Type and Geranium. Nine of these taxa were identified as contaminants at Carn Morval. Plants contributing to these taxa all grow locally and are known to be entomophilous.

As only one easily identified level in the diagram has been contaminated, no 'corrected' diagram is presented for Watermill Cove. The diagrams presented are therefore a 'total' percentage (Fig.25) and a concentration diagram (Fig.27).

In view of the sediment types described above, most pollen reaching the basin would have originated locally, including obligate aquatic and helophytic plants growing within the lake itself. Extra-local and penecontemporaneous pollen would have been introduced through the erosion of the surrounding slopes, a small regional airborne component reaching the lake surface directly.

Of the 24 levels prepared, 13 contained countable pollen, one of these being the contaminated level discussed above. The 11 uncounted levels all contain pollen concentrations below the 5000 cm^3 threshold; several traverses failed to record even one pollen grain in level 30 cm. The highest concentration of an uncounted level was at 35 cm. with 3770 grains cm^3. Level 60 cm. would not have contained a countable concentration were it not for the contamination at this level. The highest concentration of the diagram occurs in the basal level, with 148,000 grains cm^3, a second maxima of 75,000 grains cm^3 occurring at level 100 cm. in bed 3d.

As at Carn Morval, it is the change in Pinus frequencies that enables the diagram to be divided into two pollen assemblage zone, each being divided into two subzones, as indicated in Figure 25. These zones have been confirmed using the numerical ZONATION program (Gordon and Birks, 1972).

0. cm. Zone WC1a Cyperaceae-Gramineae-Solidago-Rubiaceae p.a. subzone
5-20 cm.Zone WC1c Gramineae-Solidago-Rubiaceae p.a. subzone.

Pollen assemblage zone WC1 is totally dominated by herb taxa. The separation of subzone WC1a from WC1b is based on the rapid decline in the Cyperaceae frequency from level 0 cm to level 5 cm. Subzone WC1a therefore consists of only one level, subzone WC1b consisting of four. Both subzones occur within bed 3a. Subzone WC1a is characterised by high Cyperaceae percentages (40%), relatively low Gramineae (36%), high Solidago Type (12%) and Rubiaceae (11%), and high Sparganium Type (3%).

It contains the highest frequencies of Cyperaceae, Solidago Type and Sparganium Type of the sequence. Pinus contributes less than 1%.

In subzone WC1b, Gramineae replaces Cyperaceae as the dominant pollen type, Cyperaceae dropping to 2% and Gramineae rising to 74% at level 15 cm. Solidago Type frequencies drop only slightly from their maxima in subzone WC1a, while the Rubiaceae curve reaches a peak of 12% at level 15 cm. Potamogeton and cf. Sagittaria replace Sparganium Type as the major aquatic taxa, mirrored by a small rise in the Botryococcus curve at level 5 cm. However, frequencies for these aquatic taxa remain low, Potamogeton reaching 3% at levels 5 and 15 cm., and cf. Sagittaria just over 3% at 15 cm. 1% of Plantago coronopus is recorded at level 5 cm. Pinus frequencies first rise in WC1b, reaching a maxima (intact + sacs) of 12% at level 5 cm.

Comparison with the concentration diagram, however, reveals that the dominance of Gramineae, the defining criteria of subzone WC1b, is the only 'real' feature of the zone, all the other changes being artifacts of the percentage calculation. Subzone WC1b is characterised by much lower total pollen concentrations than WC1a.

Level 60 cm., badly contaminated, is not placed in either p.a.z.

85-100 cm. Zone WC2a Pinus-Gramineae-cf. Sagittaria p.a. subzone

100-120 cm. Zone WC2b Pinus-Gramineae-Artemisia p.a. subzone.

Pollen assemblage zone WC2 is characterised by much higher Pinus frequencies than in WC1, with a concomitant decrease in the frequencies, though not the diversity, of the herb taxa. The division of subzone WC2a from WC2b is based on the relative frequencies of cf. Sagittaria and Artemisia. Subzone WC2a coincides with bed 3c, and WC2b with 3d.

Subzone WC2a contains the highest Pinus frequencies of the sequence, rising to 51% at level 95% cm. from 4% at level 85 cm. (intact and separate sacs). Examination of the two Pinus curves, intact grains and separate sacs, shows that the intact grains consistently contribute up to around 10% of total Pinus. Gramineae totals are consistently high, reaching 73% in the basal level of the subzone. The character of both the Pinus and Gramineae percentage curves is supported by the concentration diagram. Cyperaceae appears to follow a similar decline from high basal values as it does between subzones WC1a and WC1b, from 22% at level 85 cm. to 5% at level 95 cm., but examination of the concentration diagram shows this to be an artifact of the low Pinus values at level 85 cm. Sagittaria (cf.) values are consistently high in both diagrams, reaching 12% in level 95 cm.; other obligate aquatics recorded are Potamogeton and Sparganium Type. Solidago Type and Rubiaceae concentrations are similar to those in subzone WC1b, though their percentages are much lower.

In subzone WC2b cf. Sagittaria totals decline to 4% in the uppermost level, Artemisia rising to 7% at level 105 cm. Pinus and Gramineae totals, though erratic, maintain their strong presence established in subzone WC2a. The Cyperaceae values continue to decline in both percentage and concentration diagrams, reaching less than 1% in the two uppermost levels. Along with the cf. Sagittaria decline, pollen of the other obligate aquatic plants is very rare, and the rise of Botryococcus in the subzone is an artifact of the percentage calculations. Solidago Type and Rubiaceae totals remain low, but consistent.

In both p.a.z. levels of Indeterminate pollen are high though slightly higher in WC2 than in WC1. Mechanical breakdown is predominant over chemical and biological decay in that the crumpled and degraded frequencies are always dominant over corroded pollen.

The importance of obligate aquatic taxa, and the behaviour of Cyperaceae, lends support to the evidence of the sediments themselves and the geomorphological context that this sequence formed in a small lake, and that the humus represents allochthonous material washed from within the catchment. In particular, the very high values for Cyperaceae and Sparganium Type in the basal level suggests initially ponded conditions, the decline in both perhaps representing the deposition and infilling of the basin with minerogenic sediment in bed 3b times. The lack of pollen in bed 3b supports this hypothesis. Ponding once again occured in 3c times, however, for the obligate aquatics and in particular cf. Sagittaria become important, only to decline again through bed 3d. The stratigraphical disposition of the beds and the pollen record therefore lend support to an hypothesis of two ponding episodes at Watermill Cove.

As at Carn Morval, all the dry herb taxa are characteristic of arctic conditions, with grasses predominating. Many of the taxa, in particular Solidago Type and Artemisia, are characteristic colonisers of the disturbed minerogenic soils of the periglacial zone (Godwin, 1975). Once again, the Pinus peak of WC2 forms the most distinctive change in the diagram. The same hypotheses invoked at Carn Morval to explain the feature can be examined here.

The similarities between the sedimentological and stratigraphical context of the Pinus peaks at Carn Morval and Watermill Cove are striking. However, the Pinus peak at Watermill Cove is not coincident with the highly humified bed 3c; the peak transcends the lithological boundary between 3c and 3d.

The most likely hypotheses to explain the Pinus feature are the same as at Carn Morval, a combination of long-distance transport with differential weathering and a decrease in the pollen productivity of the local vegetation. The desiccation of the pond in 3d times has already been inferred; this may have coincided with climatic deterioration. In this situation, bed 3d could contain a large proportion of reworked Pinus from bed 3c below.

No identifiable macrofossils have been discovered at the site.

In his controversial paper on the radiocarbon dating of interglacial deposits in Britain, Page (1972) reported two dates from this organic material. Page regarded the organic material as Hoxnian based on the stratigraphy of Mitchell and Orme (1967) and uses the radiocarbon determinations to 'date' the Hoxnian. Shotton's reply (1973) points out that there is no evidence to justify Page's assumption that the material is Hoxnian, therefore rejecting Page's conclusions. The ^{14}C dates obtained by Page were as follows:

21,200	B.P.	(GaK-2471)
22,220	B.P.	(T-833)

As Page's stratigraphy is not recorded in detail, it is impossible to say precisely where the samples originated. The organic beds 3a and 3c were therefore re-dated. The dates obtained are as follows:

(Fig. 21)

First series	Residue	+	-	Extract	+	-	Q Number
3a	27,800	1770	1450	23,250	1720	1420	2360/1
3c	24,900	430	410	23,030	1275	1100	2362/3
Second series							
3a	33,050	960	860	31,770	850	770	2408/2447
3c	26,680	1410	1200	28,870	590	550	2407/6

The large standard deviations are because of the low carbon yields of the samples (R. Switsur, pers. comm., 1983). The first series humic extract dates are between 4,550 (3a) and 1,870 (3c) years younger than the residue dates, but with very large standard deviations. This suggests that contamination by modern humus at the face of the section is occurring, this contamination being most severe at the base (bed 3a). The second series dates are all considerably older than the first series dates, ranging from 8,520 (3a extract dates) to 1,780 years (3c residue dates). This confirms the implied contamination of the first series samples and that this contamination is most severe at the base of the section; it is perhaps significant that the biggest differences are between the 3a extract dates and the least between the 3c residue dates. This implies that the most unreliable dates are the extract dates, particularly the basal ones, and the most reliable are the residue dates, particularly the upper ones.

However, the differences between the second series residue and extract dates also have to be explained. While the 3a dates resemble the first series dates in that the extract is 1,280 years younger than the residue, the 3c extract date is older than the residue by 2,190 years. These differences imply that at the base of the section contamination by modern humus is a problem up to 3m. into the section, suggesting that the direction of contamination may not be solely from the face inwards and that in bed 3c, contamination by modern humus has ceased to be important 3m. into the section. This differential can be explained by the hypothesis that unit 2, the cemented breccia, acts as an impermeable layer; groundwater, charged with modern humus, may therefore percolate through bed 3a which acts as an aquifer, along the contact with unit 2, some of the humus being deposited in the process. Bed 3c, by contrast, is freely drained. In such a situation the introduction of recent pollen into bed 3a might be expected; examination of the pollen diagrams, however, leads to no suspicion that this is the case. The older second series bed 3c extract date can perhaps be explained in terms of the inwashing of older mor humus into the lake. The likelihood of such allochthonous humus being present has already been considered.

The large gross differences between the first and second series samples demonstrate that contamination by humus is not the only source of modern carbon at the face of the section; if it were, then the second series dates should approximate or be only slightly older than the first series residue dates. This is patently not the case. The extra contamination is almost certainly the result of rootlets and bee burrows at the face of the section.

On the basis of the above discussion, it is suggested that the most 'reliable' date for bed 3a is 33,050 $^{+960}_{-860}$ years B.P. and for 3c, 26,680 $^{+1410}_{-1200}$ years B.P. The 3a date may be slightly too young, and the 3c date slightly too old on the basis of unextracted modern and penecontemporaneous humus in the residues respectively.

Page (1972) did not discuss pre-treatment method, but it seems likely that his dates of between 21,00 and 23,000 years B.P. are too young, the samples being contaminated by recent material.

HIGHER MOORS (SV925107 - 921115) RGS

Porth Hellick nature reserve is a topogenous mire extending from Porth Hellick Bay (SV925107) inland to Holy Vale (SV921115). A maximum thickness of 76 cm of black highly humified detritus and monocotyledonous peat rests sharply on clean white (bleached) sand of low organic content. Five pollen assemblage zones have been recognised (HM: 1-5)(Figs.28a/b). The base of HM: 1 at 76 cm yielded a C-14 assay of 6330+-100bp (HAR-3695) and a pollen spectrum dominated by _Quercus_, _Ulmus_, _Betula_ and _Corylus_. This represents the character of the Atlantic forest at least in this area of St. Mary's. A decline in AP and increase in herb taxa occurs at 68 cm, including evidence of cereal cultivation. Radiocarbon dating has proved to be problematic in dating these organics (Scaife, 1983). The overall changes in the sequence appear to show that this phase of forest clearance (perhaps Neolithic) was followed by a period of regeneration (late-Neolithic/early Bronze Age). A major phrase of forest clearance is present (50cm) and this is probably of middle Bronze Age date correlating with the widespread archaeological evidence. It is this phase of openness within which the open ground evidence from soil pollen analyses at archaeological sites may be placed.

HM:1 76-70 cm. Arboreal (53%TP) and shrub pollen (18%TP) dominate this zone with _Quercus_ (42%AP), _Betula_ (53%AP) _Corylus_(9%TP) and _Salix_ being the main elements. Minor records of _Pinus_, _Ulmus_ and _Alnus_ are evident. Herbaceous pollen frequencies are low (31%TP) consisting primarily of Cyperaceae (28%TP) and other mire taxa.

HM:2 70-62 cm. This zone is characterised by a reduction in the arboreal components and increased herbaceous

HIGHER MOORS - ISLES OF SCILLY

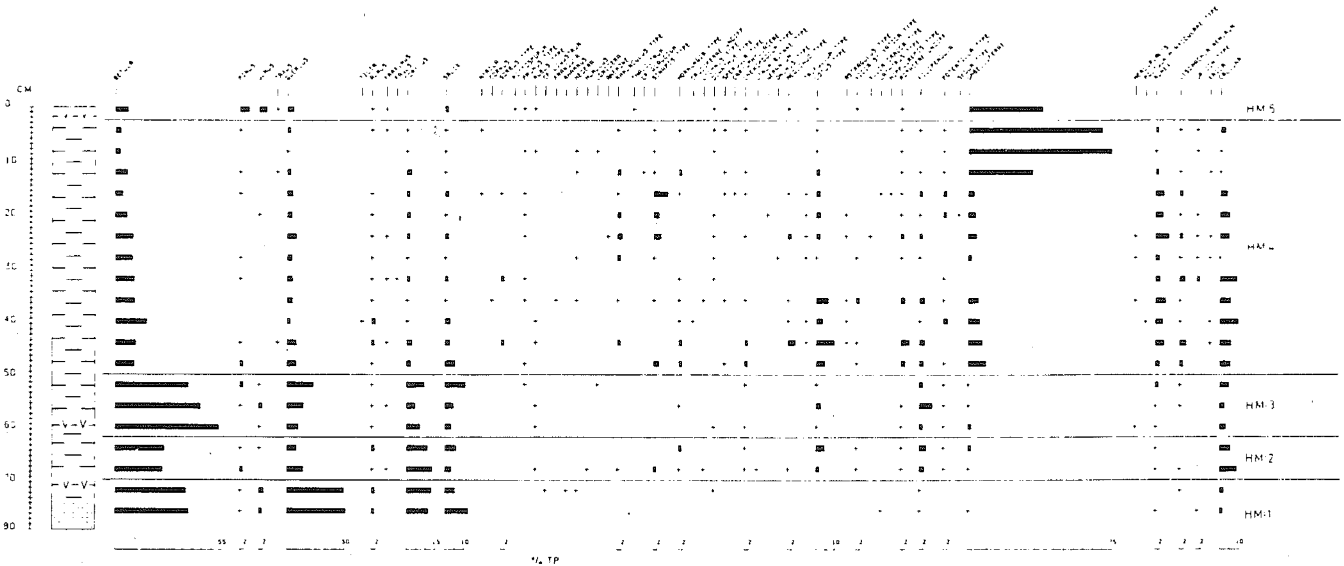


Figure 28a. Higher Moors - pollen diagram (Scaife, 1984)

HIGHER MOORS - ISLES OF SCILLY

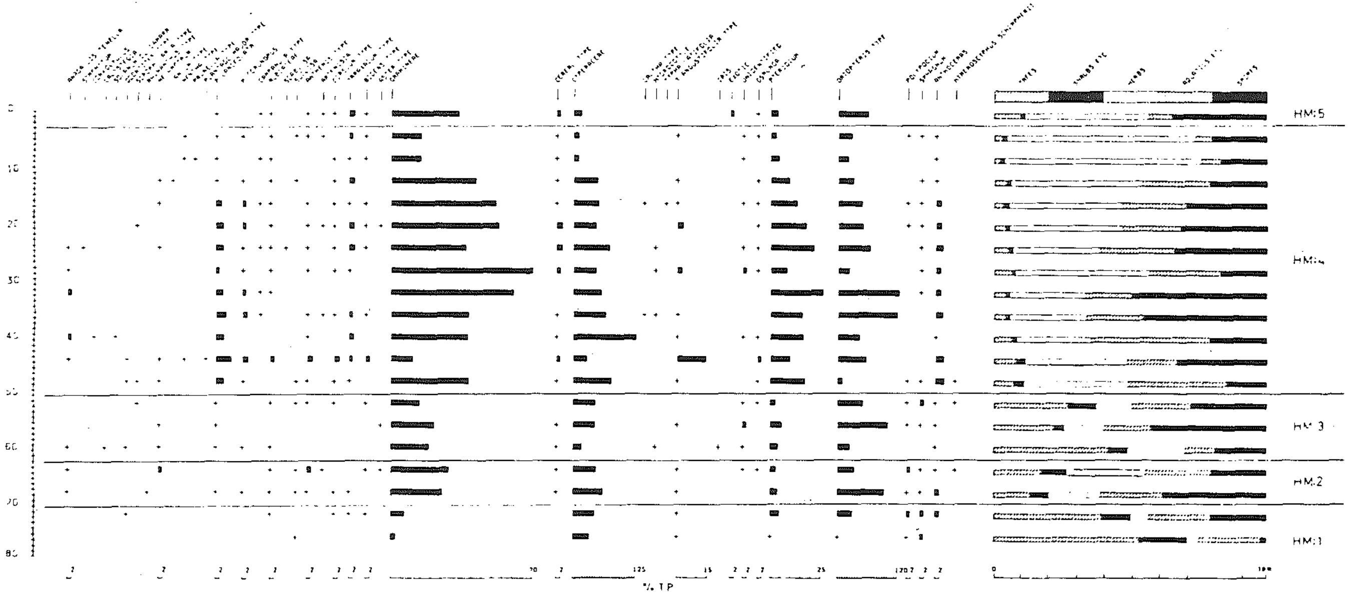


Figure 28b. Higher Moors - pollen diagram (Scaife, 1984)

percentages. Betula and Quercus decline from previous levels to 17%TP and 3-5%TP respectively. Corylus and Salix remain more or less constant with minor shrub occurrences. Calluna is incoming and expands to a maximum 6%TP. Herb taxa predominate (62%-64%TP) with Gramineae (18%TP) and Cyperaceae (34%TP) most important. The presence of pollen of Cerealia and of weeds and ruderals (i.e. plants of disturbed habitats) is of note.

HM:3 62-50 cm. Betula increases sharply (46%TP) subsequently followed by Quercus (10%TP). Corylus and Salix maintain similar levels but with a single maximum of the latter (8%TP). Herbaceous totals show a corresponding decline to 45%TP but with a continuation of taxa noted previously.

HM:4 50-4 cm. A sharp reduction in arboreal and shrub pollen totals occurs. Betula and Quercus decline to 5%TP and less than 2%TP respectively. Salix and Corylus similarly decline to less than 2%TP. Conversely, herb totals become dominant (80-90%TP). Maximum pollen frequencies of Gramineae (44%TP) and Cyperaceae (55%TP) are associated with a diverse assemblage of ruderals. Pollen of Umbelliferae expands markedly at 12 cm, attaining a maximum of 68%TP after which it remains important. Expansion of ericaceous taxa and Pteridium is noted.

HM:5 0-1 cm. This zone reflects the uppermost peat level, containing slightly higher AP percentages and some exotic pollen. Pinus (8%TP excluding Umbelliferae) and Betula (8% excluding Umbelliferae) expand. Pittosporum and other exotic types are noted. Herbaceous pollen still remain dominant, in the surface level of the mire, dominated by Gramineae (28%TP) and autochthonous Umbelliferae (32%TP).

LOWER MOORS (SV913105) RGS

Also known as Old Town Marshes, Lower Moors is a relatively extensive area of peat lying behind and protected from marine inundation by blown sand at Porthloo (SV909112) and Porth Mellon (SV909108) to the NW and to the south behind Old Town Bay (SV912102). Extensively drained and cut (easily visible), a maximum of 50 cm of highly humified peat was found in areas next to old peat cuts. These areas frequently have magnificent stands of Osmunda regalis . Four pollen zones (LM:14) have been recognised (Figs 29 a/b; Scaife 1984). The basal zone (LM:1) indicates the presence of shallow freshwater as earlier postulated by Lousley (Lousley, 1971). This community became progressively drier through hydroseral succession. Agricultural activity is present to the base of the profile and although ^{14}C dating has not yet been undertaken, the presence of cultigens and Betula, Quercus and Corylus type seems compatible with zone HM:3 of Higher Moors (Late-Neolithic/early Bronze Age). Above LM:2 is the start of the major phase of openness seen in HM:4 during the Bronze Age.

LM:1 (30-50 cm). This zone is characterised by Betula (8%TP),

LOWER MOORS - ISLES OF SCILLY

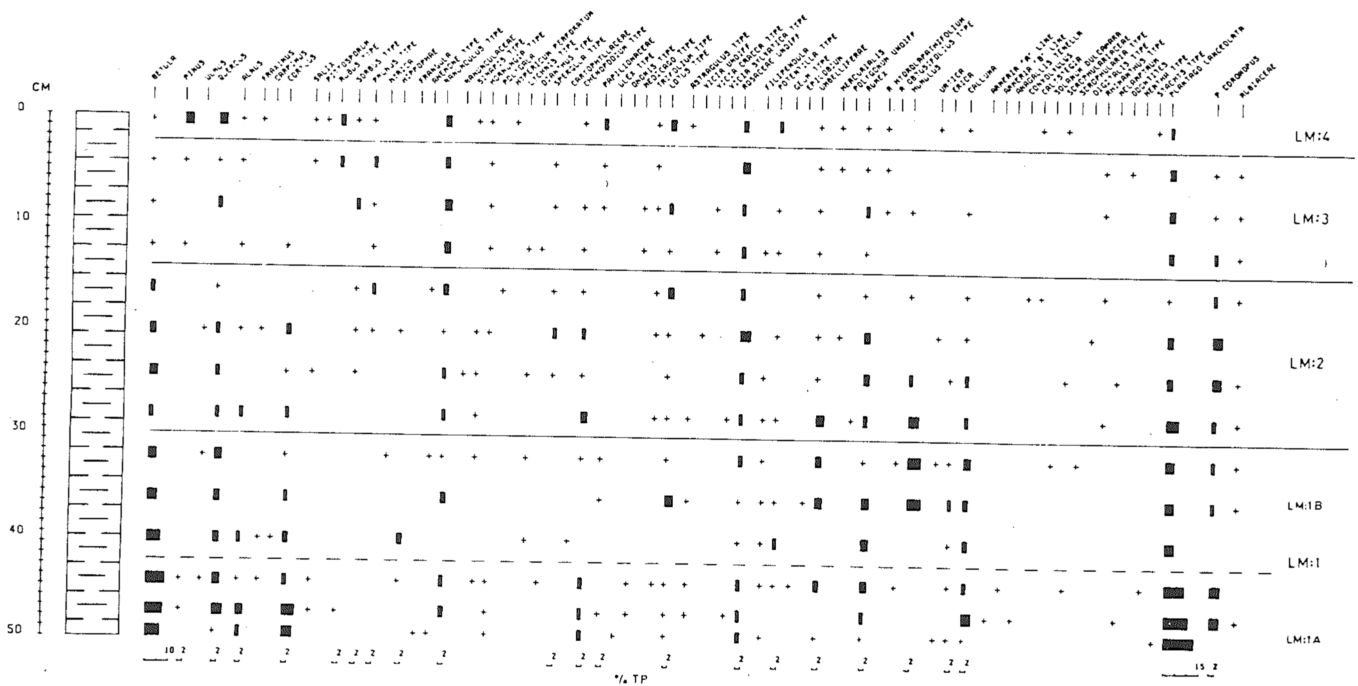


Figure 29a. Lower Moors - pollen diagram (Scaife, 1984)

LOWER MOORS - ISLES OF SCILLY

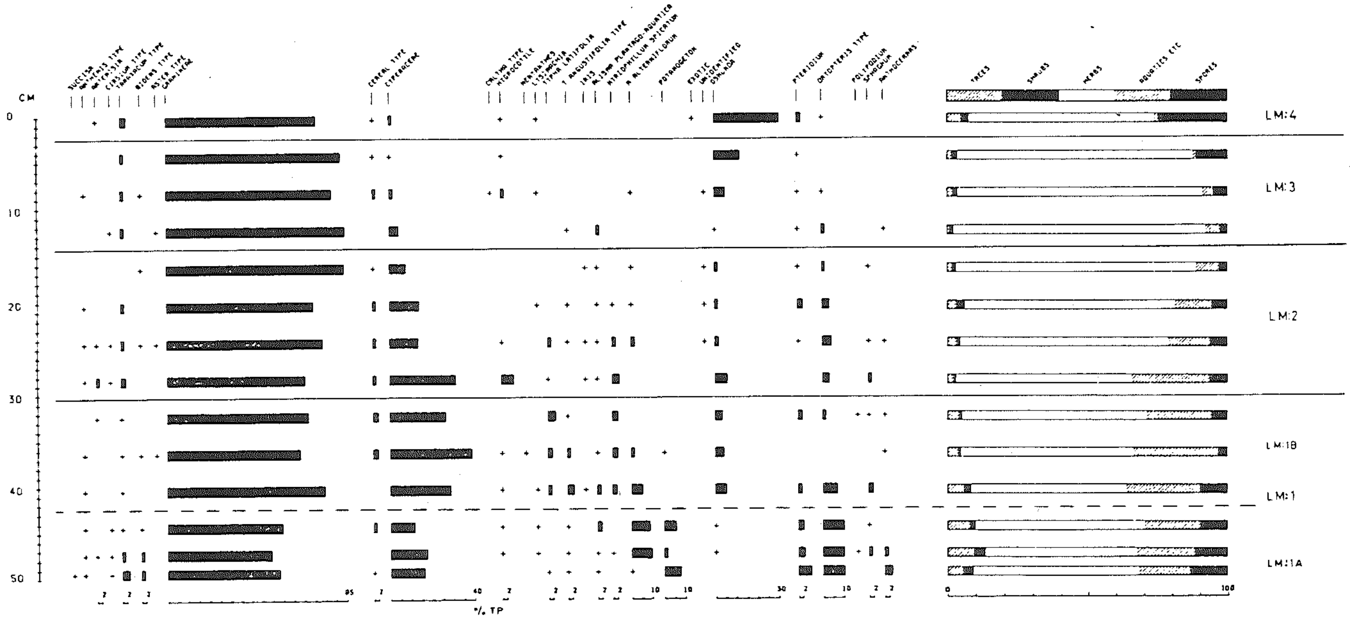


Figure 29b. Lower Moors - pollen diagram (Scaife, 1984)

Quercus (5%TP), Corylus type (5%TP) and Calluna (5%TP) present in greater numbers than in succeeding zones. Lesser quantities of Alnus and sporadic occurences of other taxa are seen. Gramineae and Cyperaceae are dominant. Herbaceous taxa present allow sub-division into two subzones.

LM:1A (42-50 cm). Plantago lanceolata, P.coronopus, Chenopodium type and Compositae are more important. Aquatic taxa are present and comprise Myriophyllum alterniflorum and Potamogeton.

LM:1B (30-42 cm). Plantago coronopus, Myriophyllum alterniflorum and Potamogeton decrease. Humulus, cereal type and the aquatics Myriophyllum spicatum, Typha latifolia, T. angustifolia type and Osmunda regalis increase.

LM:2 (14-30 cm). Betula (4-5%TP) and Quercus (12%TP) remain but in reduced percentages. Corylus type disappears. Gramineae and Cyperaceae remain dominant, although the latter declines. Cereal type is present throughout and is possibly associated with other rederals (Sinapis type, Chenopodium type and Rumex). Humulus dies out. Aquatic taxa remain but in reduced frequencies.

LM:3 2-14 cm). Characterised by virtual absence of AP and dominated by herb pollens. Gramineae are dominant whilst Cyperaceae decline. Osmunda regalis becomes important.

LM:4 (0-2 cm). This single sample reflects the uppermost level of the Moor containing higher AP percentages of Quercus and Pinus with some 'exotic' taxa present (Pittosporum). Osmunda regalis is dominant (30%TP + spores) reflecting the contemporary vegetation stands.

PENINNIS HEAD (SV912093) JDS

Fine granite tors occur at Peninnis Head, the southernmost point of St. Mary's.

Field mapping and aerial photograph interpretation has enabled the definition of four tor forms on the Isles of Scilly (Fig.30). The distribution of these is given in Figure 31.

The tors of Peninnis Head are typical of form A, 'horizontal' tors. These are characterised by large horizontal discontinuities separating large granite slabs which often touch only a few points, thus resembling 'pedestal' features. This tor form has often been described as 'mammilated', 'castellated' or 'lamellar' (Waters, in discussion of Linton, 1955). Form B, vertical tors, are characterised by vertical discontinuities, granitic rubble often filling the voids. Form C, hillslope tors, are a slope or coastal variant of forms A and B. Form D can be described as smoothed, rounded or eroded, with all loose material completely removed, the granite surfaces representing expansive eroded faces.

These tor forms represent points along a continuum. This,

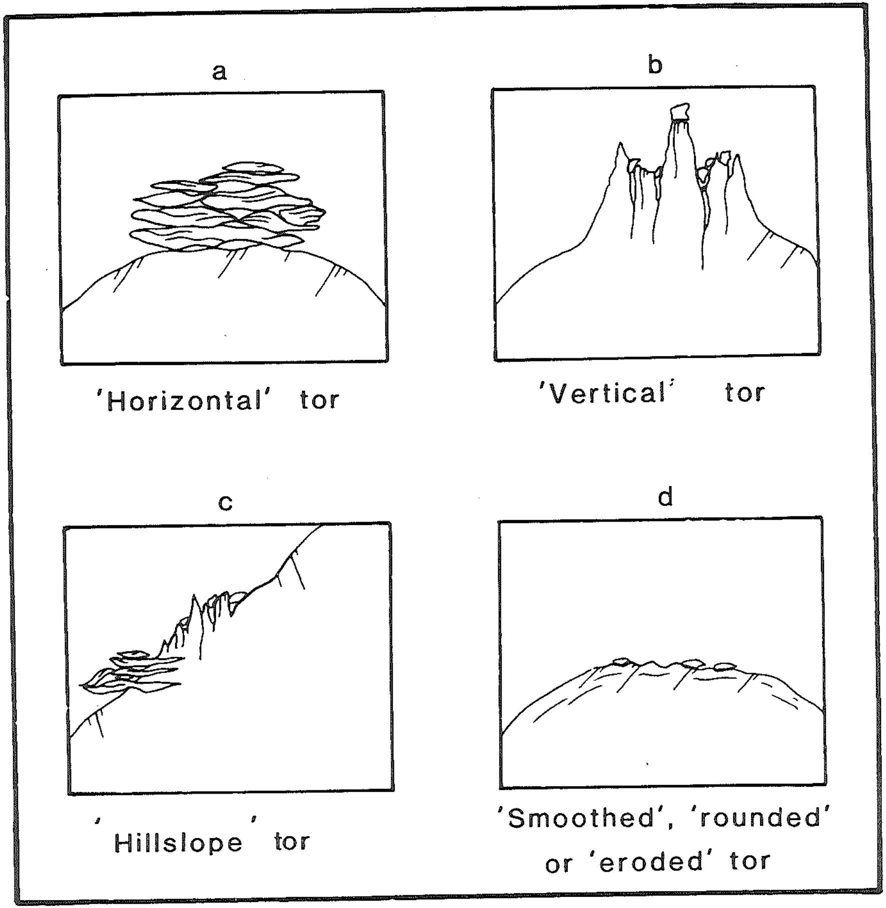


Figure 30. Tor morphological variations

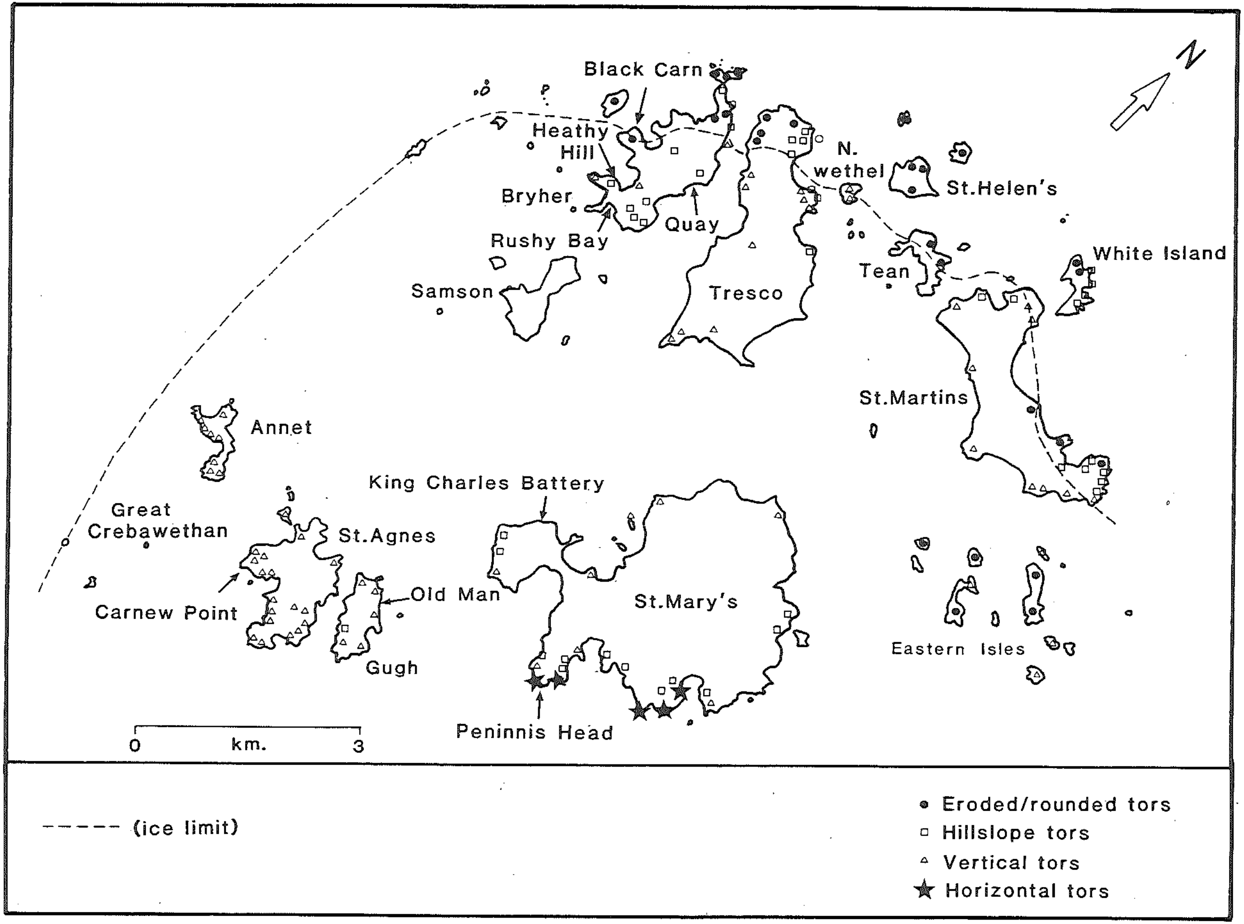


Figure 31. Distribution of tor morphological variations

combined with the difficulty of defining tors in coastal areas where much bare granite is exposed, make this tor classification and their mapping a largely subjective exercise. Nevertheless, some trends can be discerned. Forms A, B and C are all concentrated well to the south side of St. Mary's, on St. Agnes and the Western Rocks. Form D tors are only found to the north of the ice limit; many of these, such as Round Island, resemble roche moutonnée features. Between these two zones very few tors of any kind occur. Instead, rounded hills without bare granite exposure predominate. Samson, with its distinctive rounded North and South Hills, is typical of this transitional zone.

The clear association between these landforms and the ice limit suggests that the smoothed form D is a product of glacial erosion; it is difficult to see how forms A-C could withstand overriding by ice despite the fact that some authors have interpreted elaborate tor forms as occurring within apparent former ice limits (Dahl, 1966; Sugden, 1968; Clapperton, 1970). It must be stressed that the ice limit shown on Figure 31 is constructed from independent sedimentary evidence (Scourse, 1985) and is not based on the tor forms themselves.

PORTH CRESSA (SV905105) JDS

Good exposures of the Old Man Sandloess occur in the many bays and coves of the south-western part of St. Mary's. Porth Cressa (Hugh Town) may be taken as typical of these exposures.

Catt and Staines (1982) have examined loessic sediments from Cornwall and the Isles of Scilly. Though they observe that these loess samples strongly resemble undoubted loess from Kent and Belgium, they found that in 16 samples "the percentages of sand... ranged from 6.5 to 33.1% which... exceeds the amounts normally found in loess". They do not believe that these samples are "purely loessial in origin; some may contain a little loess, but this is probably mixed sand from other sources".

The loessic sediments examined by Catt and Staines have been informally defined as the Old Man Sandloess (Scourse, 1985). A grain size envelope for samples from the Old Man Sandloess is presented in Figure 32, and individual analyses are given in Figure 33.

This material contains consistently more sand than clay, including samples thought to be in situ. Most of the samples contain dominant modal classes in the sand grade. The Old Man Sandloess is, in general, too coarse to be defined as true loess, whilst too fine to be defined as coversand. It contains a dominant modal class either in the coarse silt or very fine sand fraction, with total sand usually >25% and total clay <10%.

The distribution of loess and coversand has been carefully mapped in Belgium and the Netherlands and related to source areas, usually associated with sandur and outwash plains. In Belgium, material defined as 'sandloess' forms a transitional belt between the coversands proper and the loess (Mellors, 1977). For example, at Alphen in the southern Netherlands, Vandenburghe

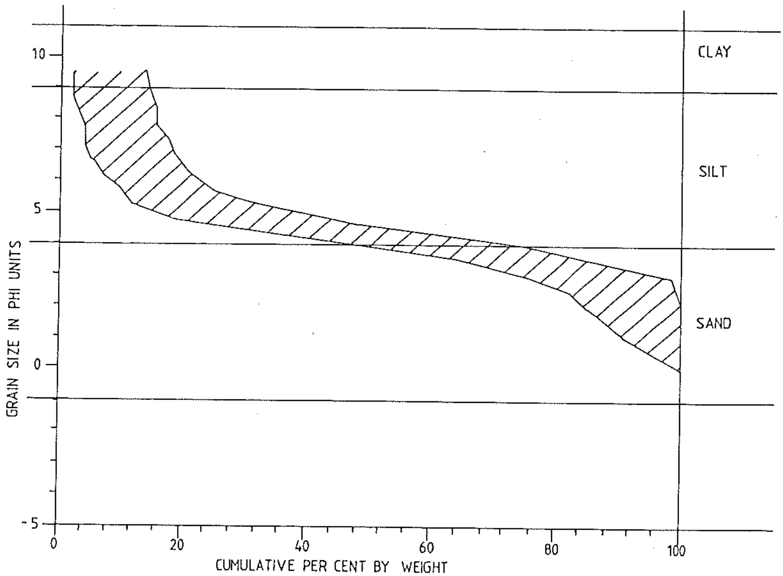


Figure 32. Grainsize envelope for Old Man Sandloess facies A,B and C

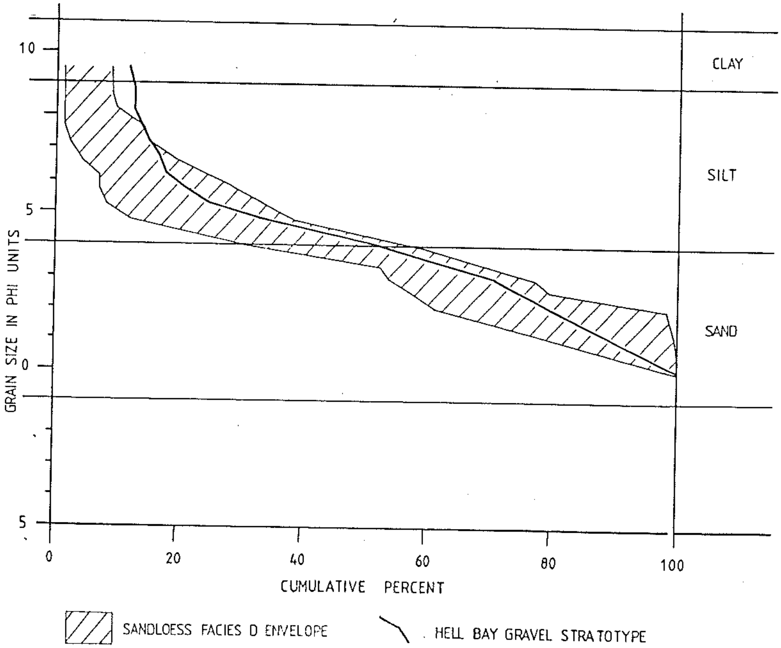


Figure 34. Grainsize envelope for Old Man Sandloess facies D

and Krook (1981) have defined a deposit, loam bed C2, which has a dominant class in the coarse silt fraction, low clay content and sand values that are too high for typical loess. They write "this can readily be explained by the fact that in transitional regions between coversand and loess areas pure loess is not common but is usually mixed with coversand". This transitional material is identical with the Old Man Sandloess; the term 'sandloess' has therefore been adopted for this unit as the most precise term available, in preference to 'loam' or 'cover-loam' which have connotations with soil texture.

Four facies of the Old Man Sandloess have been identified, based on granulometric and structural data:

1) Facies A - Homogeneous sandloess

This is structurally homogeneous with the columellar structure and pin-hole voids characteristic of in situ loess (Mellors, 1977). It contains around 53% silt, 35% sand and 12% clay, and is characterised by a very peaked distribution.

The facies is interpreted as in situ sandloess. Sites with facies A are relatively rare; apart from Porth Cressa, it has been recorded at Gimble Porth (Tresco; SV890160), Porth Killier (St. Agnes; SV882087), The Garrison (St. Mary's; SV898105), Samson Hill (Bryher; SV881142) and Stoneship Porth (Bryher; SV872143).

2) Facies B - Lacustrine sandloess

This consists of horizontal stratification, with small-scale fining upwards sequences not exceeding 5 cm in thickness, the contacts being conformable. Being relatively uncommon it is not possible to provide precise granulometric limits, but at Carn Morval this material contains 49% sand 37% silt and 14% clay.

This facies is interpreted as a 'lacustrine' sandloess, deposition having occurred through standing water bodies.

3) Facies C - Fluviatile sandloess

Non- or sub-horizontal stratification and incipient ripple structures characterise this facies. Fining upwards sequences up to 15 cm thick with erosional lower contacts grade into occasional cross-beds and incipient ripples. Occasional quartz granule stringers occur parallel with the stratification. This facies contains slightly less clay and fine silt than facies A, and has a more platykurtic distribution.

This material is interpreted as 'fluviatile' sandloess depletion of clay and fine silt being effected by the fluvial reworking of in situ sandloess. Facies C sites are relatively common.

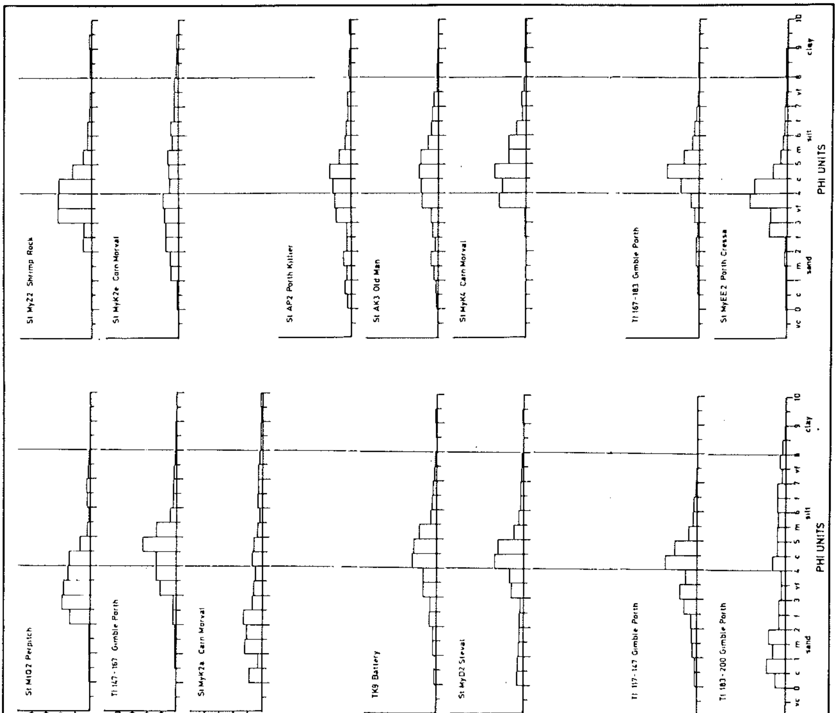


Figure 33. Grainsize analyses of samples from the Old Man Sandloess

4) Facies D - Mass-flow sandloess

This is characterised by large scale and often chaotic slump and flow structures which frequently interdigitate with juxtaposed units. The material is mixed with large granite clasts and finer material of granitic derivation. Clasts are often found towards the base of individual flow structures. Though very variable granulometrically, a grain size envelope is shown in Figure 34.

This facies is interpreted as 'mass-flow' or 'colluvial' sandloess. It contains structures indicative of both strictly gelifluncted as well as 'wetter' mudflow material. The Old Man Sandloess most commonly occurs as facies D.

All the facies described above are specific stages along a continuum from <u>in situ</u> sandloess to sandloess intermixed to such an extent with other material that its identity as sandloess is only barely recognisable. The Old Man Sandloess is very variable both laterally and vertically. In section, however, a number of facies relationships are consistent, and enable the construction of a model (Fig.35). The complete facies sequence can be seen at Samson Hill, Bryher (SV881142).

The basal facies is usually D; this implies sandloess deposition with penecontemporaneous colluvial reworking. This passes upwards into facies A, testifying to a reduction in the efficacy of the reworking processes and perhaps desiccation. This ceases with the overlying <u>in situ</u> material. Finally, facies D returns suggesting the renewed importance of colluvial and soliflual processes.

The stratigraphy of the southern Scillies (Fig. 14) contains a tripartite sequence of periglacial breccia-sandloess-breccia. Not only does this overall sequence imply humid periglacial conditions punctuated by a period of desiccation and aeolian activity but the facies model of the internal characteristics of the sandloess itself suggests such an environmental reconstruction.

The Old Man Sandloess is distributed very widely throughout the Scillies. Though localised obstacles and reworking represent 'blurring' influences, in general a pattern of increasing thickness southwards can be discerned, with the thickest sequences preserved on south-west facing slopes. This perhaps indicates transport from a northerly direction as suggested by Catt and Staines for Cornwall (1982). These authors suggested that the most likely source for this loessic material was glacial outwash in the Irish Sea basin. This hypothesis has been supported by evidence from mineralogical analyses of the Old Man Sandloess and glacigenic sediments from the Scillies (Scilly Till) and offshore (see Appendix 1) by Catt (Appendix 2). This data supports the hypothesis of a genetic association between the Scilly Till and the Old Man Sandloess, and is in accordance with the suite of radiometric dates obtained from the various sedimentary units.

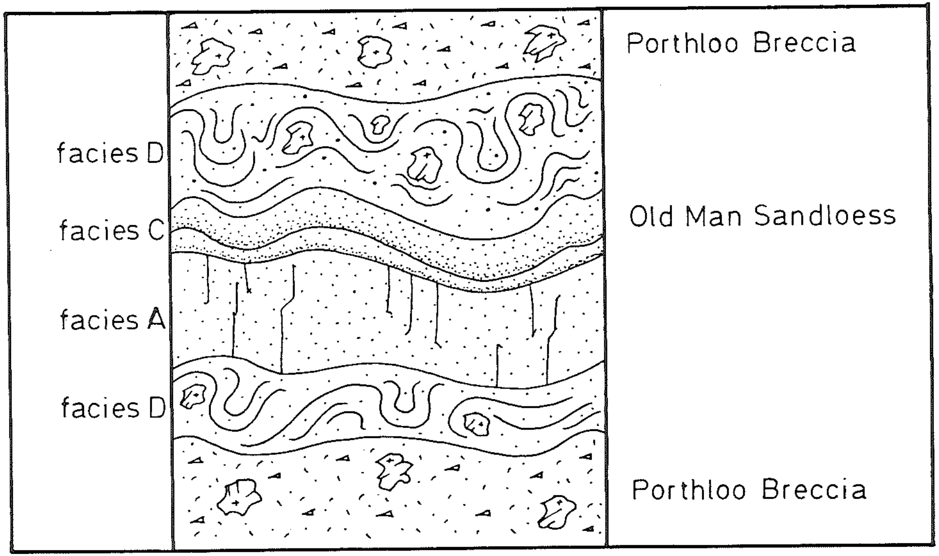


Figure 35. Old Man Sandloess facies model

THE GARRISON (SV898105) JDS

There are a number of good sections around the Garrison at the western end of St. Mary's. In particular, both the lower and the upper units of the Porthloo Breccia can be seen clearly separated by the Old Man Sandloess (Fig. 14). Different facies of both the Porthloo Breccia (Appendix 3) and the Old Man Sandloess occur, including fine examples of rafted and ploughing blocks (breccia facies E, Appendix 3).

Sunday 7 September

St. Martin's and Nornour

1.	Porth Seal	SV918166
2.	Pernagie Bar	SV920171
3.	White Island Bar	SV923170
4.	Chad Girt	SV926174
5.	Bread and Cheese Cove	SV940159
6.	Chapel Down	SV942158
7.	Northward Bight	SV944159
8.	Perpitch	SV940155
9.	Nornour	SV944148

PORTH SEAL (SV918166) JDS

Porth Seal was one of the most important sites discussed in Mitchell and Orme (1967). Here they interpreted two raised beaches as occurring in section (Fig. 11). Mitchell's current view on this site is given in Part I of the Guide.

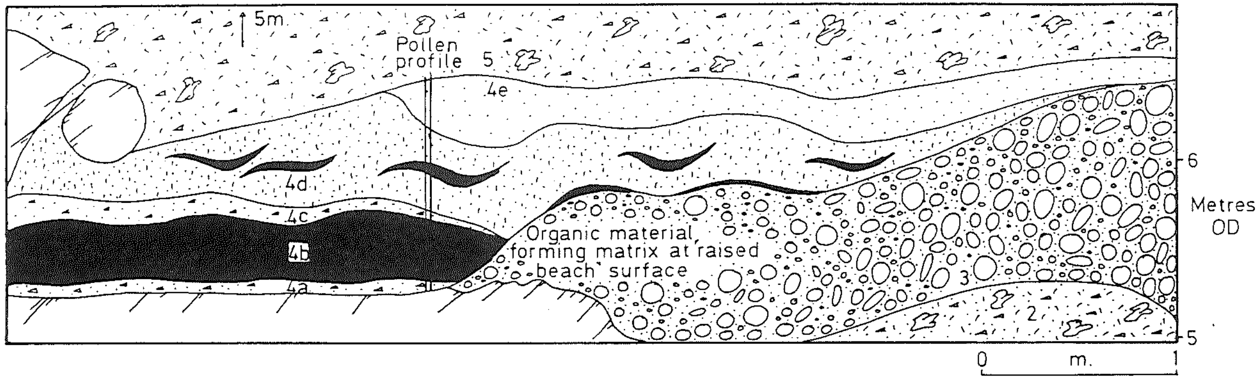
The most complete sections at Porth Seal occur on the south side of the bay (see cover of Guide). Two sequences, Porth Seal B, and Porth Seal C have been identified (Figs.36 and 37) and these will be discussed in turn. Porth Seal C corresponds to the section described by Mitchell and Orme (1967).

Raised beach cobbles (unit 3) are exposed at the western end of Porth Seal overlying a unit of solifluction breccia (unit 2). Overlying unit 3 is an organic sequence, unit 4, about a metre thick, which consists of several distinct beds, these beds being internally stratified. Immediately superposed to the raised beach cobbles is a thin layer, unit 4a, of white coarse sand and quartz granules. This lenses out laterally to the west so that the next unit, 4b, a richly organic fine silt, rests directly on the raised beach, and, in places, forms its matrix. 4c again consists of inorganic coarse granite sand and granules, and is overlain by 4d, a thick unit of internally variable organic silty sands with granite clasts and quartz granules. The whole unit is overlain by up to 5 m. of coarse granite breccia (unit 5), the base of which lies between 5.7 and 6.5 m. OD. Units 2-5 all form part of the Porthloo Breccia.

As at Watermill Cove and Carn Morval, the organic sequence can perhaps be best interpreted as a lacustrine deposit, with variable minerogenic and organic sedimentation into the basin. Two samples from this organic material have been analysed for pollen (at Porth Seal A, some 100m to the east). The results are as follows:-

PORTH SEAL A 27-33 cm.

Pinus	2.8%	Broken 10.8%
Alnus	0.3%	Crumpled 30.1%
Corylus	0.3%	Degraded 12.2%
Gramineae	75.1%	Concealed 0.5%
Cyperaceae	1.4%	
Ericales (cf. _Empetrum_)	5.2%	
Solidago Type	1.4%	
Achillea Type	0.3%	
Compositae Liguliflorae	0.8%	



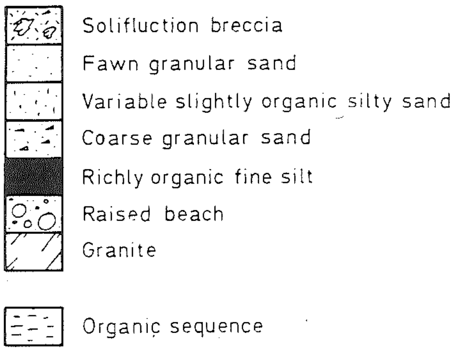


Figure 36. Porth Seal B - organic sequence

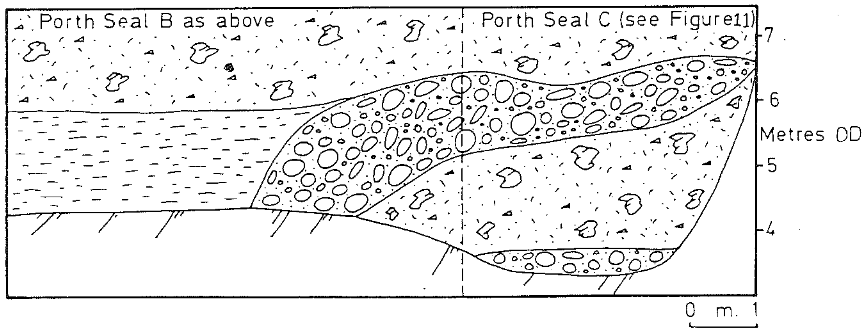


Figure 37. Porth Seal B and C - organic sequence

Plantago maritima	0.6%
Plantago undiff.	1.7%
Ranunculus repens Type	6.4%
Rubiaceae	3.0%
Potomogeton	1.0%
Sparganium Type	1.1%
Type latifolia	0.1%

Total land pollen and spores (P) = 362

(P + I + Aq) = 818

% I = 45.7%

PORTH SEAL A over 33 cm.

Pinus	0.3%	Broken 0.2%
Corylus	0.3%	Crumpled 33.2%
Gramineae	78.7%	Degraded 13.6%
Cyperaceae	1.3%	Concealed 0.5%
Solidago Type	9.3%	Corroded 0.3%
Achillea Type	0.3%	
Cruciferae	0.6%	
Plantago major/ P. media	0.6%	
Rubiaceae	6.0%	
Apium-Berula Type	0.3%	
Sparganium Type	2.0%	

Total land pollen and spores (P) = 300

(P + I + Aq) = 603

% I = 50.2%

Both samples were extremely well humified, and pollen preservation was consistently poor, indicated by the indeterminate percentages of 45.7 and 50.2 respectively. Pollen concentrations were not calculated.

If lacustrine in origin, the sediment probably contains a large local and extra-local component, with a much smaller regional component.

Important elements are Gramineae, 75.1 and 78.7 % respectively, Solidago Type, 1.4 and 9.3%, and Rubiaceae, 3.0 and 6.0%. Consistent minor taxa are Cyperaceae, Achillea Type and Plantago spp. The low percentages for the tree taxa Pinus, Alnus and Corylus can be accounted for as either long-distance transport, or reworking.

The low but consistent presence of Sparganium Type, along with Potamogeton and Typha latifolia in the lower sample is further evidence supporting the lacustrine genesis of the deposit. The lower sample contains a number of taxa not recorded in the upper, including Alnus, Ericales, Compositae Liguliflorae, Plantago spp., Ranunculus repens Type, Potamogeton and Typha latifolia. Of these, the most important are the Ericales (5.2%), Ranunculus repens Type (6.4%), and the two aquatic taxa. All the herb taxa are characteristic of arctic tundra vegetation, the grasses dominating but with sedges in favourable, perhaps wetter localities, and other herb taxa being common colonisers of the disturbed minerogenic soils of the periglacial zone (Godwin, 1975).

Samples of beds 4b and 4d have been radiocarbon dated. The dates are as follows:

First series	Residue	+	-	Extract	+	-	Q number
4b	18,780	260	250	16,440	120	120	2364/5
4d	15,450	120	120	11,220	1550	1300	2366/7
Second series							
4b	-			34,500	885	800	2410
4d	25,670	560	530				2409

The first series dates, though consistent in their stratigraphy, make little sense in their geological context suggesting serious contamination by modern carbon. The extract dates are between 2,340 (4b) and 4,230 (4d) years younger than the residue dates, indicating contamination by modern humus at the face of the section; it was noted during pre-treatment that the organic sediment was contaminated by rootlets.

This is perhaps confirmed by the second series samples, which were taken from about 3 m. into the section. As a result of low carbon yields on combustion it was not possible to date the residue of bed 4b, or the extract of bed 4d in the second series. The first series residue date on bed 4d is younger than the second series by 10,220 years, and the first series extract date on bed 4b by as much as 18,060 years. In the absence of any measurement of the second series 4b residue and 4d extract samples it is unfortunately not possible to arrive at any conclusions concerning humus contamination of the second series samples, or on the allochthonus/autochthonous status of the humus in the deposit. However, it seems likely that the second series dates, being so much older, do indicate serious contamination of the first series samples, and it is unlikely that such large differences could be accounted for solely by the inwashing of recent humus.

Despite this lack of control information, it is suggested that the second series dates are perhaps the most 'reliable', bed 4b being dated at 34,500 $^{+885}$ years BP and bed 4d at 25,670 $^{+560}$ years BP.

No identifiable macrofossils have been discovered at this site.

The stratigraphic relationships between Porth Seal B and C are illustrated in Figure 37.

The lowest unit at Porth Seal B, unit 2, is a granite breccia (soliflluct). This can be traced laterally as unit 2 of Porth Seal C, the 'Gipping' head without erratics of Mitchell and Orme. At Porth Seal C, this breccia is underlain by another unit of raised beach cobbles, unit 1, the 'Chad Girt' beach. No humic horizons are present at Porth Seal C, the upper raised beach unit (3), the 'Porth Seal' beach, being overlain by a coarse breccia which can be traced laterally as Porth Seal B unit 5.

Rather than the direct litho-chronostratigraphical interpretation suggested by Mitchell and Orme, an hypothesis of only one <u>in situ</u> raised beach (unit 1) is preferred, the upper parts of which have become entrained within the solifluction flow to appear as an upper, younger, raised beach (unit 3). This phenomenon has been recorded at almost every site in the present study where raised beach sediments are covered by solifluction breccia. Where three-dimensional sections are available in West Cornwall, 'tongues' of the underlying beach sediments can be seen within the overlying breccia, which, in the absence of the third dimension, as at Porth Seal C, would simply appear as a higher body of raised beach sediment (Fig.61). Units 2 and 3 can therefore be interpreted as facies Aa deformation breccia (Appendix 3). Unit 1 represents the Watermill Sands and Gravel, with the base of the unit lying at 3.25 m. OD.

PERNAGIE BAR (SV920171) JDS

Pernagie Bar is a marine bar extending for 0.5 km from Pernagie (SV920171) to Plumb Island (SV918171), Pernagie Brow (SV918173) and Pernagie Isle (SV918175) (see cover of Guide). It consists of large granite boulders which are submerged at high tide, and at its southern end the bar is "cored" by Scilly Till. This massive stony clay has been observed to extend over

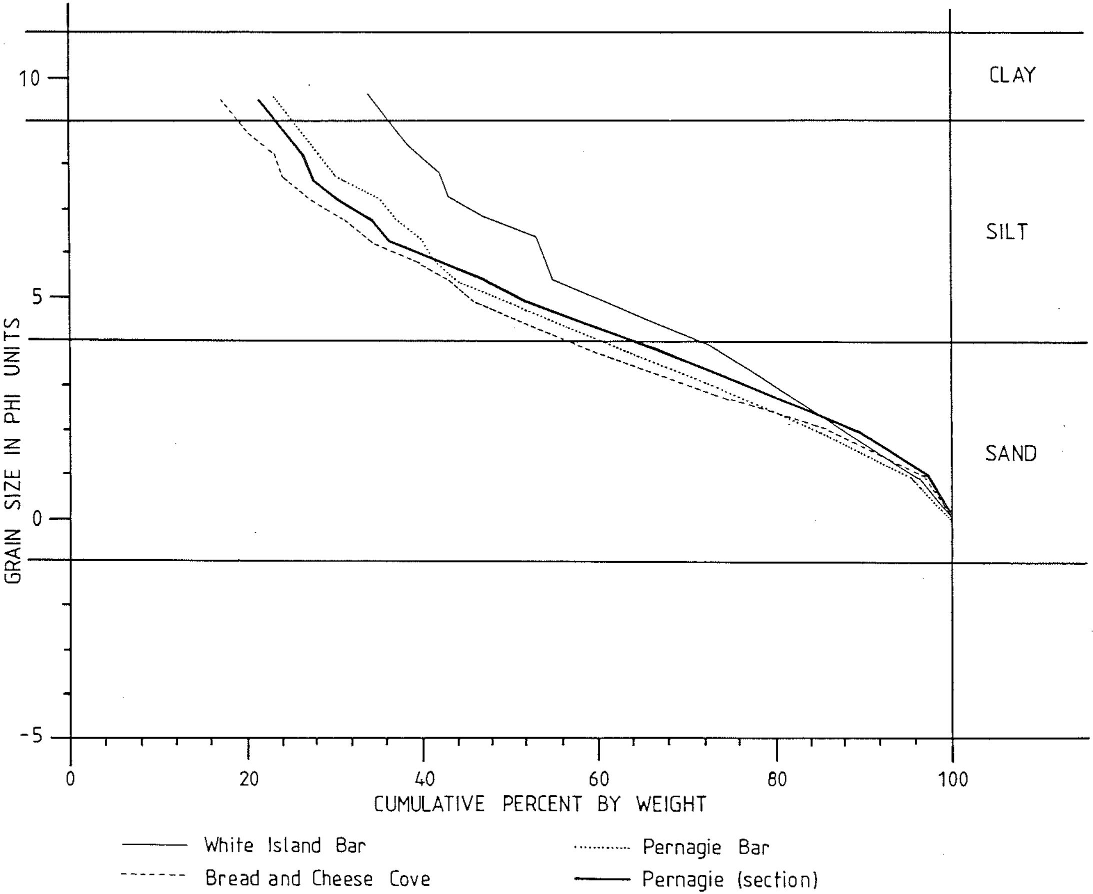


Figure 38. Scilly Till - grainsize analyses

an area of > 10 m^2 underneath the granite boulders, but it may be much more extensive. The till is of unknown total thickness, but it is greater than 1.2 m.

At this site the Scilly Till is 10 YR 6/6 (brownish yellow) in colour, drying to 10 YR 7/4 (very pale brown). It has been analysed granulometrically, and for fine gravel and pebble counts (Figs.38 and 39). It is extremely poorly sorted, contains 39% sand, 37% silt and 24% clay, and is distinctively negatively (coarse) skewed. It contains a distinctive erratic clast assemblage, with 2% flint, 12% greywacke/quartzites, 2% sandstone, 3% metamorphics and 83% local granitically derived material in the fine gravel fraction. The unit contains a clast concentration of 107 granules and 11 pebbles > 4 mm. per 100g. sediment.

Scilly Till is also exposed in a small section to the south of the bar site underlain by the Porthloo Breccia. Here it is a distinctively mottled massive stony clay. When wet the mottlings vary from 10 YR 5/4 (yellowish brown) to 10 YR 5/1 (grey), and when dry from 10 YR 7/8 (yellow) to 10 YR 7/3 (very pale brown). The unit has been analysed granulometrically, and for fine gravel and pebble counts (Figs.38 and 39). It is extremely poorly sorted, consists of 38% silt, 35% sand, and 26% clay, and is strongly negatively (coarse) skewed. It contains a distinctive erratic clast assemblage, with 1% flint, 15% greywacke/quartzites, 2% sandstone, 5% metamorphics and 78% local granitically derived material in the fine gravel fraction. This assemblage is mirrored in the >4 mm. pebble fraction. The unit contains a clast concentration of 58 granules and 8 pebbles >4 mm. per 100 g. sediment.

A sample of Scilly Till from the Pernagie locality has been analysed mineralogically (J. Catt, Appendix 2). The results are given in Table 3 under sample 3.

Though this material can be interpreted as a till, there is as yet insufficient evidence to define its facies more precisely.

WHITE ISLAND BAR (SV923170) JDS

Another similar bar links St. Martin's to White Island (see cover of Guide) where pebbles, cobbles and boulders of a wide variety of lithological types are again underlain by a "core" of Scilly Till. During the spring of 1984 the surface of the till unit covered an area of around 20 m^2, but it may actually be more extensive. The stratigraphy of a Dutch-type wing auger borehole through the Scilly Till at this site is given in Figure 40. A maximum of 2.6 m of till has been proved, resting on 19 cm of granitic breccia without erratics which passes downwards into an unknown thickness of black to dark brown granular silt. This latter sediment may be organic, but a pollen preparation proved to be barren.

Towards the surface the Scilly Till consists of a very stiff, massive stony clay, 10 YR 4/4 (dark yellowish brown) in colour drying to 10 YR 6/3 (pale brown). It has been analysed granulometrically, and for fine gravel and pebble counts (Figs.38

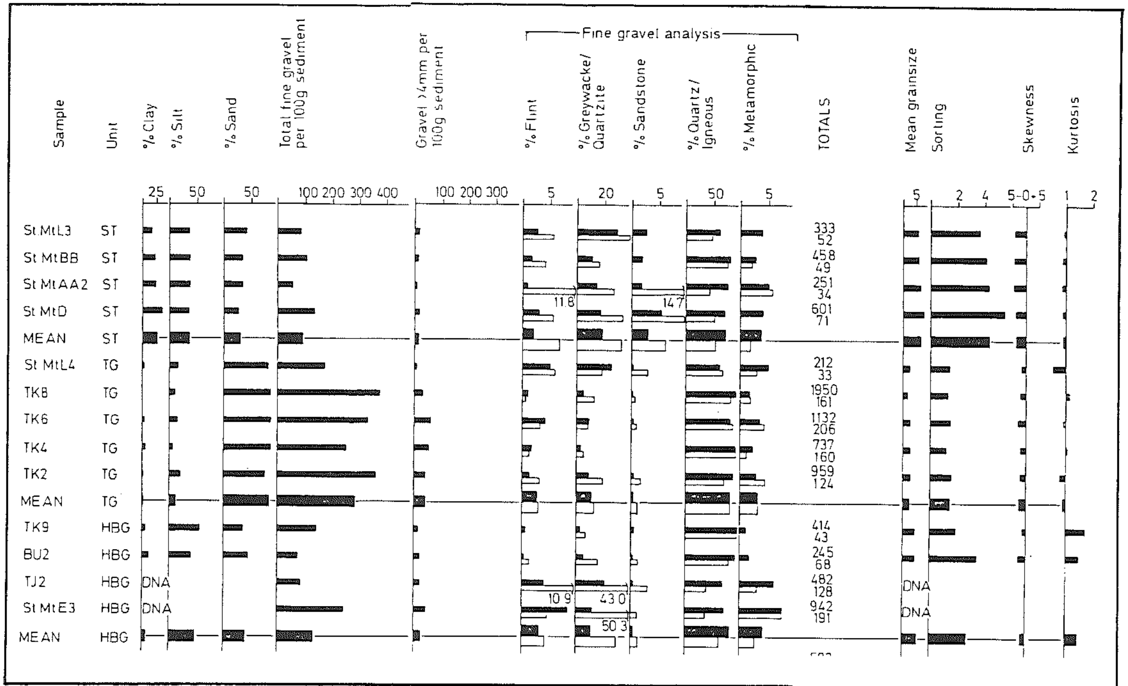


Figure 39. Scilly Till (ST), Tregarthen Gravel (TG) and Hell Bay Gravel (HBG) - summary of granulometric and clast lithological analyses

DNA - Data not available
Fine gravel fraction
>4mm fraction
ST Scilly Till
TG Tregarthen Gravel
HBG Hell Bay Gravel

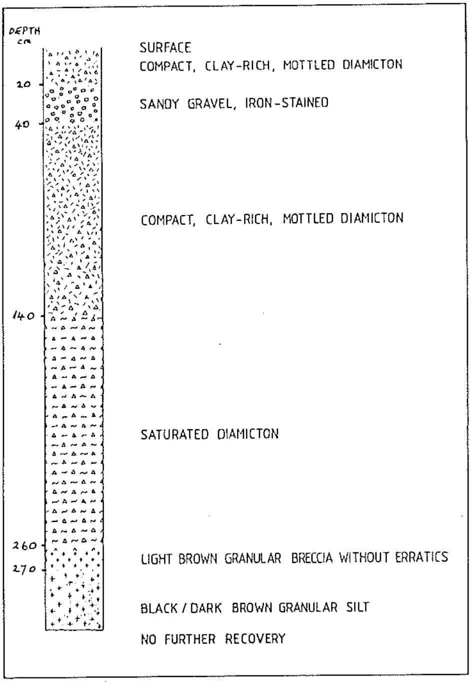


Figure 40. White Island Bar - wing auger borehole

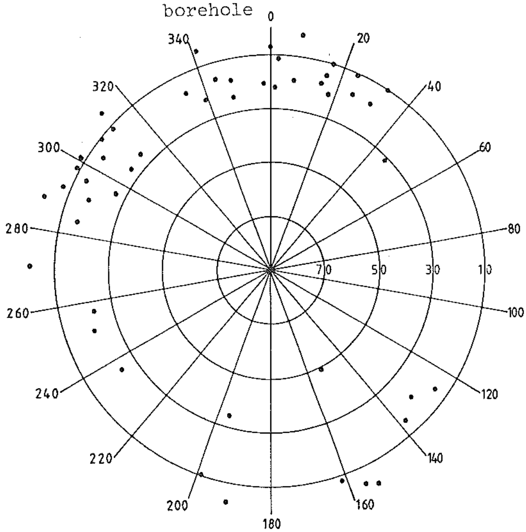


Figure 41. Scilly Till, White Island Bar - fabric diagram

and 39). It is extremely poorly sorted, contains 36% clay, 35% silt and 29% sand, and is distinctively negatively (coarse) skewed. It contains a distinctive erratic clast assemblage, with 3% flint, 17% greywacke/quartzites, 5% sandstone, 4% metamorphics and 71% local granitically derived material in the fine gravel fraction. This assemblage is mirrored in the >4 mm. fraction. The unit contains a clast concentration of 136 granules and 16 pebbles >4 mm. per 100 g. sediment.

A clast macrofabric analysis from the upper part of the Scilly Till sequence indicates strong clast preferred orientations from N/S to NW/SE with predominant clast dips in the 0 - 30° range towards the N/NW (Fig. 41).

A sample of Scilly Till from White Island Bar has been analysed mineralogically (J. Catt, Appendix 2). The results are given in Table 3 under sample 1.

The Scilly Till from White Island Bar may be of lodgement facies. Both Pernagie and White Island Bars themselves may represent remnants of glacial depositional landforms.

CHAD GIRT (SV926174) JDS

This section was first described by Barrow (1906) (Fig. 10), who regarded it as typical for the Pleistocene of the Scillies.

The basal unit, resting on the granite wave-cut platform, is the Watermill Sands and Gravel, a massive raised beach. No erratics have been observed within this unit. Unit 2, a coarse granite breccia (= 'Main Head' of Barrow) is interpreted as a solifluction deposit and is correlated lithostratigraphically with the Porthloo Breccia Member; it contains no erratics. Unit 3 is Barrow's 'glacial deposit' ("iron-cement and erratics"), which, at this site, Mitchell and Orme reinterpreted as an "outwash gravel".

The fine gravel and pebble content of this unit has been analysed (Fig. 39). It consists of 8% flint, 12% greywacke/quartzites, less than 0.5% sandstones, 8% metamorphics and 71% local granitically derived material in the fine gravel fraction. The >4 mm. fraction mirrors this assemblage. Clast concentration is 234 granules and 47 pebbles per 100 g. sediment. These clasts are set in a sandy silt matrix. The unit is a solifluction deposit and is lithostratigraphically correlated with the Hell Bay Gravel Member. As a unit, the Hell Bay Gravel consists of material of glacigenic origin (Scilly Till, Tregarthen Gravel) thoroughly mixed with Old Man Sandloess and subsequently soliflucted. The affinity of the matrix of the Hell Bay Gravel with the Old Man Sandloess can be seen from Figure 34.

Unit 4, the 'upper head' of Barrow, is also interpreted as a solifluction deposit, and can be lithostratigraphically correlated with the Bread and Cheese Breccia Member on the basis that it contains abundant erratics.

BREAD AND CHEESE COVE (SV940159) JDS

This section was described in detail by Mitchell and Orme (1967); Mitchell's current views on the site are described in Part I of the Guide.

A granite wave-cut platform rises upwards towards the west to meet the base of a coarse granite breccia, unit 2 (Figs.42 and 43). At the base of the section there is a substantial amount of very coarse granite rubble and boulders which extend outwards from the cliff across the granite platform. Forming the matrix between these boulders, and also a consistent unit at the base of the section is a humic horizon, unit 1b, a dark brown silty sand with quartz granules. A number of pits were dug at the base of the section, revealing a richly organic sand, 1a, resting on the granitic boulders and wave cut platform. Unit 1a passes upwards into the less organic, brown granular sand, unit 1b, in turn overlain by the granitic solifluction breccia, unit 2. The base of the solifluction breccia lies at 5.89 m OD, and the contact with the organic deposit below is sharp. Immediately above the organic deposit the breccia, unit 2, is never more than about 2 m. thick (Fig. 42), overlain, with a sharp erosional contact, by a clay-rich light brown diamicton containing abundant erratic clasts. This unit, 3, is lenticular in form, thickening towards the north where its base passes beneath the present beach level. The lens is around 22 m. in length, and at its greatest, around 2 m. thick. At one point unit 3 is overlain by a smaller lens of cemented matrix supported sandy gravel (unit 4), again containing abundant erratic clasts. Units 3 and 4 are both overlain by up to 4 m. of coarse, dominantly granitic breccia (unit 5) which contains occasional erratic clasts. The top of unit 5 is capped by large granite boulders.

Units 1 and 2 are the Porthloo Breccia, 3 the Scilly Till, 4 the Tregarthen Gravel and 5 the Bread and Cheese Breccia.

A profile through Pit B was sampled for pollen and loss on ignition. The microstratigraphy of the organic deposit at this point is presented in the sediment column of the percentage pollen diagram, Fig. 44, and the pollen washings/loss on ignition diagram, Fig. 45. Both Figures 44 and 45 concern unit 1a; unit 1b has not been analysed in detail.

Figure 45 demonstrates that the unit has a generally high organic content, the highest values, up to 35%, occurring towards the base, lower values towards the top; the lowest value for organic content is 10% at level 35 cm.

These loss on ignition results support the sediment description in Fig. 44, with declining organic content upwards being mirrored by declining humification upwards. No macroscopic organic detritus was observed; around 95% of the organic content is estimated to consist of humus, the remaining 5% being made up with pollen and spores. There is an abundance of fine organic detritus towards the top, declining only slightly downwards; coarse inorganic detritus values are relatively low, rising only slightly upwards to 'frequent' at level 35 cm. Unit 1b is richly organic, highly humified and relatively homogeneous.

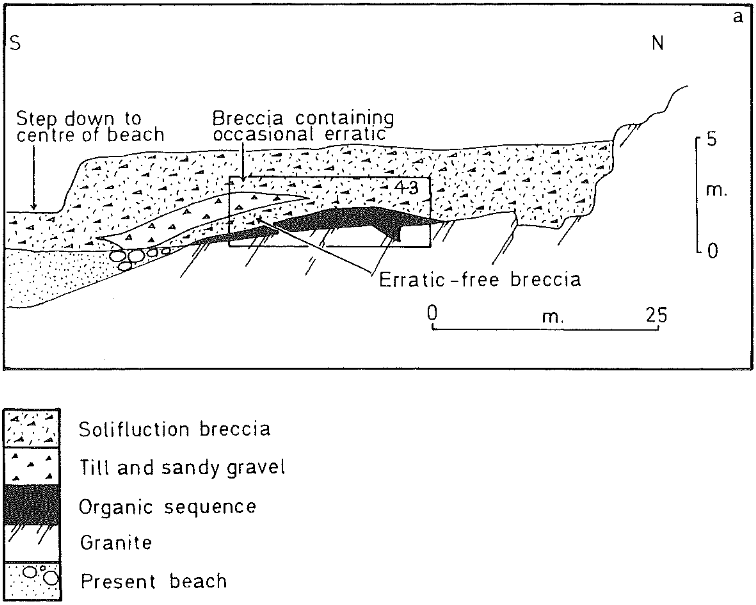


Figure 42. Bread and Cheese Cove - stratigraphy

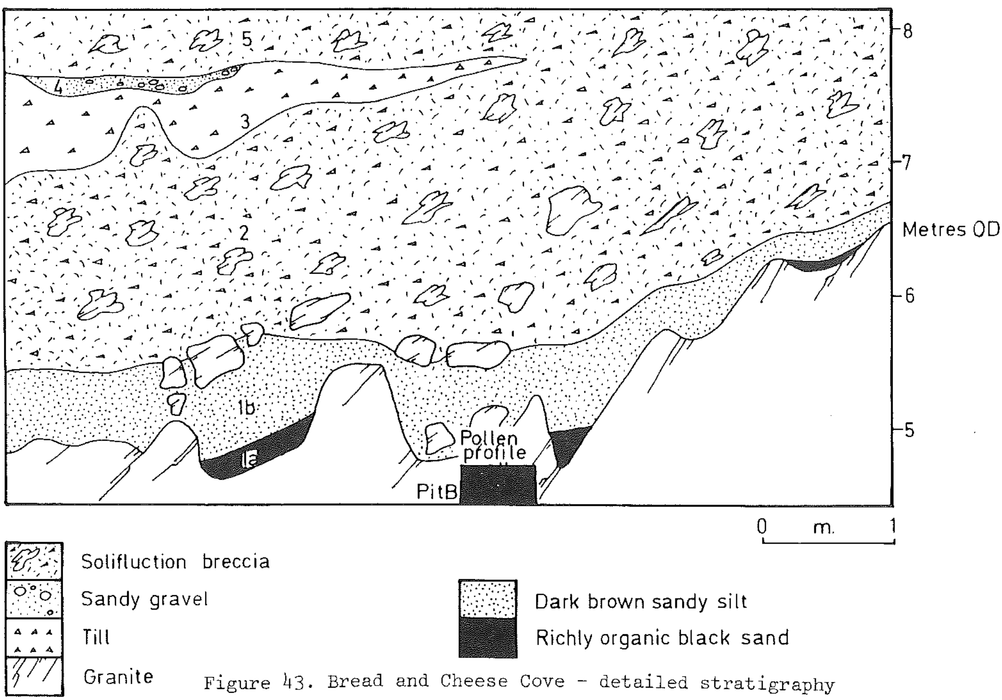
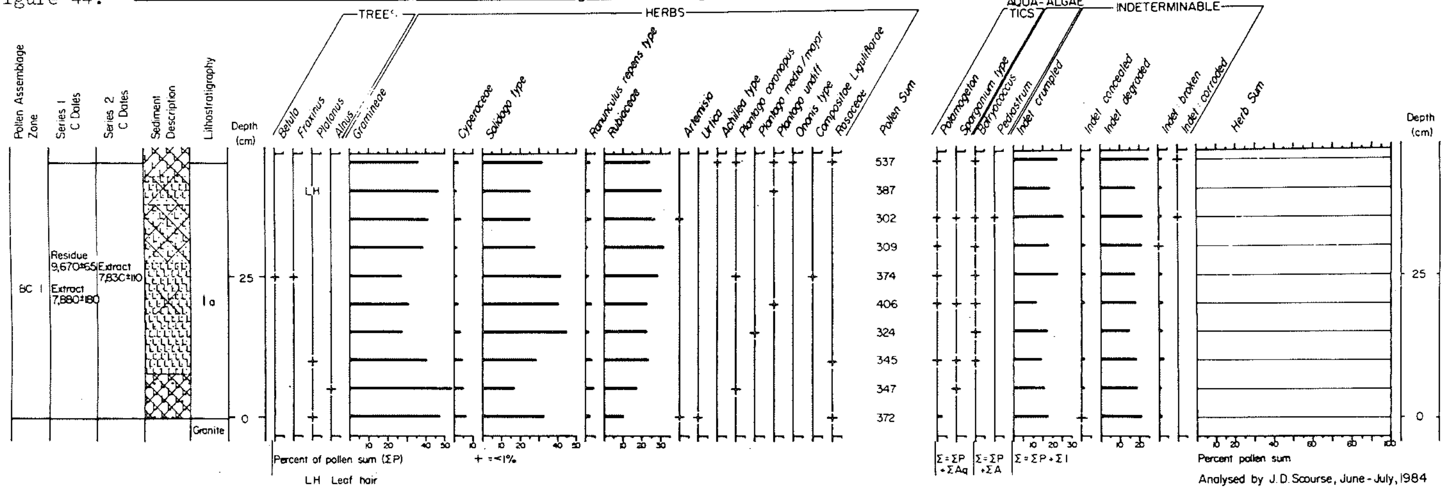


Figure 43. Bread and Cheese Cove - detailed stratigraphy

Figure 44. BREAD AND CHEESE COVE, PIT B - Percentage Pollen Diagram



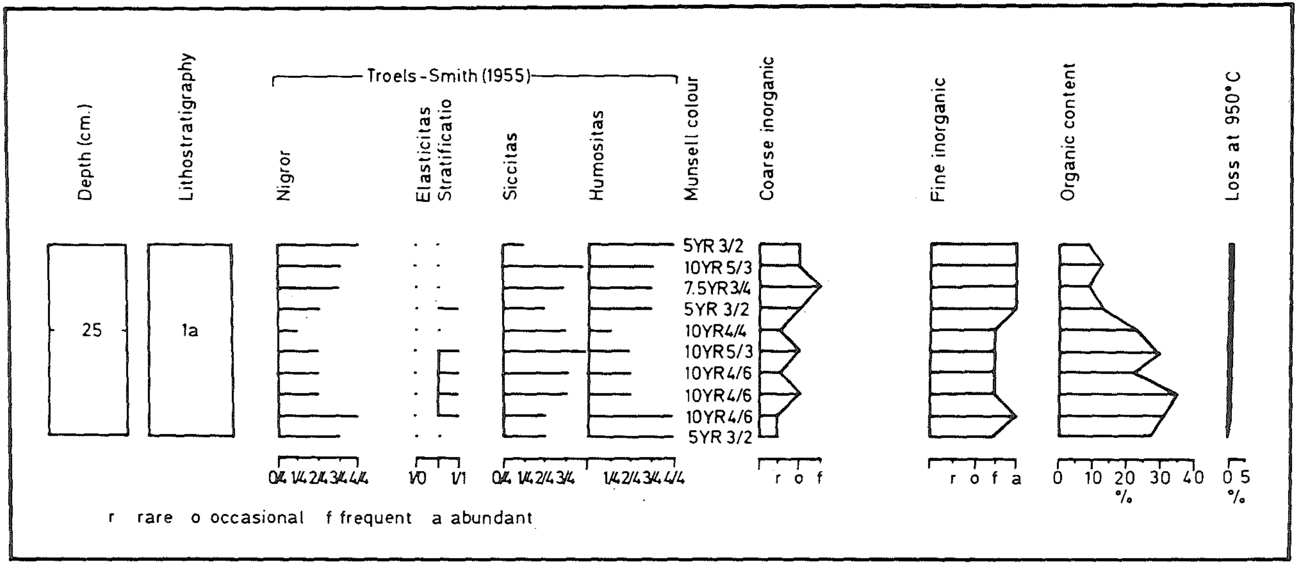
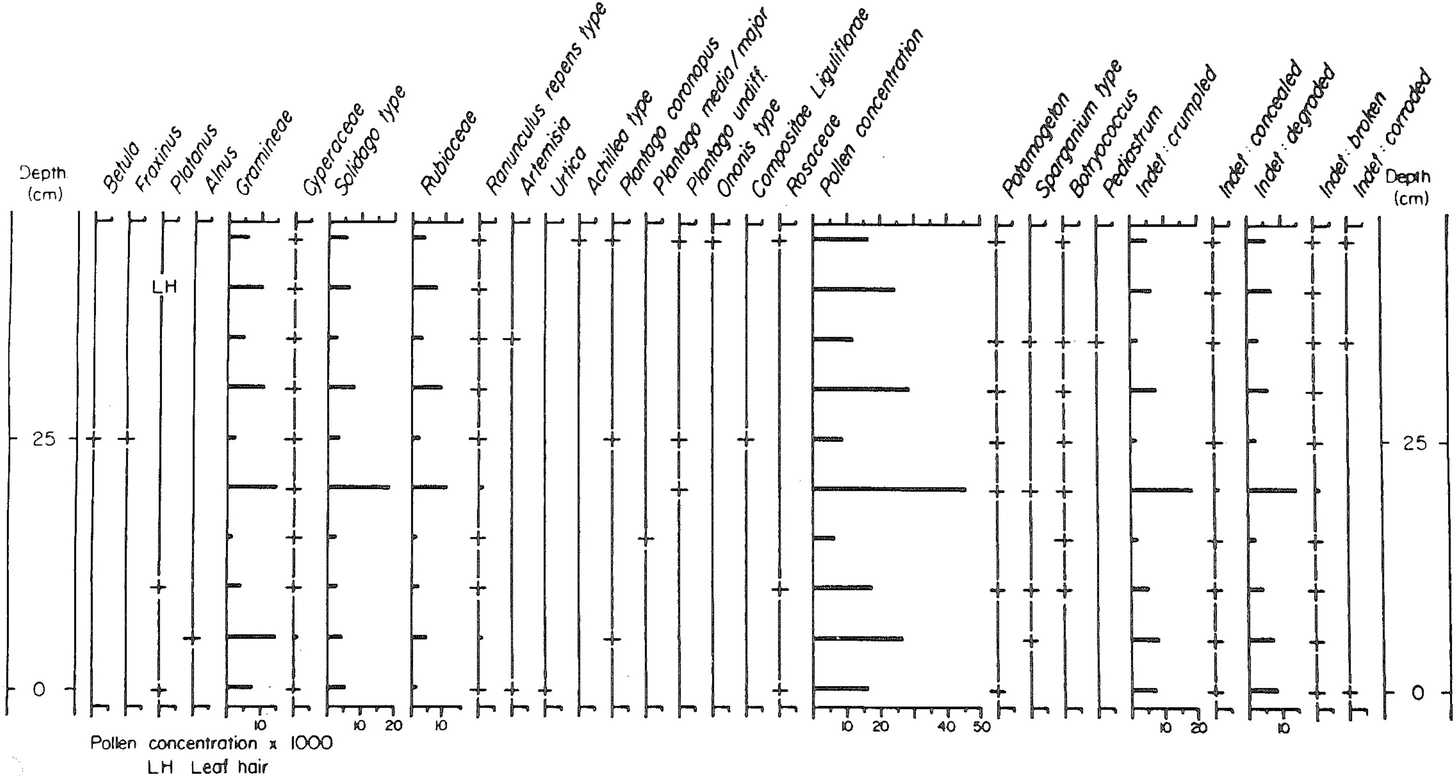


Figure 45. Bread and Cheese Cove, Pit B - loss on ignition and pollen washings diagram

Figure 46. BREAD AND CHEESE COVE, PIT B - Concentration Pollen Diagram



There is no evidence for breccia deposition, and therefore active solifluction, between the granite platform and the organic unit. The organic sediments fill the cracks of the platform, and the interstices of the granite boulders associated with the platform. The boulders can perhaps be regarded as an 'immature' raised beach deposit, organic deposition having occurred directly on the surface of the old beach. Many of the sand grains and granules found in the pollen washings were very well rounded, perhaps suggestive of a marine origin. The most likely origin for the organic deposit is lacustrine, ponding being effected by contemporaneous local solifluction. There is no evidence for the secondary solifluction of this deposit; the boulders which occur throughout unit 1 are thought to represent beach rather than solifluction material.

Two pollen diagrams are presented, a percentage (Fig.44), and a concentration (Fig.46) diagram. In a lacustrine context of this sort, most pollen arriving in the basin would be from local or extra-local sources, with a smaller regional component landing directly on the water surface. The low obligate aquatic and Cyperaceae values suggest that autochthonous as well allochthonous humus is probably present.

The pollen diagrams show very few changes through the ten levels, and they have therefore not been zoned. The spectrum is totally dominated by herb taxa, in particular Gramineae, which varies between 56% (level 5 cm.) and 27% (level 25 cm.), Solidago Type, which varies between 49% (level 15 cm.) and 17% (level 5 cm.) and Rubiaceae, whose curve increases gradually upwards from 10% at level 0 cm. to 31% at level 30 cm. Cyperaceae values are low and decline upwards, the highest value of 6% occuring in the basal level; Potamogeton values behave similarly, with a maximum of 3% in the basal level. These slight changes may indicate the filling of the pool, or a lowering of the water level, upwards. The only other herb taxa that occurs with any consistency is Ranunculus repens Type, reaching 4% in level 5 cm. Not one Pinus sac was counted through the entire profile.

Pollen concentrations fluctuate greatly between levels, ranging from 11,000 grains cm^3 to 81,000 grains (15 and 20 cm. respectively). Comparison of the pollen concentrations with the loss at 550° C. reveals the very high levels of humus in the organic deposit.

All the herb taxa are characteristic of arctic tundra vegetation, the grasses dominating but with sedges in favourable, perhaps wetter localities, and other herb taxa being common colonisers of the disturbed minerogenic soils of the periglacial zone (Godwin, 1975).

No identifiable microfossils have been found at this site.

Bed 1a has been radiocarbon dated. The dates are as follows:

	Residue	+	-	Extract	+	-	Q number
First series	9,670	65	65	7,880	180	180	2368/9
Second series		--		7,830	110	110	2411

The second series sampling programme was very unsatisfactory. Wing auger penetration of bed 1a was minimal because of the large boulders found throughout the deposit. In all, 64 wing auger boreholes were attempted. Of these, only 8 penetrated more than 40 cm. into the section. The second series sample quoted above came from no more than 0.5 m. into the section. On combustion, it was found that the second series residue sample contained insufficient carbon for counting.

These radiocarbon dates are clearly severely contaminated by modern carbon. They make no sense in their stratigraphical context, and accordingly the origin of the contamination has to be explained. Three sources of contamination by modern material can be invoked; burrowing solitary bees, rootlet penetration and humus from groundwaters. Contamination by burrowing bees is possible, but not thought to be important. No bee holes were observed at the site in the bed concerned, and contamination was not suspected in the pollen diagram.

A combination of rootlet penetration accompanied by groundwater percolation charged with modern humus are the most likely sources. The granite/bed 1a contact forms an impermeable interface, and such situations seem to exacerbate contamination by modern humus (cf. Carn Morval and Watermill Cove). The difference of 1,790 years between the two series dates does suggest that humus contamination is a problem. The pollen diagrams show no such indication of contamination, and are clearly 'cold stage' in character.

Unit 2, the granite breccia, has been analysed granulometrically and for fine gravel (Fig. 47). It is extremely poorly sorted, contains 58% sand, 39% silt and 3% clay, and is highly negatively (coarse) skewed. Lithologically, as indicated from the fine gravel analysis, it consists of 100% granitically derived material. Of the 1368 granules counted, not one could be classed as an erratic. The same is true of the 195 clasts over 4mm. counted. The absolute fine gravel and pebble content is very high, consisting of 573 granules and 82 pebbles per 100 g. sediment, testifying to the coarseness of the deposit suggested by the matrix skewness.

A clast macrofabric analysis of this breccia unit is presented in Figure 48. A moderately strong (Eigenvalue 1: 0.6384) SSW/NNE preferred orientation is indicated with dips concentrating towards the SSW (Eigenvector 1: 7°/195°). This fabric is highly typical of facies D breccia (Appendix 3) with preferred orientation parallel with the local slope and dip into the slope.

Unit 3 is the stratotype of the Scilly Till. Its colour is 10 YR 4/4 (dark yellowish brown) drying to 10 YR 6/4 (light yellowish brown). Though largely homogeneous, it does contain horizontal iron-stained sand partings. Many of the contained clasts are well rounded, whilst some are striated and faceted. The sediment has been analysed granulometrically, and for fine gravel (Figs. 38 and 39).

It is extremely poorly sorted, contains 43% sand, 38% silt and 19% clay, and is strongly negatively (coarse) skewed. It contains 85 granules and 18 pebbles per 100 g. sediment, and

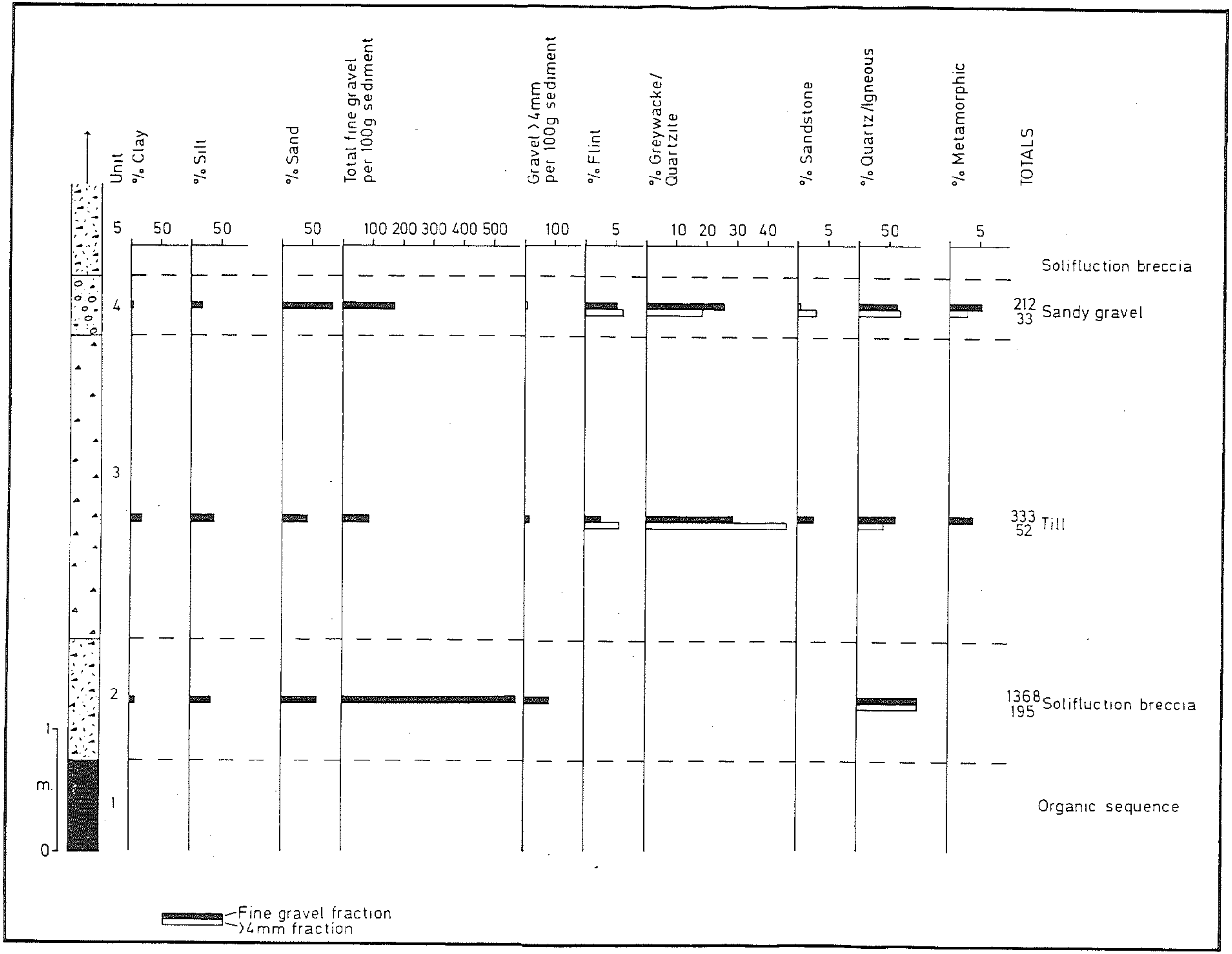


Figure 47. Bread and Cheese Cove - granulometric and clast lithological data

both 2-4 mm. and >4 mm. fraction analysis indicate that it contains an abundant erratic assemblage, consisting of nearly 3% flint, 29% greywackes/quartzites, nearly 3% sandstone, 4% metamorphics and 62% locally derived granitic material. Three features therefore set this material off sharply from the underlying breccia, the high clay content, the lower granule and pebble concentrations and the rich erratic assemblage.

A coarse lag of angular granite boulders occurs at the base of the Scilly Till at its junction with the Porthloo Breccia, whilst the upper contact with the Bread and Cheese Breccia is clearly soliflucted.

Three clast macrofabric diagrams from the Scilly Till, and one from the overlying Bread and Cheese Breccia are presented in Figure 48. Sample A was from the base of the unit, sample B from the middle and Sample C just beneath the soliflucted upper contact. Sample A shows no strong preferred orientation (Eigenvalue 1: 0.4914: Eigenvector 3°/175°) but the weak orientation is in sympathy with the underlying Porthloo Breccia. Sample B, however, has a strong (Eigenvalue 1: 0.7940) NW/SE preferred orientation (Eigenvector 1: 19°/148°), as does sample C (Eigenvalue 1: 0.7026: Eigenvector 1: 18°/143°). The overlying Bread and Cheese Breccia has a similar fabric signature, with strong (Eigenvector 1: 0.7580) NW/SE preferred orientation (Eigenvector 1: 7°/130°). The strong fabrics from Scilly Till samples B and C and the Bread and Cheese Breccia differ in their vectors from the Porthloo Breccia.

The S_1 and S_3 eigenvalues (Mark, 1973) for all fabrics from Bread and Cheese Cove have been plotted against fabric data from modern glacigenic sediments (Dowdeswell and Sharp, in press) in Figure 49. This indicates that while samples B and C plot close to 'melt-out till' and 'undeformed lodgement till', sample A is significantly different in resembling 'glacigenic sediment flow'. However, the Porthloo Breccia, which is undoubtedly soliflual in origin, plots between 'undeformed lodgement till' and 'glacigenic sediment flow', as does the Bread and Cheese Breccia. The Scilly Till fabrics have also been plotted against Rose's (1974) data on 'lodgement' and 'slumped' till from Hertford and Hatfield (Dowdeswell and Sharp, in press) in Figure 50. Samples B and C clearly resemble lodgement till whilst sample A plots within the slumped till samples.

In terms of fabric then, samples B and C are typical for lodgement till from both modern and fossil contexts, but the validity of this interpretation is cast in some doubt when the breccia fabric results are considered. Sample A may represent solifluction or slumped till, but it may also be indicative of local stresses generated at the base of the ice as a result of movement into the cove itself. Samples B and C may indicate ice movement from the NW, which accords with the fabric data from the White Island Bar site, whilst the strong but different preferred orientation of the Bread and Cheese Breccia compared with the Porthloo Breccia may represent solifluction in response to a glacial modification of the local slope orientation.

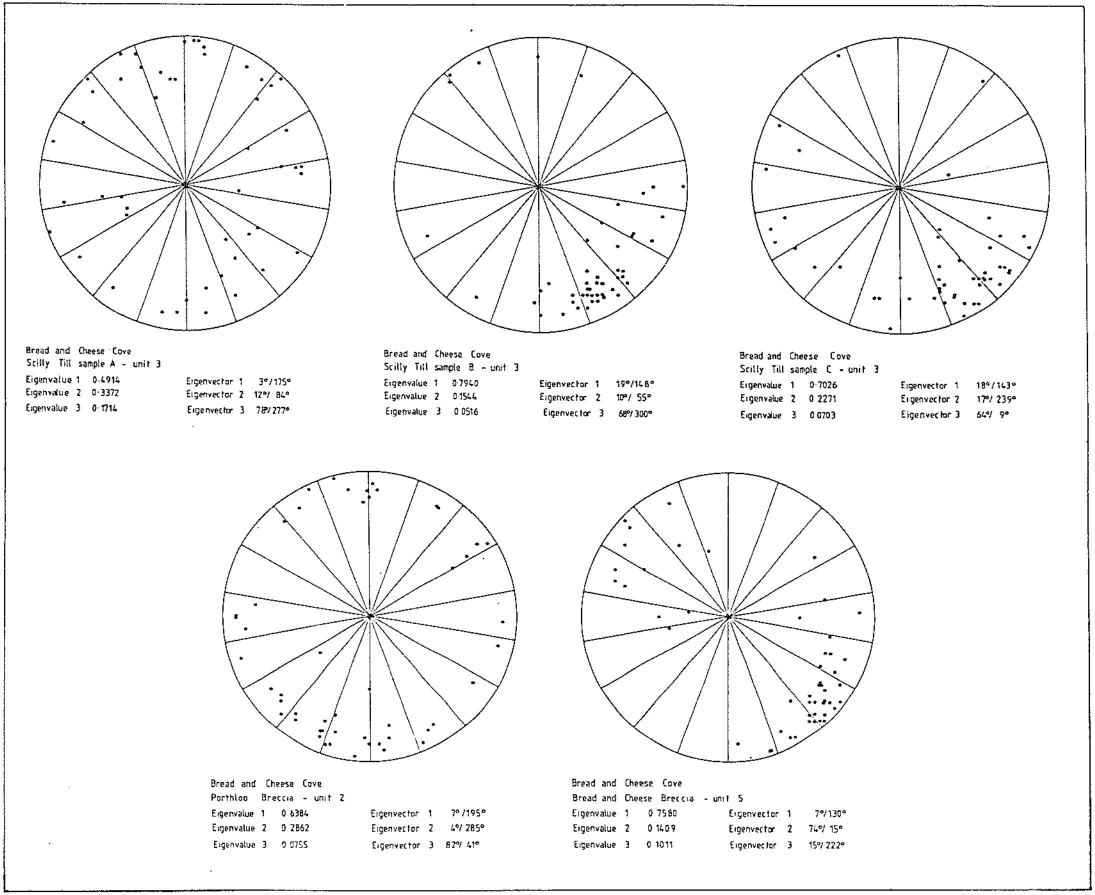


Figure 48. Bread and Cheese Cove - fabric analyses

Figure 49. Bread and Cheese Cove - fabric eigenvalue data plotted with eigenvalue data from modern glacigenic sediments as compiled by Dowdeswell and Sharp (in press)

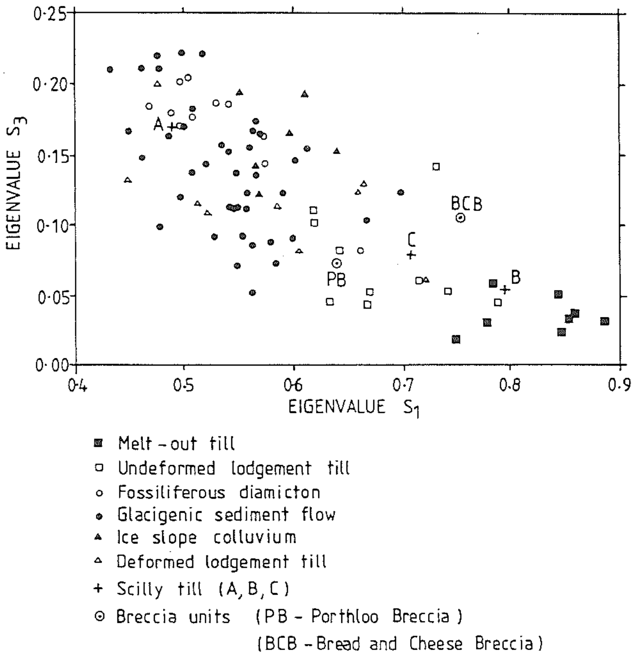
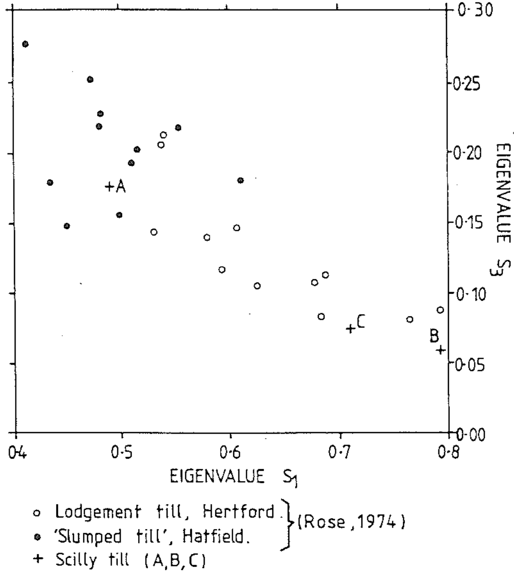


Figure 50. Bread and Cheese Cove, Scilly Till - fabric eigenvalue data plotted with eigenvalue data from lodgement and slumped till in S.E. England (Rose, 1974)



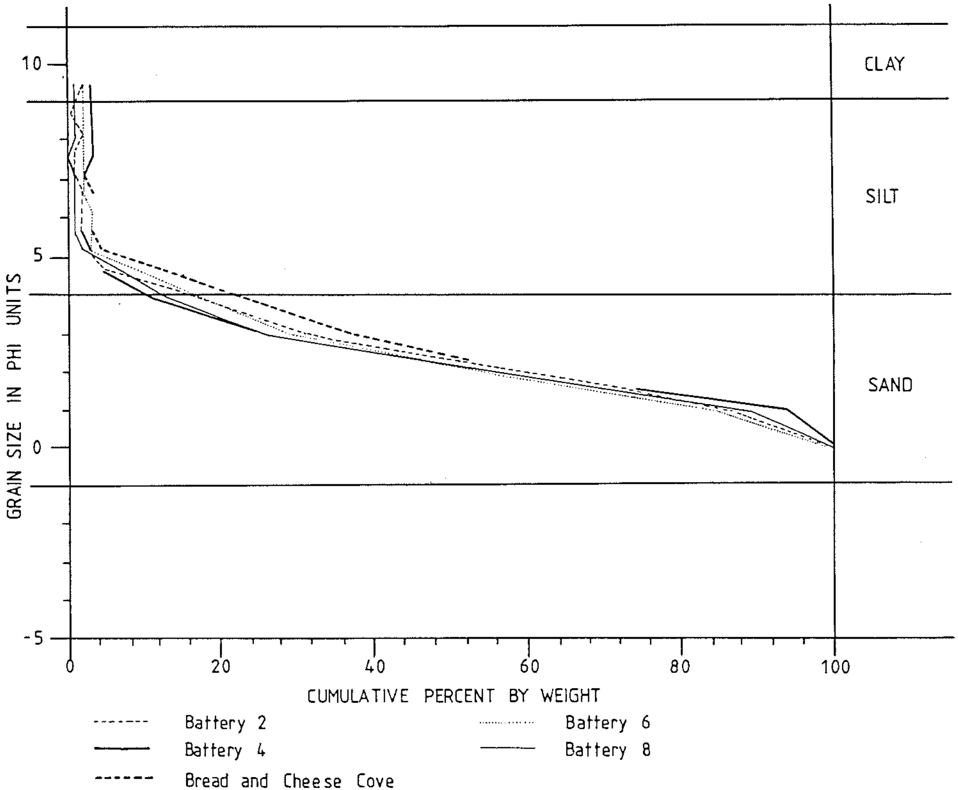


Figure 51. Tregarthen Gravel - grainsize analyses

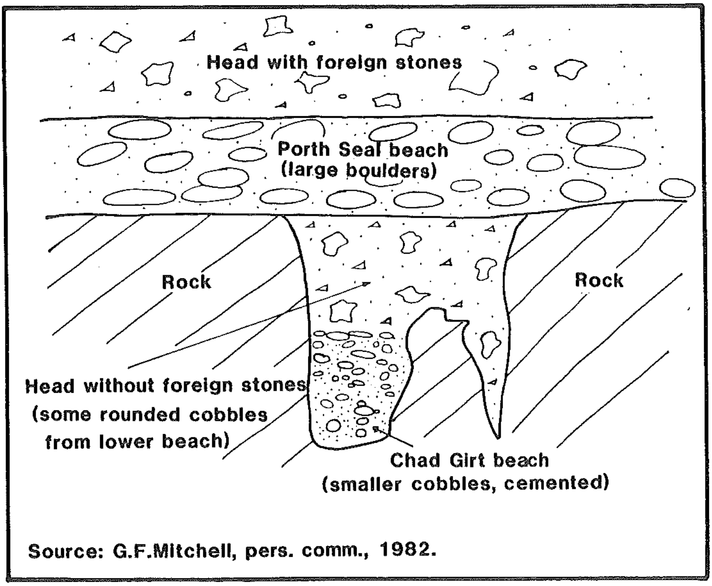


Figure 52. Northward Bight - stratigraphy

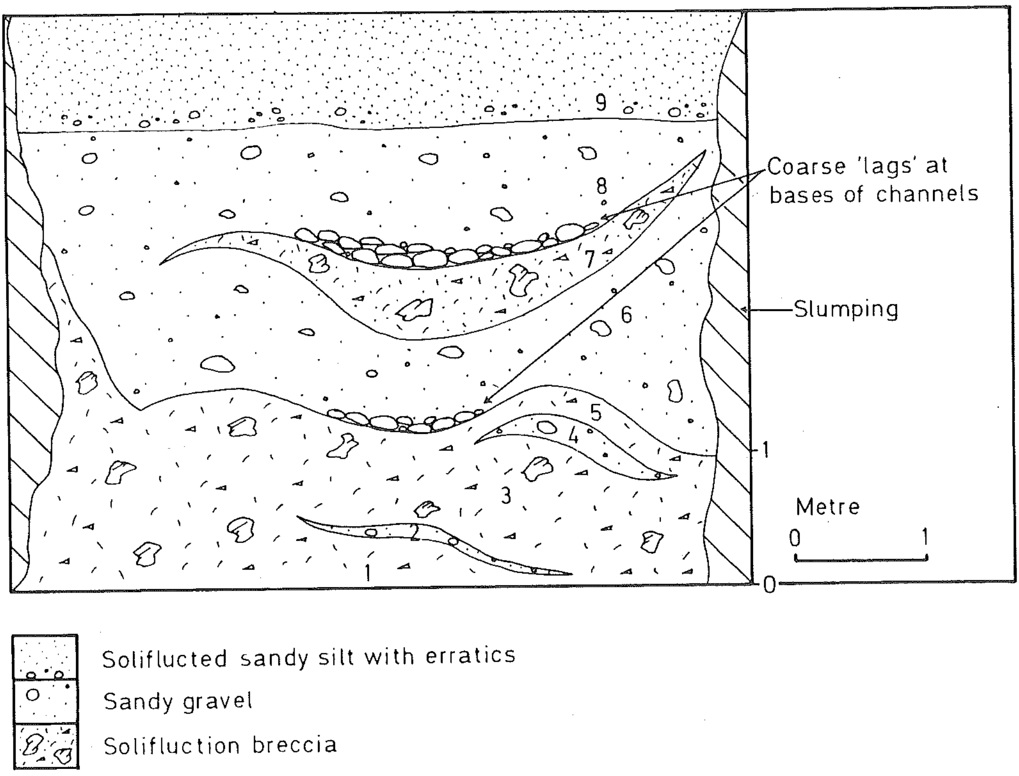


Figure 54. Battery - stratigraphy

Mineralogical analysis and discussion of the Scilly Till is given in Appendix 2 (J. Catt; Sample 2).

Thin sections of the Scilly Till indicate the co-existence of both heavily weathered and almost fresh material (J. Rose, pers. comm. 1985), and very high quantities of siliceous marine sponge spicules (D. Jenkins, pers. comm. 1986).

The Scilly Till at its type-site may well be of lodgement facies, though it may be slumped towards the base and is soliflucted towards the top. It is not thought to be slumped/reworked in entirety.

The Tregarthen Gravel, unit 4, has been analysed granulometrically, and for fine gravel (Figs. 47 and 51). It is moderately sorted with a dominant mode in the fine sand fraction, contains 84% sand, 15% silt and 1% clay. It contains nearly 13 granules and 9 pebbles per 100 g. sediment, these comprising an assemblage of erratics clearly related to the underlying Scilly Till, with 5% flint, 26% greywackes/quartzites, 0.5% sandstone, 5% metamorphics and 64% local granitically-derived material. The unit is interpreted as a waterlain gravel on the basis of these internal characteristics. Its stratigraphic proximity to the Scilly Till suggests an outwash origin.

In its general characteristics the Bread and Cheese Breccia is very similar to the Porthloo Breccia, being dominated by granite clasts and with an abundantly sandy matrix, but it does contains occasional erratic clasts, clearly derived from the underlying Tregarthen Gravel and Scilly Till. On purely lithological grounds, then, it cannot be correlated with the Porthloo Breccia, even though its origin can be attributed to similar massive solifluction. It is therefore defined separately.

The granulometric and fine gravel analyses of the Scilly Till, Tregarthen Gravel and Bread and Cheese Breccia are presented stratigraphically in Fig. 47.

CHAPEL DOWN (SV942158) JDS

Chapel Down is where Barrow (1906) identified Eocene (?) gravels. These gravels were later attributed to the Pliocene (Dollar, 1957) and then Wolstonian glacial outwash (Mitchell and Orme, 1967).

Small patches of erratic pebbles can be observed between and beneath clumps of heather. The erratic assemblage of these gravels is consistent with the assemblage characterising the Scilly Till, the Tregarthen Gravel and the Hell Bay Gravel, and it is thought that they represent a remanié of one of these units.

NORTHWARD BIGHT (SV944159) JDS

Northward Bight is the northernmost of two deep gullies trending SW/NE on the north-eastern side of St. Martin's Head. Mitchell has described a section here (Fig. 52). His interpretation of this section is included in Part 1 of the Guide.

An alternative hypothesis can be invoked whereby the upper ('Porth Seal') raised beach represents solifluction of the lower ('Chad Girt') raised beach, as at Porth Seal.

PERPITCH (SV940155) JDS

Three units can be observed at this section, the Old Man Sandloess between the lower and upper Porthloo Breccia units (Fig. 14). No clasts of foreign derivation have been found here; the site lies to the south of the southern limit of the Hell Bay Gravel (Fig. 7).

The Old Man Sandloess forms a channel-like feature cut into the underlying breccia. It is fairly well stratified throughout, with incipient cross-beds, and consists of moderately well-sorted silty sand (69% sand, 30% silt and 1% clay). It represents sandloess of facies C type, its coarseness being explained by depletion of fines by running water. An additional explanation for its coarseness may be proximity to the ice front.

NORNOUR (SV944148) HCMK/JRAG

Nornour, Ganilly, Great and Little Innisvouls form the north-east margin of the group of small islands known as the Eastern Isles. A settlement occupied in prehistoric and Roman times has been excavated on Nornour (Dudley, 1968; Butcher, 1970, 1971, 1972, 1974). In 1972 the slope of the island behind the settlement was investigated in a series of trenches. The samples discussed here were taken from the highest trench which was about 6 m south of the crest of the island and 30 m north of House 6.

All these trenches showed the same general stratification; a deposit of blown sand lying over a thin soil covering granite rocks. There were no artifacts or other signs of human activity. The sand covers the whole of the south side of Nornour including the ancient settlement, and the soil seems to correspond to the ground surface on which the buildings stand. However, since it would have been open during the occupation of the site this gives a very wide chronological range. The earliest radiocarbon dates are before 1,000 B.C. and occupation continued until the fourth century A.D. There is no evidence as to how long the surface remained open after the settlement was finally abandoned but it seems reasonable to suggest that the sand began to accumulate soon afterwards.

On Nornour soil parent material appeared to consist of locally derived head deposits of gravelly loam with variable stone content, overlying granite rock, similar to that found on the granites in Cornwall (Clayden, 1964). The soil buried beneath the regosol derived from blown sand on the south side of Nornour was a ranker with a shallow A/C profile approximately 30 cm in depth, and it appeared to be similar to the soil associated with the ancient settlement. The site was on a slope of 10° and freely drained. The vegetation was predominantly *Pteridium aquilinum* (bracken) and earthworms were absent from the profile.

0-22 cm (the F horizon): A dark brown (10YR3/2) fibrous organic layer containing bulbs of Endymion non-scriptus, bracken roots and undecomposed and decomposing plant debris. Sand grains were present.

22-32 cm: Grey (10YR6/2) structureless sand containing roots and small particles of amorphous organic matter, probably washed down from the F horizon.

32-42 cm: Structureless sand, stained dark grey to black by eluviated organic matter (10YR3/1) containing bracken roots. There may have been some consolidation of the blown sand at this stage of development.

42-62 cm: A light coloured (10YR6/3) wind-blown sand; structureless and containing bracken roots.

62-86 cm: The buried A horizon of the original soil on which the sand was deposited. This layer consisted of a black (7.5YR2.5/0) silty sand, with weak crumb structure, containing amorphous organic matter and few roots and was more compact than the layers above.

86-91 cm: (bC horizon) was dark brown (7.5YR3/2) rotted (weathering) granite, containing granite fragments, with coarse loamy sand texture and weak crumb structure. Roots were absent and the organic matter content was much less than in the layer above.

91 cm: Granite boulders occurred below 91 cm.

The upper part of the profile where the soil was light and sandy was sampled for pollen every 5 cms, but below 62 cm where it was darker and more organic the sampling interval was reduced to 2.5 cm. The samples consisted mainly of sand, and the organic matter was extracted by standard treatment.

There was abundant pollen in most of the samples, but counting was made difficult by the fact that it was usually very shrunken and crumpled and the abundance of thick-walled pollen grains in some samples suggests differential preservation. Counts of 200-500 pollen grains were made and although absolute counting was not done, an estimate of pollen abundance was made, recorded in the right hand columns of the pollen diagrams. The pollen diagrams (Fig. 53) has been drawn up on the basis of percentages of total pollen (tree pollen - herbaceous pollen), and it has been somewhat simplified by the exclusion of some sporadic pollen records.

The pollen diagram (Fig. 53) can be divided into three sections on the basis of pollen frequencies as follows:-

10-30 cm: Characterized by high Gramineae, Ericales, Armeria, more Compositae-Tubuliflorae than Liguliflorae. Moderate pollen content.

35-60 cm: High Compositae-Liguliflorae, Caryophyllaceae, Umbelliferae, Cyperaceae. Low Gramineae, Ericales, Armeria, tree pollen. Low pollen content.

62.5-87.5cm: High Plantago, Gramineae, moderate Ericales, Cerealia, tree pollen, Armeria present. Low Compositae and both types nearly equal, practically no Umbelliferae or Cyperaceae. Very high pollen content.

The top section of the pollen diagram (10-30 cm) is dominated by herb pollen, mainly that of grasses, plantains and heather and the topmost sample contains significant numbers of bracken spores. This part of the diagram represents to some extent the pollen rain from the present day vegetation growing in the vicinity. The tree and shrub pollen record is much smaller than that from the herbs but Alnus, Betula, Carpinus, Corylus and Quercus are represented, although the topmost sample has only a single grain of hazel pollen. It is not easy to see the parallels between this part of the pollen diagram and the regional flora because Scilly is today virtually treeless. Alder and oak grow in a few places, but birch, hazel and hornbeam do not (Lousley, 1971) and Nornour itself is treeless.

There are several possibilities which might explain the occurrence of these three apparently exotic tree pollen types in this part of the profile. The first is that the sand just below the present ground surface may have been deposited some time ago with, perhaps, little build-up since and the signs of woodland represent something that existed previously. An alternative is that the soil profile may have been truncated at some time by wind erosion, thus exposing older deposits on which the present ground surface formed. Another factor is the deposition of sand eroded from elsewhere which could result in the mixing of some older deposits with younger ones, for blown sand seems to be an important factor in Scillonian soil formation.

The next pollen assemblage (35-60 cm) would appear to represent a somewhat different vegetational type from that above it but the pollen was generally poorly preserved. Some of the changes, like the superabundance of Compositae pollen, could be due to differential preservation and thinner walled pollen grains may have become corroded beyond recognition. Without the additional information from absolute counts it is difficult to be sure whether the abundance of Compositae pollen is mainly due to preservation factors. Even so, there are discernible changes such as the smaller amounts of pollen from Armeria and Ericales which are robust pollen grains too unlikely to be affected by preservation factors. This pollen assemblage would appear to correspond with the phase of consolidation of blown sand, and the low pollen values could well correspond with this observation with an unstable dune surface supporting less of the heather and thrift.

The next pollen assemblage (62.5-87.5 cm) corresponds with the buried soil surface and has the highest pollen values. The most abundant pollen type is Plantago which with the large amount of Gramineae pollen would suggest a kind of maritime sward vegetation, maybe maintained by grazing pressure which would favour plants with basal rosettes like grasses and plantains at the expense of others not so adapted to tolerate grazing. There are occasional records of pollen considered to be that of Cerealia. It is rather a sporadic record, but the largest

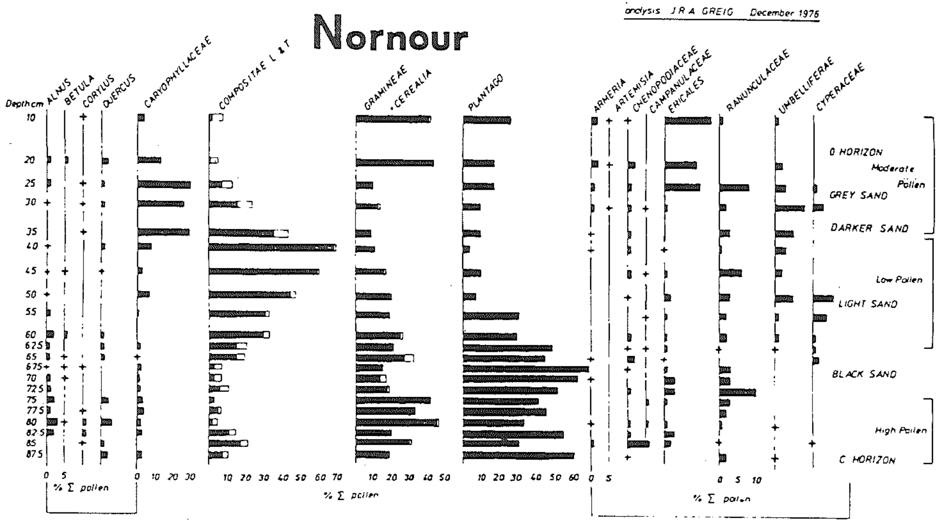


Figure 53: Nornour - pollen diagram (Dimbleby et al., 1981)

amounts occur in this lowest part of the pollen diagram and provide evidence of arable farming as well as the possible pasture land suggested by the plantain and grass pollen. The blackness of this soil may be due to the use of seaweed, spread on the fields to counteract the "hungry" quality of sand soil, but of course no direct traces of this could survive.

The tree pollen record is at its most consistent, with almost continuous occurrences of Alnus and Quercus, more scattered ones of Betula and Corylus and perhaps traces of Ulmus which amounts to evidence that there was at least some woodland within range of pollen dispersal at this stage.

This part of the pollen diagram may correspond with the occupation of the Nornour site, on stratigraphic grounds, although the dating for the latter is not very precise, 1,000 B.C.-400 A.D. It may be added that in 1966 Dimbleby (personal communication) examined the buried soil beneath the buildings for pollen but none was found.

Monday 8 September

Tresco and Samson

1.	Gimble Porth	SV890160-SV888164
2.	Battery	SV887165
3.	Tregarthen Hill	SV885165
4.	Castle Porth	SV882160
5.	Samson Flats	SV880130

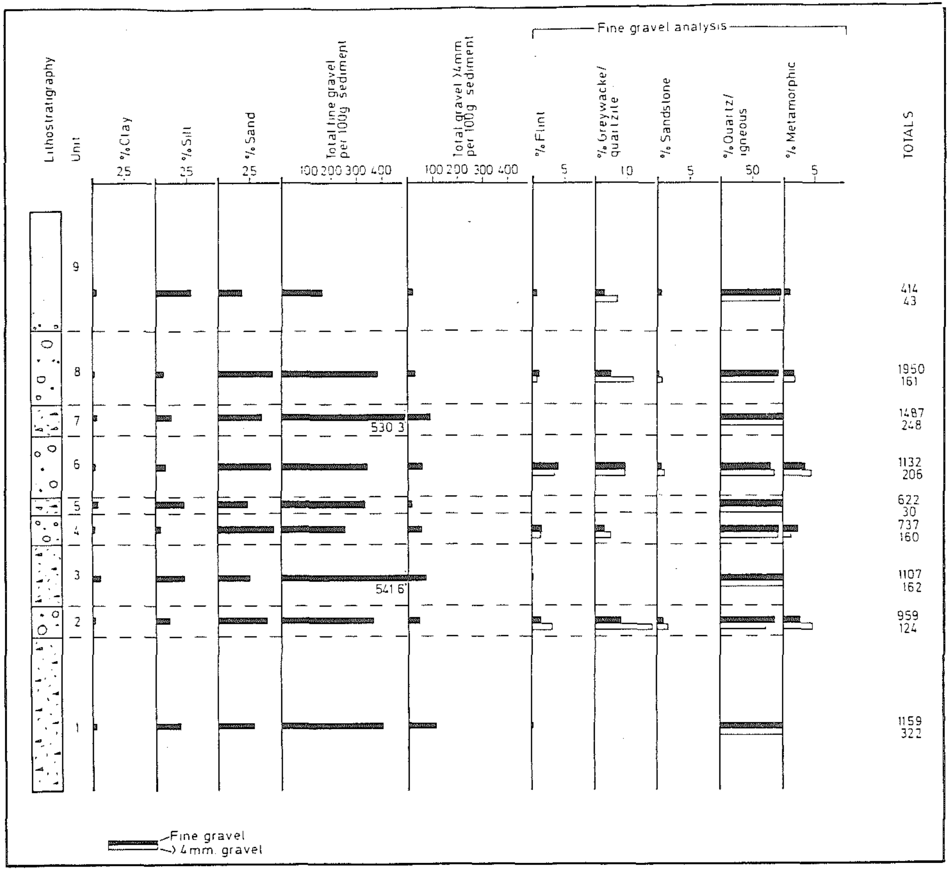


Figure 55. Battery - granulometric and clast lithological data

GIMBLE PORTH (SV890160) JDS

At the extreme southern end of Gimble Porth (SV890160) three units can be seen, the Old Man Sandloess separating the upper and lower units of the Porthloo Breccia. The Old Man Sandloess can be divided into facies as indicated in Figure 35 (see Porth Cressa above) based on structural and granulometric data.

At the northern end of Gimble Porth (SV888164), towards Castle Down Brow, the Old Man Sandloess (facies D) is replaced by the Hell Bay Gravel, underlain by the Porthloo Breccia and overlain by the Bread and Cheese Breccia, indicating that Gimble Porth lies astride the southern limit of the Hell Bay Gravel (Fig. 7).

The fine gravel and pebble content of the Hell Bay Gravel has been analysed (Fig. 39). In the fine gravel fraction it contains 4% flint, 21% greywacke/quartzites, 0.5% sandstones, 6% metamorphics and 69% local granitically derived material. This assemblage is reflected in the >4 mm. fraction. The material has a clast concentration of 85 granules and 23 pebbles per 100 g. sediment. This data, combined with the dominantly silty matrix, confirms the similarity of this material with the Hell Bay Gravel stratotype.

BATTERY (SV887165) JDS

This section can be found in the small cove just to the south of Piper's Hole on Tresco. At the extreme northern end of the section, where it is 5.8 m. thick, a complex of sandy gravels and breccias can be seen, overlain by the Hell Bay Gravel (Fig. 54). In all, ten units have been identified, units 1, 3, 5, and 7 representing coarse granite breccias, units 2, 4, 6 and 8 coarse sandy gravels. All contacts in the centre of the drawn section are erosional; the units and the contacts between them become more confused laterally in both directions. The coarse gravels, especially units 6 and 8, occur in channel fills with very coarse lag material at the base of the channels, and fine upwards. The breccia units form lobate rather than channelised bodies, most being continuous with the more massive solifluction on either side of the drawn section. However, breccia unit 7 has a lenticular form, entirely enclosed by the coarse gravels, units 6 and 8.

Units 1-8 have been analysed granulometrically and for fine gravel (Figs. 55 and 56). These results are presented stratigraphically in Figure 55. All the breccia units are extremely poorly sorted, and contain between 48% and 70% sand, 24% and 47% silt, and 6% and 8% clay. Unit 7 may be differentiated from the other breccia units in having a coarser mean grainsize and in being slightly better sorted. It also contains substantially more sand and less silt than the other breccia units.

The sandy gravel units contrast with the breccia units in being very much better sorted, containing between 87% and 91% sand, 8% and 21% silt, and 1% and 2% clay. Figure 55 reveals that these units are all very similar granulometrically. These units are also easily distinguished from the breccia units in terms of their rich erratic assemblage as revealed by the fine gravel and pebble counts. In the fine gravel fraction, the gravel units contain between 1% and 4% flint, 3% and 9% greywackes/quartzites, up to 1% sandstone, and between 1% and 4% metamorphics, the remainder being made up with granitically derived material. By contrast, only three erratic granules were found in all breccia units, a flint granule and a greywacke/quartzite granule in unit 3, and a flint granule in unit 1. The breccia units can also be differentiated in having a higher clast concentration, ranging between 333 and 542 granules per 100 g. sediment, compared with a range of 252 and 352 granules in the gravel units. Lithological and clast concentration data are confirmed in all cases by the >4 mm. fraction.

Units 1, 3, 5 and 7 are interpreted as solifluction deposits, made up largely of material derived from the breakdown of the local granite, while units 2, 4, 6 and 8 are interpreted as outwash gravel. The occasional erratic found within the breccia units is indicative of the ingestion of the underlying outwash material into the solifluction flows. The single flint granule in unit 1 is difficult to explain in that no outwash gravel units have been identified below it; perhaps a small as yet identified outwash channel exists within unit 1, or perhaps a small channel has been completely eroded out by the solifluction flow of unit 1.

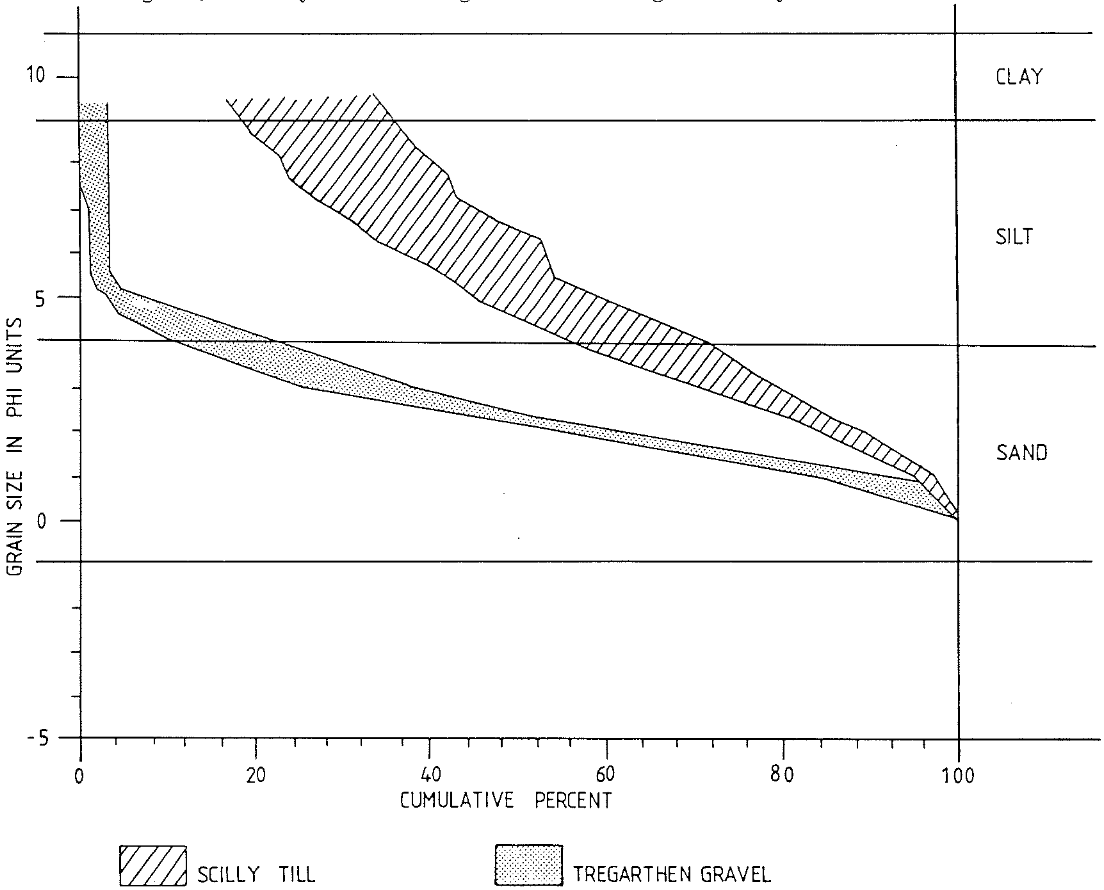
The outwash gravel interpretation is strengthened by the discovery in unit 6 of clasts of striated greywacke and Tertiary micrite. The latter clast has been identified as glauconitic micrite of a type commonly found in the Neogene (Miocene) strata of the Southern Irish Sea Basin (A. Morton, pers. comm., 1984).

The overall impression of the sequence is of massive solifluction occurring penecontemporaneously with pulses of fluvial outwash. The outwash palaeocurrent is estimated to have been in an easterly direction on the basis of the bed geometry, with solifluction occurring normal to this direction from both the north and south. Breccia bed 7, however, represents a body of solifluction moving parallel to the dominant outwash flow direction; its high sand content suggests the ingestion of the underlying outwash material. At the base of the sequence, the dominant process operating was clearly solifluction, but gradually the solifluction lobes became overwhelmed by the outwash channels. The sequence was then covered by the sandloess, which was then soliflucted along with the uppermost outwash material to produce unit 9.

Units 2, 4, 6 and 8 represent the composite stratotype for the Tregarthen Gravel, and units 1, 3, 5 and 7 represent the Bread and Cheese Breccia. The fine gravel assemblages of the Tregarthen Gravel and Scilly Till, along with the Hell Bay Gravel, are compared in Figure 39, and a granulometric comparison of the Tregarthen Gravel with the Scilly Till is made in Figure 56.

That unit 9 can be correlated with the Hell Bay Gravel is indicated in Figure 55. It is moderately well sorted, with

Figure 56. Scilly Till and Tregarthen Gravel - granulometry



a dominant mode in the coarse silt fraction, contains 57% silt, 37% sand and 6% clay, with a fine gravel and pebble assemblage consistent with the underlying Tregarthen Gravel, with 0.5% flint, 2% greywacke/quartzites, 0.5% sandstone, 1% metamorphic and 96% granitically derived material.

TREGARTHEN HILL (SV885165) JDS

Tregarthen Hill is covered by a remanié gravel identical with the gravel veneer on Chapel Down, St. Martin's.

CASTLE PORTH (SV882160) JDS

Castle Porth, like Gimble Porth, lies astride the southern limit of Hell Bay Gravel, but on the western side of Tresco. The Hell Bay Gravel can be clearly seen at the northern end of the section separating the Porthloo and Bread and Cheese Breccias, but the unit lenses out towards the south.

SAMSON FLATS (SV880130) JDS

Thomas interprets submerged structures here as field walls, but Mitchell interprets them as fish traps (Part I of Guide).

APPENDICES

APPENDIX 1: GLACIGENIC SEDIMENTS IN THE SOUTH-CENTRAL CELTIC SEA (JDS)

The 'till-like' sediments recovered during the Institute of Geological Sciences vibrocoring programme in the Celtic Sea and recorded by Pantin and Evans (1984) have been analysed in detail using a number of different techniques. Workers involved in this project have been Dr. J. D. Scourse (sedimentology, lithological analysis, general interpretation), Dr. J. A. Catt (mineralogy), Dr. J. E. Robinson (ostrocod and foram analysis), Dr. J. D. Peacock (molluscan analysis), Mr. J. Young (calcareous nannoplankton analysis of chalk erratics) and Dr. J. R. Hawkes (petrological analysis).

Site Locations

The coring sites recovering 'till-like' sediments are shown in Figure 9. The fourteen sites discussed below are situated between the submarine Haig Fras granite outcrop and the edge of the continental shelf which in this region lies at the relatively low level of -185 to -205m. OD (Pantin and Evans, 1984). The furthest north sample is 49/$\overline{09}$/43, on a latitude with, but 320 km. to the west of, the Scillies; the furthest south sample is 48/$\overline{09}$/137 on a latitude with, but 650 km. to the west of Ushant, Brittany; to the west, the furthest sample is 48/$\overline{10}$/53, on a longitude with, but 450 km. to the south of Bantry Bay, southern Ireland, and in the east the furthest sample is 49/$\overline{07}$/336 on a longitude with, but only 100 km. south of, the Scillies. The sites thus cover an area over twice the size of East Anglia.

The continental shelf in this area is reported to be almost featureless apart from the large linear tidal sand ridges and isolated boulders (Pantin and Evans, 1984) which are considered below. It dips gently towards the south-west, the dip becoming greater as the shelf edge is approached (Fig. 57). In general, therefore, the samples recovered from the deepest water were in the south-west, and *vice versa* in the north-east; the deepest sample, 48/$\overline{09}$/137, the furthest south sample, was cored at -211 m. OD, the shallowest, sample 49/$\overline{09}$/44, at -125 m. OD. Sample 48/$\overline{09}$/137 was therefore cored beyond the defined 'shelf edge break' (Fig. 57).

Stratigraphy

The 'till-like' sediments represent a member of the Melville Formation, a unit underlain by the Early Pleistocene upper Little Sole Formation, and overlain by a cover of recent sediments (Dr. C. Evans, pers. comm., 1984; Fig 57). In no instances have the cores penetrated through the identified glacigenic

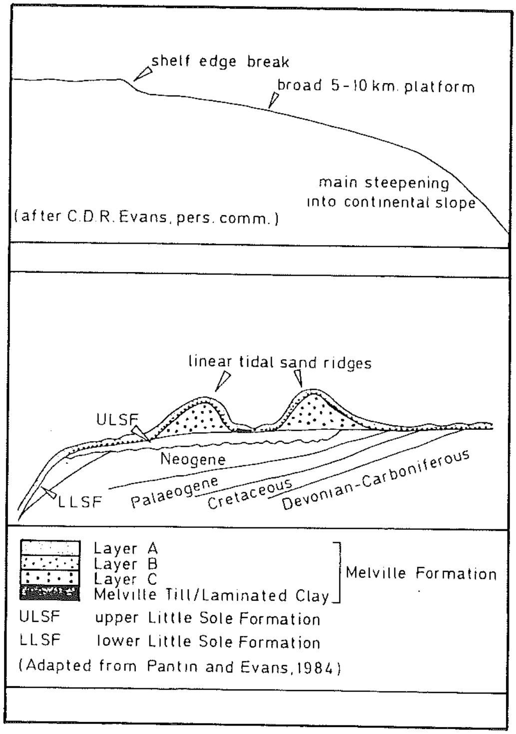


Figure 57. South-central Celtic Sea - shelf edge morphology and geology

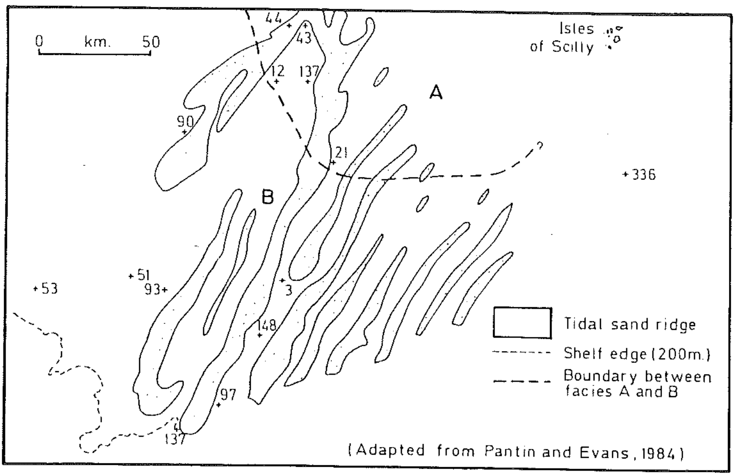


Figure 58. South-central Celtic Sea - distribution of linear tidal sand ridges

samples of the Melville Formation into an underlying unit of that or an older formation.

From the other borehole and seismic evidence on this region, Evans and Hughes (1984) have mapped the bedrock geology (Fig. 9). Working south-westward from the Scillies the outcropping units become progessively younger, firstly the Variscan rocks, followed by the upper chalk, a wedge of Palaeogene, early-mid Miocene (Jones Formation), two wedges of mid-upper Miocene (Little Sole Formation) strata. Though none of the glacigenic deposits was penetrated, Evans and Hughes' mapping indicates that the glacigenic samples were cored mostly overlying Neogene strata. Samples 48/10/53, 48/10/51, 48/10/93, 48/09/137, 48/09/148 and 48/09/3 all overlie the Early Pleistocene Little Sole Formation, sample 49/09/90 the mid-upper Miocene Cockburn Formation, samples 49/09/21, 49/09/12, 49/09/137, 49/09/44 and 49/09/43 the early-mid Miocene Jones Formation and sample 49/07/336 the Palaeogene.

Most of the glacigenic samples have been recovered from bathymetric 'lows' between the linear tidal sand ridges, whilst one sample, 49/09/44, was from a flank of a tidal sand ridge, overlying the sand forming the ridge (Fig. 58). The recent sediments overlying the glacigenic material have been classified into two layers, 'A' and 'B' (Pantin and Evans, 1984). Layer A consists of the superficial mobile sediments, layer B a relatively coarse pavement underlying layer A. Boulders up to lm. in diameter are widely scattered across the area; these have retrieved on the anchors of the drilling ships, are identifiable on the sidescan sonar and have been observed in submarine photographs (Hamilton et al., 1980). They probably represent the larger clasts attributable to layer B.

In all cases except one, the cores were not able to penetrate more than a few centimetres into the sediment. This is in itself a measure of the 'till-like' nature of the material. At site 49/09/44, however, a few decimetres of material was recovered.

Evidence from both sampling and acoustic devices suggests that the glacigenic sediments do not occur as a sheet, but form isolated patches or mounds, separated by the tidal sand ridges and exposures of non-glacigenic Melville Formation units.

Facies Classification and Distribution

The various characteristics and analysis of the samples described enable their classification into two facies, 'A' and 'B'. Samples 48/09/137, 48/10/53, 48/09/97, 48/10/57 and 49/07/336 cannot be ascribed to facies A or B with any certainty.

Facies A is represented by samples 49/09/43, 49/09/12, 49/09/21, 49/09/137 and the lower subunit of 49/09/44. The facies is overconsolidated, in the case of 49/09/44 verified geotechnically (Lambert and Khowaji, 1978), structurally homogeneous, contains abundant fine gravel, with between 8 and 54 granules per 100 g. sediment, and pebbles > 4mm. The matrix is very poorly sorted and consistently coarse skewed. Facies A samples are either devoid of ostracods and forams, or contain very few specimens at least some of which can be attributed to reworking. Two of the samples contain Hiatella sp. and three contain barnacle fragments; these are attributable to reworking. The clast assemblage is fairly consistent, with, in general, greywackes/quartzites > quartz/igneous > metamorphics > sandstones > flint > chalk.

Facies A is interpreted as either a basal till or a proximal glacio-marine sediment. Samples assignable to facies A were recovered from between -127 and -157 m. OD.

Facies B is represented by samples 48/09/148, 49/09/90, 48/10/93, 48/09/3 and the upper subunit of 49/09/44. Facies B samples are not overconsolidated but plastic silty clays, contain very small amounts of fine gravel, bewteen 0 and 6 granules per 100 g. sediment, and sometimes display well developed fining-upwards laminae and sand pods. These sand pods probably represent small frozen sand clasts. The matrices are moderately to moderately poorly sorted, and consistently very coarse skewed.

Facies B stands apart from A most distinctively in containing a rich ostracod and foram fauna. Samples 48/09/3, 48/09/148, 48/10/93 and 49/09/90 contain species which today are not found south of the Arctic Circle. Of the ostracods, Rabilimis mirabilis (Brady) occurs no nearer than the fjords of East Greenland (76° N.) or the inlets of the White Sea coast. Krithe glacialis (Brady, Crosskey and Robertson) is similarly distributed, while Cytheropteron monstrosiense Brady, Crosskey and Robertson, is not known alive anywhere today but appears to be Arctic by its association with other organisms.

Each of these Arctic species is represented by a wide range of valve sizes consisting a growth series of instars making up almost a complete life history; Rabilimis is represented by seven moults in sample 48/09/3. This indicates deposition under extremely quiet conditions with practically no current activity, otherwise the wide range of valve sizes would have been dispersed. The additional species of Cytheropteron, Acanthocythereis, Elofsonella, Heterocyprideis and Jonesia suggest affinities with the pre-Ipswichian open sea marine fauna of the Bridlington Crag of Holderness (Catt and Penny, 1966; Neale and Howe, 1974; Dr. J. E. Robinson, pers. comm., 1983).

Foraminifera support the low water temperatures suggested by the ostracods in the abundance of Islandiella islandica (Nørvang) and Islandiella norcrossi (Cushman), species which constitute the 'High Arctic' assemblage of Feyling-Hanssen (1982). Sample 49/09/90 contained five valves of the mollusc Yoldiella (Portlandia) fraterna (Verrill and Bush), also an Arctic indicator (Nordsieck, 1969; Dr. A. Waren, pers. comm., 1983).

Facies B sediments have been recovered from between -135 and -183 m. OD. They are interpreted as distal glacio-marine in origin, having formed very quiet conditions beneath icebergs or an ice shelf which provided a fairly continuous rain of sediment to the sea floor.

In general, the facies A samples are grouped in the north with a transition to more distal glaciomarine conditions at about 49° 30' N. between -127 and -145 m. OD. This transition is reflected in Figure 59 c-g with the facies B samples being characterised by high clay, high silt but low sand values, this also being reflected in the sorting coefficient and mean grainsize plots. These diagrams also reveal the basal till or proximal glacio-marine (facies A) affinities of some of the samples towards the continental shelf edge, especially 48/10/53 and 48/09/137. By analogy with glacio-marine sedimentation models developed for the George V - Adelie continental shelf in Antarctica these samples may represent residual glacio-marine sediments containing much reworked material typical of the continental shelf edge and slope (Domack, 1982). Sample 49/09/44, however, displays an up-core transition from facies A to facies B.

Environmental and Dating Interpretation

The complexities of the glacio-marine sedimentary environment (Drewrey and Cooper, 1981) militate against the over-precise interpretation of suites of interbedded glacial and glacio-marine sediments. This caution is increased in situations where there is little stratigraphic control; this is the case in the present study. There is no independent dating evidence that the separate samples considered above were deposited during the same event, though their geomorphological context would suggest that this is the case.

If the assumption is made that the material was deposited during one event, some very general glaciological conclusions can be drawn. Evidence from the lithological analysis of the clasts in facies A, the presence of Neogene lignite in some of the samples and the calcareous nannoplankton analysis of chalk erratics suggests that an ice body moved from the north-east towards the south-west across the area between the Haig Fras and Scilly Isles granite outcrops, eroding a variety of rock types including Turonian and Miocene sediments. At around 49° 30' N a change in depositional environment occurred, either a grounding line representing a transition from grounded to floating ice, or simply a change from proximal to more distal glacio-marine conditions. This transition occurred between the present-day water depths of -127 and -145m. OD. The evidence from sample 49/09/44 suggests that marine conditions gradually become more predominant, extending further to the north, perhaps causing the floatation and calving of the former grounded ice.

Both the biological (Dr. J. E. Robinson, pers. comm.) and lithological evidence of facies B suggests very quiet conditions during deposition, possibly indicating deposition beneath an ice shelf rather than ice-bergs (Vorren et al., 1983). However, such an hypothesis is difficult to reconcile with glaciological theory. If -135 m. OD is taken as the fossil grounding line, to float on ice shelf at least 200 m thick sea level must have stood at around + 30 m. OD assuming isostatic rebound of 0.33 x ice thickness and a 4:1 ratio of submergent to emergent ice. There is no evidence in the region as a whole for shorelines higher than OD post-dating the Ipswichian.

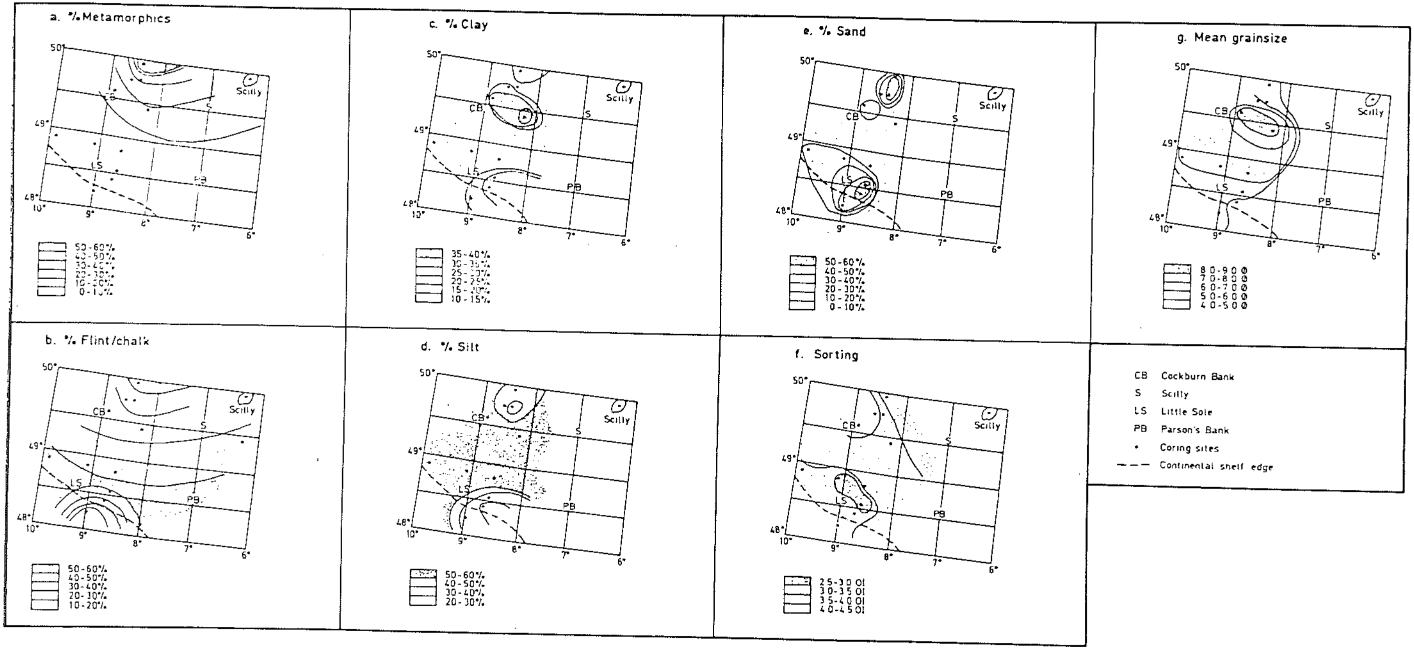


Figure 59. Distribution maps of selected parameters from the Melville Till and Melville Laminated Clay

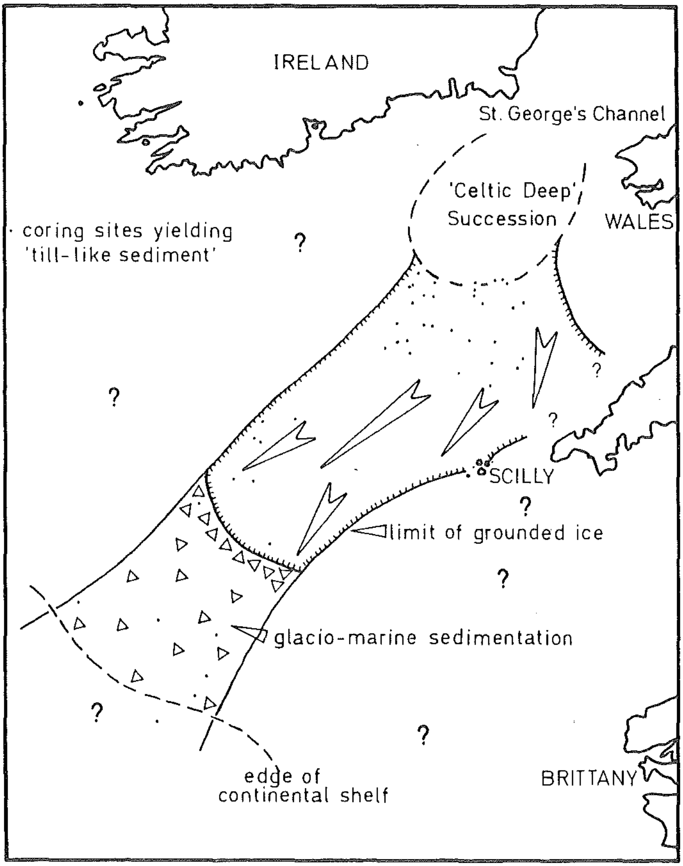


Figure 60. Glaciological reconstruction

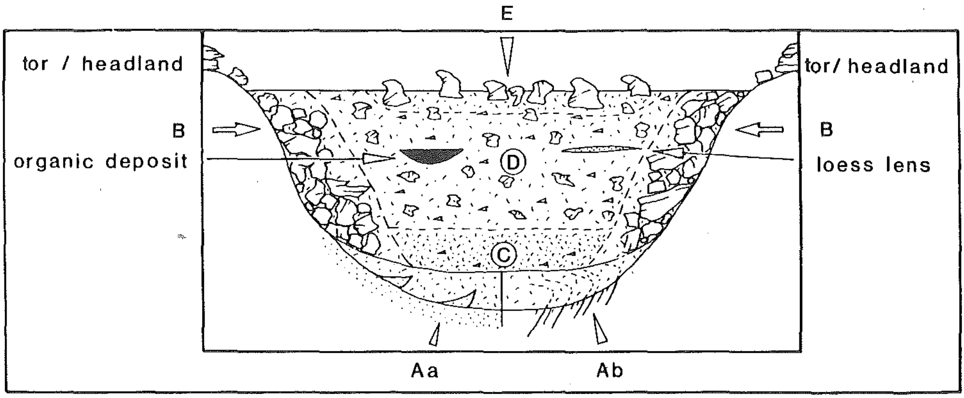


Figure 61. Porthloo Breccia - facies model

The most likely hypothesis for these sediments is therefore ice rafting. The conditions indicated by the ostracods perhaps suggest that basal melt-out from ice-bergs was more important than slumping or dumping. The ice-rafting hypothesis is favoured by Pantin and Evans (1984), who refer to the 'mounds' of sediment recorded by the side-scan sonar as indicating individual ice-berg 'dumps'. Some of these may be such features, but at least some of the remnant glacigenic samples suggest quieter conditions and therefore an originally more extensive cover prior to erosion.

The geomorphological context of the glacigenic samples cored in the 'lows' between the tidal sand ridges, and in one case on the side of a sand ridge, suggests that the glacigenic deposition took place after the main period of formation of the sand ridges. Pantin and Evans (1984) regard the sand ridges as having formed in around 60 m. of water by the Huthnance mechanism (Huthnance, 1982) during the Devensian-Flandrian transgression. Sand ridges of this size, up to 60 m. high and 50 km. long, could not have survived subaerial exposure (Dr. C. Evans, pers. comm., 1984). This would date the glacigenic material to the Late Devensian.

This dating implies the survival of the sand ridges during the succeeding glacial event. Figure 58 shows the distribution of the sand ridges; they stop fairly abruptly along a north-west/south-east line about 100 km. to the south-west of the Scillies in the vicinity of the facies A/B transition. This perhaps suggests that any sand ridges that may have existed to the north west of their present limit were eroded by the grounded ice sheet, ice-berg rafting taking place over, and on the flanks of, the sand ridges to the south-west.

Sample 49/$\overline{09}$/44 is crucial in this dating argument; there is no doubt that it is located on the side of a sand ridge. Not only is it the shallowest sample to be recovered, at -125 m. OD, but it was positioned using Pulse 8, Decca's most accurate navigation system. The existence of a sub-unit of facies A material at the base of the sample suggests that it may mark the grounded ice limit on the margin of the surviving sand ridges.

The altitudes of the various glacigenic units both onshore and offshore in the region can be reconciled with glaciological theory. Assuming an offshore grounding line around -135 m. OD and ice thickness around 100 m., global stadial sea level would have stood at -84 m. OD with a post-rebound shoreline at -50 m. OD.

Recent B.G.S. cores and seismic evidence from the continental shelf to the north of the Scilly and Cockburn Bank sheets supports the idea of an ice stream advancing from the north-east. Though samples of glacigenic sediment from this area have not yet been analysed in detail, the mapping of their occurrence (Fig. 60) strongly suggests a link with the ice advance further south. This inferred ice stream originates immediately to the south of St. George's Channel in an area recently defined as the 'Celtic Deep', "a Quaternary succession up to 250 m. thick which includes a number of till units" (Dr. C. Evans, pers. comm., 1984). The southern limit of the Celtic Deep succession is at around 51° 10' N (Dr. R. Wingfield, pers. comm., 1984).

	Scillies tills			Scillies loess			Mean of 3 till samples	Mean of 3 loess samples	Loess mean (3) re-calculated to include likely weatherables	Mean of 10 till samples, Scillies and sea floor	Mean of 9 till samples, Scillies and Lizard	Loess mean (9) re-calculated to include likely weatherables	$\bar{X}_1-\bar{X}_2$ / SED
	St. Martin's SV 923171	St. Martin's SV 940158	St. Martin's SV 920171	St. Mary's SV 918101	St. Mary's SV 907115	Samson SV 878125							
a) Light Fraction	1	2	3	4	5	6	7	8	9	10	11	12	13
Quartz %	64.5	63.7	60.9	87.3	81.4	78.3	63.0	83.1	69.9	60.2	83.1	65.2	2.72
Felspar %	13.7	13.8	12.2	7.4	14.1	14.0	13.2	11.9	10.0	11.8	12.9	10.1	1.55
Calcite %	0.1	–	0.5	–	–	–	0.2	–	*0.2*	11.3	–	*11.3*	–
Muscovite %	9.5	11.5	13.2	2.0	2.1	4.4	11.4	2.8	*11.4*	7.9	2.3	*7.9*	–
Glauconite %	7.9	6.2	9.2	1.1	1.6	1.4	7.8	1.4	*7.8*	4.9	0.9	*4.9*	–
Flint %	4.3	4.8	4.0	0.6	0.5	1.1	4.4	0.8	0.7	3.9	0.8	0.6	3.95
b) Heavy Fraction													
Epidote %	32.7	20.1	18.2	29.8	31.5	34.0	23.7	31.8	23.6	23.9	36.1	25.0	0.43
Zoisite %	2.0	1.1	1.0	2.9	2.0	2.8	1.4	2.6	1.9	1.5	2.6	1.8	1.09
Zircon %	10.3	14.5	10.2	16.1	4.7	8.2	11.7	9.7	7.3	9.5	13.7	9.5	0.00
Tourmaline %	5.8	3.7	4.8	5.0	2.1	4.2	4.8	3.7	2.8	3.7	5.0	3.5	0.26
Chlorite %	17.9	42.6	47.0	8.7	26.7	20.0	35.8	18.5	*35.8*	27.7	11.7	*27.7*	–
Biotite %	3.1	1.5	2.4	0.6	1.8	1.4	2.3	1.3	*2.3*	1.4	0.6	*1.4*	–
Green hornblende %	6.3	5.9	4.4	14.4	17.1	17.6	5.5	16.4	12.2	8.7	12.7	8.8	0.06
Brown hornblende %	0.1	0.7	0.2	0.6	0.4	0.5	0.3	0.5	0.4	0.4	0.5	0.3	0.55
Tremolite/Actinolite %	5.1	1.6	2.8	1.4	1.7	2.9	3.2	2.0	1.5	3.3	4.6	3.2	0.11
Augite %	6.9	–	–	1.3	0.3	–	2.3	0.5	*2.3*	2.5	0.2	*2.5*	–
Garnet %	2.5	0.6	1.5	8.8	4.0	4.5	1.5	5.8	4.3	2.7	3.5	2.4	0.29
Yellow rutile %	2.5	5.1	3.3	5.6	4.0	2.7	3.6	4.1	3.0	3.0	4.0	2.8	0.33
Brown rutile %	0.6	–	–	1.9	0.8	0.5	0.2	1.2	0.9	0.5	1.3	0.9	1.84
Anatase %	2.2	2.2	1.7	1.8	0.8	0.5	2.0	1.1	0.8	1.8	1.6	1.1	1.55
Brookite %	0.4	–	0.4	0.1	0.1	–	0.3	0.1	0.1	0.2	0.1	0.1	1.72
Brown spinel %	–	–	0.4	–	–	–	0.1	–	–	0.2	0.6	0.4	0.72
Apatite %	0.1	–	–	–	–	–	0.1	–	*0.1*	1.2	–	*1.2*	–
Monazite %	–	–	–	–	0.1	–	–	0.1	0.1	0.1	–	–	0.94
Sphene %	1.0	0.4	1.3	–	–	–	0.9	–	–	0.9	0.1	0.1	5.26
Olivine %	0.1	–	–	–	–	–	0.1	–	*0.1*	0.3	–	*0.3*	–
Staurolite %	–	–	0.4	0.6	0.6	0.7	0.1	0.6	0.4	0.2	0.7	0.5	3.00
Kyanite %	0.4	–	–	0.4	–	0.2	0.1	0.2	0.1	0.1	0.3	0.2	1.36
Collophane %	–	–	–	–	–	–	–	–	–	0.5	–	*0.5*	–
Siderite %	–	–	–	–	–	–	–	–	–	5.2	–	*5.2*	–
Dolomite %	–	–	–	–	–	–	–	–	–	0.5	–	*0.5*	–

Table 3. Silt mineralogy of loess and 'till' on the Isles of Scilly

APPENDIX 2: SILT MINERALOGY OF LOESS AND 'TILL' ON THE ISLES OF SCILLY (JAC)

Catt and Staines (1982) drew attention to thin loess deposits on the Scillies, and gave the mineralogical composition of coarse silt (16-63 μm) fractions separated from three samples (2 from St. Mary's, 1 from Samson). Wintle (1981) obtained thermoluminescence dates of 18.6 x 10^3 yr for samples from St. Mary's and St. Agnes, and on St. Mary's, St. Martin's and St. Agnes the loess overlies head with interbedded organic horizons which have given ^{14}C dates in the range 20,000-35,000 yr B.P. The loess is therefore Late Devensian in age, and equivalent to the extensive thin loess deposits in Cornwall (Catt and Staines, 1982), Devon (Harrod et al., 1973), and other parts of southern and eastern England. The loess of eastern England is mineralogically similar to the coarse silt from tills which Madgett and Catt (1978) correlated with the Late Devensian Skipsea Till of Holderness (Catt et al., 1971 , 1974), and was therefore probably derived from the outwash of the Late Devensian ice sheet in the North Sea basin. The loess of theScillies and western Cornwall is slightly different in mineralogical composition, and Catt and Staines (1982) suggested that it was derived from Late Devensian outwash in the Irish Sea basin, though they offered no mineralogical comparisons with glacial deposits in that region.

Samples of glacial sediment from the northern Scillies (St. Martin's) and from the seafloor southwest of the Isles, which have recently become available through the work of Dr. J. Scourse and the British Geological Survey, now allow a mineralogical comparison with the loess to be made.

Table 3 shows the composition of coarse silt from three samples of 'till' from St. Martin's (columns 1 - 3) and the three of loess from St. Mary's and Samson (columns 4-6). Means for these 'till' and loess samples are given in columns 7 and 8. As in eastern England, a major reason for differences between the two means is the partial or complete loss of weatherable minerals from the loess, such as calcite, muscovite, glauconite, chlorite, biotite, augite, apatite and olivine. This is because the loess has remained at the surface since it was deposited, but the till was buried soon after deposition and its silt fraction has not been so strongly modified. To facilitate comparison between the original (unweathered) Scillies loess and the Scillies 'till', the mean for the loess samples was recalculated (column 9) after restoring the amounts of weatherable minerals to their levels in the 'till' (figures in italics). The choice of weatherable minerals was based upon studies of Holocene mineral weathering in English coversands (Bateman and Catt, 1985). Comparison of columns 7 and 9 shows that the loess could indeed have been similar to the 'till'. Both contain the same suite of non-weatherable minerals in approximately similar proportions; the small differences in amounts of some of these materials (quartz, felspar, flint, zircon, tourmaline, green hornblende, tremolite/actinolite, garnet, yellow rutile, brown rutile, anatase and staurolite) can probably be explained by the lateral variation in composition often seen in glacial deposits and the fact that the Scillies loess was probably derived from glacial outwash some distance from the islands. Also, too few samples were analysed to evaluate the natural variation in either deposit.

To evaluate more clearly the variation within both deposits, additional samples from outside the Scilly Isles were also examined. Columns 10 and 11 of Table 3 give the mean composition of coarse silt fractions for 10 'till' samples and 9 loess samples respectively. These include the 3 samples of each from the Scillies discussed above; additional 'till' samples were from the sea floor up to 250 km southwest of the islands, and additional loesses were from Cornwall (Catt and Staines, 1982). In column 12 a correction has been made for the possible loss of weatherable minerals (calcite, muscovite, glauconite, chlorite, biotite, augite, apatite, olivine, collophane, siderite and dolomite), again shown in italics. The differences between this recalculated mean and the mean composition of the 10 'till' samples (column 10) are less for all minerals, except epidote and kyanite, than the differences between the equivalent means for 3 loess and 3 'till' samples (columns 7 and 9). In fact only 4 out of the 20 non-weatherable minerals remain significantly different (i.e. difference between the two means is more than twice the standard error of the difference); these are quartz, flint, sphene and staurolite (Table 3, column 13), the last two occuring sporadically and in very small amounts. The value for x^2 for all nonweatherable minerals in columns 10 and 12 is 26.57, which with 19 degrees of freedom indicates only 11% probability that the two are the same; however, if flint is omitted the probability of similarity increases to 97%, and if quartz, sphene and staurolite are also omitted it is >99.8%. This indicates that before weathering there was a very strong resemblance in almost all minerals between the coarse silt fraction of the same size fraction of Devensian loess in the Scillies and west Cornwall; this similarity suggests that the loess was probably derived from the glacial sediment when it was exposed and unconsolidated on the seafloor, so the two were deposited at approximately the same time.

The three weatherable minerals (collophane, siderite and dolomite) present in the 'till' on the sea floor but absent from the 'till' on St. Martin's suggest either that the latter is slightly weathered, or that the original glacial sediment was locally deficient in these minerals. The second of these explanations is preferred, because the till on St. Martin's shows no other features of strong weathering, and the three minerals are also absent from one of the sea floor samples which cannot have been weathered subaerially. This was from a site approximately 60 km south of the Scillies. The remaining sea floor samples (containing collophane, siderite and dolomite) were from longitudes at least 120 km west of the Scillies. So, as the ice movement across the sea floor was probably north-south, the ice stream carrying these three minerals seems to have passed some distance to the west of the Scillies, and the ice that reached the Scillies did not carry them. It is hoped that additional sea floor samples will soon become available, to help clarify lateral variation in the composition of the glacial sediments and their similarity to the well-dated Devensian loess.

APPENDIX 3: SEDIMENTOLOGY OF SOLIFLUCTION DEPOSITS IN THE ISLES OF SCILLY (JDS)

Terminology

As also adopted by other workers (Henry, 1984), the term 'breccia' is used here in preference to 'head' as the former is specifically non-genetic. Since the term head was first introduced by de la Beche in 1839 it has become genetic through usage. Some 'heads' as described may not be the product of solifluction over permafrost, or indeed of mass movements in general. 'Solifluction' as a term used in isolation refers to mass movement phenomena usually, but not necessarily, associated with permafrost. 'Solifluction breccia' is therefore used to denote coarse angular accumulations formed by mass movements, probably, but not by definition, over permafrost.

Facies Model - Granitic breccia

Examination of many sections of granitic solifluction breccia has enabled the definition of five facies, one of which can be subdivided into two subfacies. These have been incorporated into a model (Fig. 61) which illustrates the stratigraphic and sequential relationships between the facies (Scourse, in press).

Facies A as a whole may be termed 'deformation' breccia by analogy with deformation till (Dreimanis, 1976). It is subdivided into two subfacies, Aa and Ab, and always occurs at the base of the soliflual body. Subfacies Aa occurs at sites where the mass movement sheet/lobe has overridden unconsolidated, usually Pleistocene raised beach sediments (Watermill and Godrevy Sands and Gravel members, Fig. 14), and Ab where the unit rests on solid bedrock. Subfacies Aa represents the entrainment of basal material into the downslope flow. Structurally this entrainment takes the form of flames or tongues when seen in three dimensional view (Fig. 63) and can eventually lead to the formation of plications. Bryan (1946) noted that the downslope movement itself can produce deformation or drag structures owing to differential lateral movements, and Jahn (1956) has illustrated stages in the development of such forms, the final stage being characterised by roll-like or cylindrical forms. Such structures, when only seen in two-dimensional view, can lead to stratigraphic and palaeoenvironmental misinterpretations. Where the entrained sediments are dominantly beach sands they may be distinguished from <u>in situ</u> material by silt/clay ingestion, slump and flow structures, and where rounded pebbles and cobbles, by being matrix supported and with distinctive dip in the flow direction (see Facies D below). Subfacies Aa is extremely common.

Subfacies Ab represents the frost-heave of the bedrock,

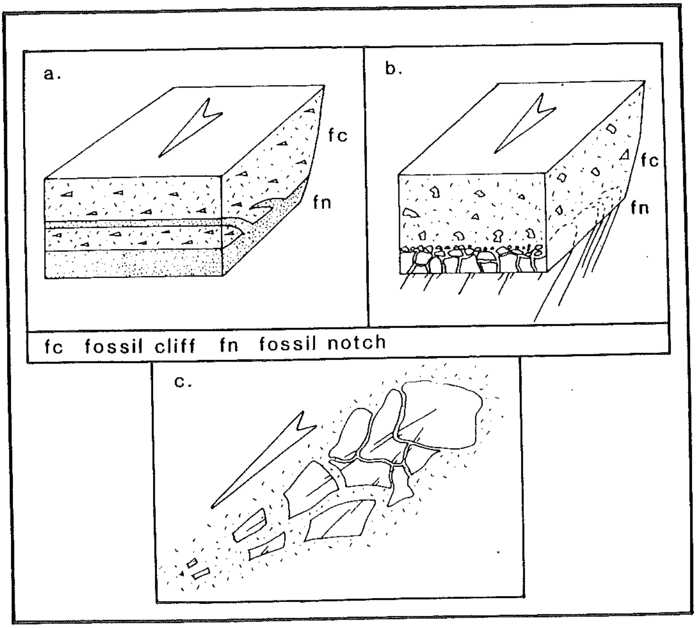


Figure 62. a - Deformation breccia facies Aa, b - Deformation breccia facies Ab, c - Clast-trail structure

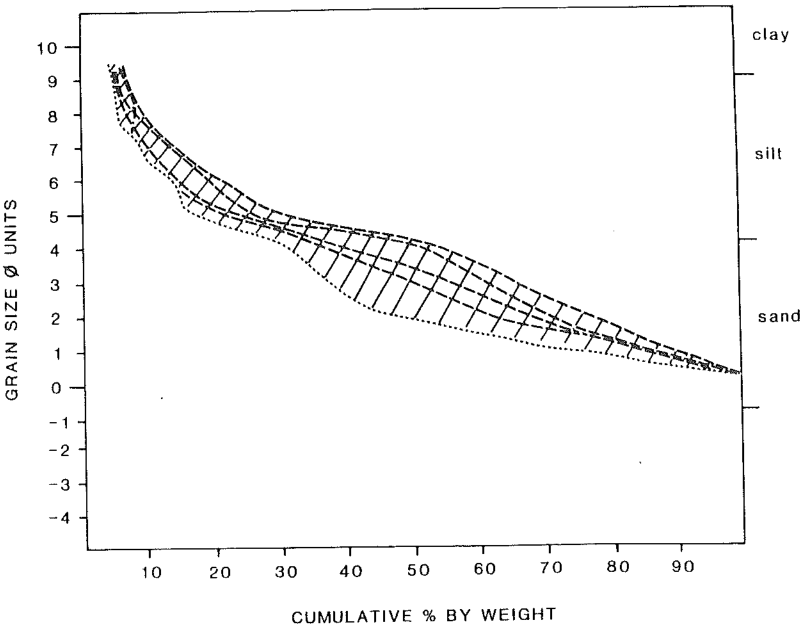


Figure 63. Porthloo Breccia facies D - granulometry

the production of discrete clasts, often related to bedrock discontinuities, and their entrainment downslope into the solifluction flow proper (Fig. 63). Similar structures are reported by Waters (1971) who interprets them as formed by a two-stage process of slopewash over a former land surface followed by subsequent solifluction. An alternative explanation of contemporaneous frost-heave and solifluction is preferred. The resultant deformation of weathered bedrock, involving the downslope deflection of inclined strata has been reported underlying solifluction deposits throughout South West England (Mottershead, 1971; Green and Eden, 1973; Cresswell, 1983) and elsewhere (Penck, 1953; Fitzpatrick, 1963; Jahn, 1969; J. Hutchinson, pers. comm. 1985) Cresswell believes the deformation structures to be the result of high pore fluid pressures associated with confined aquifers in the active layer.

Subfacies Aa and Ab are most commonly observed close to the fossil cliff line (Fig. 63). Away from the fossil cliff line in thick sequences the basal facies is most commonly C.

Close to bedrock headlands, facies B predominates (Fig. 61). This consists of extremely large clasts with 'a' axes in excess of 10m and estimated to weigh over 10^2 tonnes. These boulders are usually clast supported whilst the matrix is extremely poorly sorted and structurally chaotic. The facies represents the frost-heave of enormous blocks from hillslope tors and other exposed bedrock, only transported small distances away from their source by solifluction. Facies B sometimes contains practically no matrix and resembles rockfall deposits; with more matrix it approximates to blockfield or felsenmeer deposits (French, 1976).

Facies C is usually crudely stratified, matrix-supported with only occasional clasts, the matrix being dominated by granules. It represents an early stage of solifluction with the removal of fine material from the upslope land surface, including soil and weathered bedrock. Such fine, crudely stratified horizons have been reported from South Wales, where associated reddening is thought to represent the solifluction of rubified soil (Bowen, 1971). In many places facies C appears to have been either partially or totally removed by and incorporated into the overlying facies, D.

Facies D represents the most commonly observed variant of granitic breccia. It commonly overlies facies A, B or C in section (Fig. 61), and consists of matrix supported angular clasts set in an extremely poorly sorted silty sand with small amounts of clay; the matrix is commonly coarse-skewed (Fig. 63). Lobate structures in section are common, with stone accumulations marking lobe margins. Facies D is characterised by a classic solifluction fabric (Washburn, 1973; French, 1976). The clasts display a distinctive downslope preferred orientation and dip into the slope. Such typical angles of dip of between 5° and 45° from the horizontal can be explained in terms of penecontemporaneous upfreezing and the mass movement of material under gravity processes in the seasonally thawed layer (French, 1976).

Contemporaneous frost-heave and mass movement explains what can be described as 'clast-trail' structures common in facies D (Fig. 62). Large clasts have been frost-heaved into a number of smaller clasts and then strung out to form a trail by subsequent solifluction. The smaller clasts can often be joined together to form the parent clast, so fresh are the products. Such clast-trail structures, like the fabric characteristics, can therefore be related to the seasonal cycle of frost-heave and mass movement.

Facies D contains occasional lenses of loessic material and organic sequences representing ponding associated with nalyedi (Brown, 1967) or soliflual processes. These have proved critical in dating the sequences.

Facies E forms the most consistant capping of the sections (Fig. 61). The upper parts of the Porthloo and Bread and Cheese Breccias most commonly consist of this material (Fig. 14). It consists of extremely large blocks of granite set in a granular matrix, with a distinctive lack of material in the pebble/cobble grade. Deposits of this sort have previously been described from South West England (Mitchell and Orme, 1967; Brown, 1977) and from elsewhere, such as the French Pyrenees (R.G. West, pers. comm. 1983).

Three hypothesis can be invoked to explain the occurrence of the large boulders in facies E:

i) mudflow transport,
ii) solifluction rafts, and
iii) ploughing blocks.

High energy mudflows can raft large boulders, as documented by Broscoe and Thompson (1972) in the St. Elias mountains, Alaska. Large boulders thought to have rafted on the surface of solifluction sheets and lobes have been invoked to explain the striking 'rock streams' of Wiltshire and Dorset (Williams, 1968; Small et al., 1970). However, large actively moving blocks and boulders lying on the surface of solifluction sheets and lobes have been extensively reported from contemporary periglacial environments where they have been described as 'ploughing blocks' (Tufnell, 1972) because they move faster than the soliflual body they rest on, and as a result produce an upslope depression and downslope mound. The essential difference between rafted and ploughing blocks is therefore the velocity of the boulder in relation to the movement of the underlying material.

Some of the facies E boulders overlie deformational structures in the underlying material thought to result from the loading of the sediment by the boulder. Such deformational relationships are probably indicative of rafting. Other boulders, however, exhibit erosional basal contacts suggestive of ploughing behaviour. It is therefore thought that at least some of the facies E boulders represent fossil ploughing blocks; such blocks have not been readily identified in fossil situations (an exception is Lyford et al., 1963).

The blocks are usually found only semi-buried at the top of the sections, rarely fully embedded within the soliflual sequence. This phenomenon also requires explanation and two hypotheses can be invoked:

i) upfreezing to the surface, and
ii) penecontemporaneous frost-heave of boulders during solifluction.

The well-documented tendency for large objects to upfreeze in the periglacial environment would tend to lift or push such large boulders to the surface (French, 1976). Though this hypothesis may explain the situation of some smaller boulders, the penecontempoaneous frost-heave and break-up of the boulders during solifluction is thought to be the most likely general explanation. The ploughing and rafted blocks can be seen to be intimately related to the clast-trail structures described above. During the very last phase of periglacial conditions large blocks of material would have been removed from summit and hillslope tors and other bedrock exposures, forming block and clitterfields on the surface of solifluction sheets and lobes. Individual blocks would constitute ploughing or rafted blocks moving in one of the four ways enumerated by Tufnell (1972). During cold periods these blocks would be subject to frost-heave, reduced in size and finally incorporated into the underlying solifluction proper. Ploughing and rafted blocks therefore represent a transitional stage between the breakdown of the solid bedrock and the formation of typical soliflual sediment i.e. facies D. The sudden climatic amelioration 10,000 years B.P. fossilised the blocks as they moved downslope on the land surface, where they have remained. Clast-trail structures accordingly represent partially destroyed ploughing and rafted blocks.

Sections where all the facies described above can be observed together are rare; the model is based on the frequency of repeating facies relationships at many sites. Where sequences of soliflucted material are most commonly developed, it will be clear that a broadly coarsening upwards sequence occurs i.e. facies C-D-E (Fig. 51). This characteristic has been observed within solifluction deposits elsewhere (Jessen and Milthers, 1928) and previously within South West England (Waters, 1964; Brunsden, 1968; Gregory, 1969). Waters (1964) attributes such coarsening upwards sequences to an inverted weathering stratigraphy i.e. first the solifluction of weathered bedrock mantle through finally to freshly fractured bedrock. Mottershead (1971) and Green and Eden (1973) both dispute the validity of this observation. Green and Eden undertook a quantitative study of the location of blocks >15 cm within soliflual material in sections on Dartmoor. They propose a less ordered pattern of solifluction, but with a general tendancy towards a fining upwards sequence. Large blocks, they argue, occur most commonly in the basal sediments. From their discussion, however, it is clear that their analyses concentrated largely on facies A type material, deformation breccia, which, as stated above, often contains a high concentration of freshly heaved blocks. Had they considered a wider variety of soliflual sediments it is suggested that a coarsening upwards sequence would have emerged from their analyses. The detailed explanations for the facies variations given above largely agree with the general model proposed by Waters (1964).

Solifluction and Permafrost

The specific sedimentological characteristic of these deposits and their geomorphological context leave no doubt that they are the result of mass movements. They can therefore be accurately described as 'solifluction' deposits. Whether they were deposited in association with permafrost, however, is less easy to answer.

'Solifluction' in the periglacial context has been defined as a mass movement phenomenon involving the interaction of the frost-creep and gelifluction processes (French, 1976). The existence of permafrost and an active layer are necessary prerequisites for gelifluction *sensu stricto*. The number of features observed within these sequences that require explanation in terms of penecontemporaneous frost-heave and/or the presence of ground ice along with mass movement suggests a truly gelifluval origin. This is supported by the fact that high pore fluid pressures are necessary to explain many of the described features. An origin in terms of cold climate mudflows without any necessity for regional permafrost cannot, however, be ruled out.

If of gelifluval origin, the thicknesses of sediment preserved would suggest the accretion of multiple lobes or sheets based on the recorded maximal thicknesses of around 1.5 m of contemporary periglacial active layers. As the sediments accumulated so the permafrost table would have migrated progessively upwards through the previously deposited material. Structures within the sediments in conjunction with the presence of buried organic layers support this hypothesis of incremental growth.

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