

QUATERNARY RESEARCH ASSOCIATION

**Field Handbook
West Cornwall Meeting
September 1980**

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**WEST CORNWALL
FIELD MEETING
18-21 September 1980**

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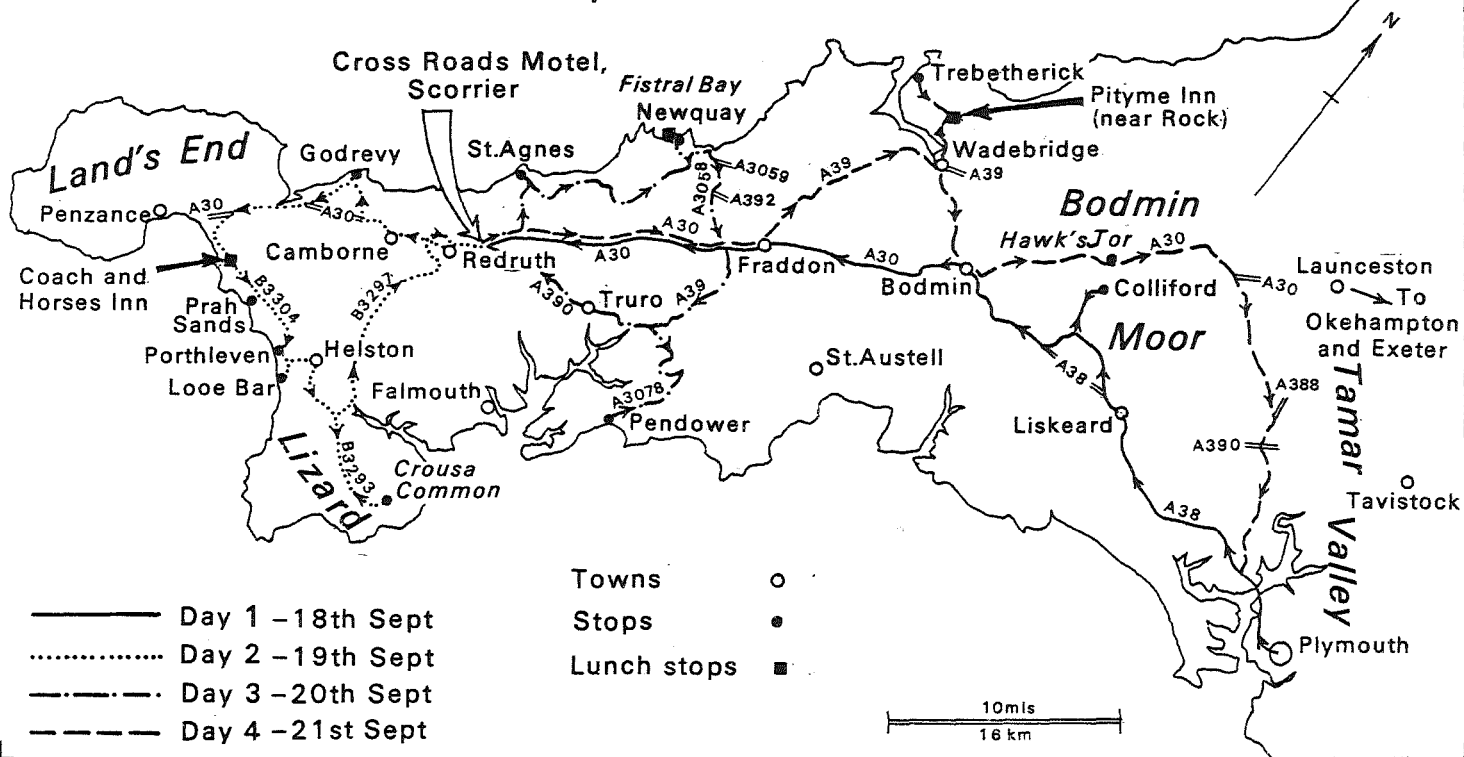
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Route Map



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INTRODUCTION

Geology and Physiography

Strongly folded, cleaved and recrystallised Devonian shales and sandstones occupy much of West Cornwall, while the granites which form the most prominent features of the relief are of late Carboniferous to Permian age. The folding of the sedimentary rocks along east and west lines and the intrusion of the granites is related to the Armorican (Hercynian) orogeny. The larger granite masses extending westwards from Dartmoor are Bodmin Moor (Day 1, Colliford site; and Day 4, Hawk's Tor site), St. Austell Moor (prominent China Clay workings), Carnmenellis and Land's End. The oldest rocks occur in the Lizard peninsula, where ancient igneous and metamorphic rocks of various kinds are exposed, and believed to be pre-Devonian and possibly even Pre-Cambrian.

There is evidence from gravity surveys to suggest that a continuous granite batholith extends from Dartmoor westwards to the Scilly Islands, where a zone of large negative gravity anomalies has been detected. The exposed granite masses may form cupolas above the batholith, which probably achieves a thickness of 6-12 miles, and were emplaced by intrusion with stoping. The general east-west Armorican trend of the major synclinalum of the country rocks (Devonian and Carboniferous) containing the granites is also reflected in the trend of dykes and important metalliferous lodes, except to the south of a line running west from St. Austell Bay. Here, in Devonian rocks, including the area known as Veryan, around Gramscatho and particularly to the south-west of St. Austell, the pattern of lodes is north-east to south-west, a trend followed by the general alignment of West Cornwall. The Meneage Crush Zone, which occupies a position between the Devonian Sedimentary Rock series to the north and the Older Lizard Igneous Complex to the south, contains rocks reduced to breccias. Flanking Veryan Bay (north-east of Gerrans Bay and the Pendower site of Day 3) are masses of gabbro and serpentine in a belt of crush breccia, and these have been linked by the arcuate Lizard-Dodman-Start Thrust to the Lizard Igneous and Metamorphic series and the Start Point Schists. The trend of the Thrust is east-west, until west of Plymouth it curves to take on a distinctive north-east to south-west alignment, approximately parallel to the patterns of the lodes and dykes, and the trend of the southern edge of the granite batholith.

The evolution of the major relief of the peninsula must begin with the 'blocking out' of a land mass separating the Celtic Sea to the north and the English Channel to the south. This is believed to post-date the emplacement of the granites and to have continued from Permo-Triassic times through the Mesozoic to the Cainozoic, (King, 1954; Hancock, 1975). However, the mid-Tertiary earth movements were of considerable importance in re-activating some of the Permo-Carboniferous structures, and imposing a set of north-north-west to south-south-east trending sinistral wrench faults upon the peninsula, as well as perhaps bringing about a north to south tilting of the peninsula. Such N.N.W. - S.S.E. faults have been described by Dearman (1963) and Shearman (1967), as contributing significantly to the evolution of major geomorphological features of the peninsula. It has probably brought about the N.N.W.-S.S.E. alignment of the western edge of Exmoor with the Bovey Tracey basin, and trend of the Petrockstow basin, and possibly the alignment of the troughs and ridges of east St. Austell Moor (Everard, 1977), as well as major displacement of the Lizard-Dodman-Start Igneous and Metamorphic complexes. Permo-Triassic, Jurassic and

Cretaceous strata are known in either or both the Celtic Sea and the English Channel areas, some with important terrestrial facies, and together with exposure of parts of the granite batholith point to considerable erosion of a former Cornubian land mass.

In West Cornwall a vast break in the geological succession exists between the Palaeozoic and Igneous basement rocks on the one hand, and the tiny patches of cover rocks of imprecise age, some of which, at Crousa Common and St. Agnes Beacon, we are to examine. There is no sign of Upper Cretaceous strata on land, although marginal facies of this age occurs west and north-west of the Isles of Scilly, and in the English Channel. According to Smith (1961a and b), the Dartmoor Granite was exposed and transgressed by the Cenomanian Sea, although the Chalk cover was probably thin, and there is no indication that the granite masses further west were affected.

The Early to Mid-Tertiary appears to be marked by alternating phases of sub-aerial erosion and marine transgression, but with much of the peninsula upstanding as a land mass, and in response to the Tertiary earth movements tilting has been invoked to explain the predominant trend of the major rivers, N.W. - S.E. Undoubtedly, a much larger area of 'peninsula' was involved in the evolution of the drainage pattern, which some would have as originating on a Chalk-covered surface, with the Mesozoic formations occupying the broad Palaeozoic flooded depressions between the upstanding granite masses, (Everard, 1977).

The importance of the age of the relic deposits remaining as unconformable outcrops in West Cornwall is at once evident. If some of these deposits, such as the St. Agnes sands and clays, are fluvial in origin and in situ, and as old as the Early Tertiary, then the river systems had probably shaped much of the area by that time. By the mid-Tertiary, the general macro-topography of West Cornwall may have been in existence and much, if not all, of the Mesozoic cover rocks removed. Deformation by any continuing earth movements would have revived structural control of valley development, which Everard (1977) has demonstrated so clearly.

The last stages of major landform modification may have resulted from the marine transgressions and regressions of the Early Pleistocene (Calabrian?) sea.

Erosion or Planation Surfaces

The reality of the existence of planation surfaces is at once evident in West Cornwall. A long recognised feature is the 130 m (400-430 ft) surface, which in the Camborne-Redruth area encircles three granite moorland areas, which themselves are believed to carry remnants of higher surfaces. These hill masses do not everywhere coincide with the more resistant rock outcrops. Other examples of the remnant surfaces occurring in areas to be visited are:

1. North and west of Camborne, where a series of flat-topped ridges have a height range of 90-93 m.
2. On Predannack Downs in the Lizard at 90-93 m.

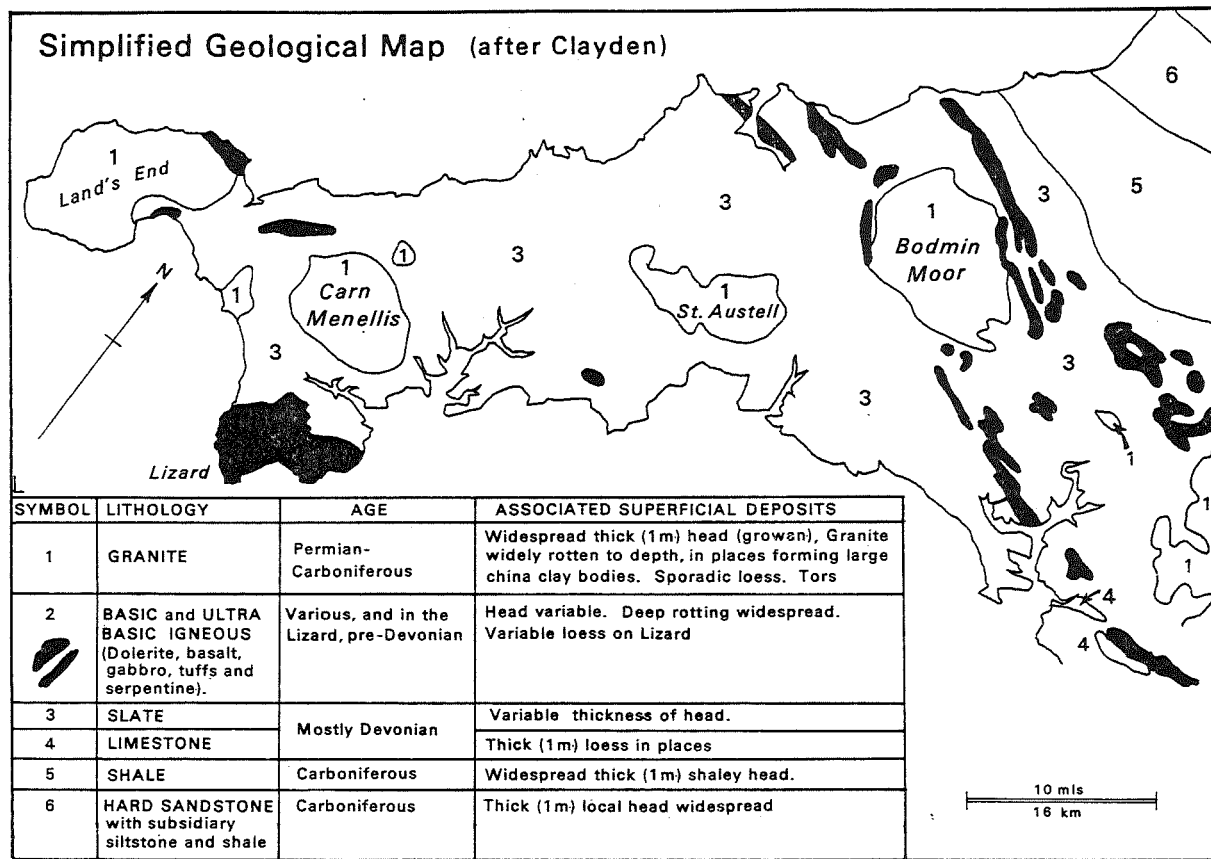


Fig. 1.

3. On Goonhilly Downs and at Crousa Common near St. Keverne at 112 m.

Tentative marine strandlines have been assigned to the most prominent platforms or groups of planated spurs, ridges and plateaux, and these appear to occur at 160 m, 150 m, 130 m, 106 m, 92 m and 82 m, (Goode, *et al*, 1976; Wilson, 1975). Such constructions and interpretation depend upon certain assumptions being made, more particularly that there has been no tectonic disturbance of the area, post-dating the cutting of the surfaces - a dubious proposition when we consider the evidence provided by Dearman (1967), Exley (1965) and Shearman (1967) for extensive vertical and wrench faulting to have occurred in the mid or late Tertiary. Furthermore, studies by King (1963) of so-called 'modern' abrasion rock platforms indicates that these achieve a maximum width of c. 1.2 km. Because the lower plateau relics in West Cornwall range from 4.6-12.9 km in width, for those with gradients of 1.1-7.1 metres/km, it has been suggested that such features could not be eroded under stable sea-level conditions. Thus, by implication 'other factors' may be introduced:- (a) a rising, transgressing sea-level for each particular platform; or (b) the involvement of other processes in combination with marine abrasion: freeze-thaw action and/or ice scouring has been invoked.

High level marine deposits

The relic marine deposits which are found resting upon certain of the platforms is deemed by some as powerful evidence for a marine origin for all these erosion surfaces, although this is probably another doubtful assumption. The deposits are found at heights ranging from 35-149 m O.D., are different in appearance from one another and occupy only five very small areas, (Reid, 1890; Milner, 1922; Boswell, 1923; Wooldridge, 1950; Edmonds, *et al*, 1975).

At St. Erth, near Hayle, the marine clays were interpreted as indicating a marine transgression to 125 m., given tectonic stability since deposition. However, investigations by Mitchell (1965) and Mitchell *et al*, 1973a) indicated that some 6 metres of marine clay, beach and dune sands are present, overlain by head deposits. The faunal content of the clay indicates a sea-level of about 45 m O.D. and the age of the deposits was suggested as Late Pliocene. There was no sign of glacial deposition of till or outwash gravels at the site, which is perhaps surprising when we consider the low altitude of the deposit and its relatively close proximity to the suggested southern limit of Wolstonian ice indicated in Figure 2. Nor is there any sign of the St. Erth deposits being re-submerged or re-worked by wave action, which may place an upper limit of any subsequent marine activity at below 30-40 m O.D., where the deposits are found.

At St. Agnes Beacon some 7 m of clay and sand (with basal pebbles) rests on what has been referred to as a water-worn rock surface, which extends from 107 to 128 m O.D. as an erosion surface cut across the St. Agnes granite and its metamorphic aureole. The site is to be visited and is described in detail by K. Atkinson on pages 23-26.

At Polcrebo, at about 150 m O.D. on the west side of the Carmmenellis upland, there is 2-3 m thick gravel deposit composed mainly of granite and quartz pebbles. The gravels are unfossiliferous, but although possessing

the general characteristics of marine shingle, no direct association can be proved. This is the highest of the relic gravel, sand and clay deposits.

On the St. Austell Moor, in an area known as Red Moor, well-rounded, ferruginous gravels have been recorded at 130 m below tin-bearing gravels in flat-floored alluvial basins, (Ussher *et al*, 1909). On Crousa Common at about 110-112 m O.D. mainly quartz gravels occur on a rather isolated plateau area composed of Lizard Gabbro. A site will be visited and a further description appears on page 21.

It can therefore be argued from the field evidence that marine planation may have occurred at several different levels during the Mid-Late Tertiary, at heights up to 160 m O.D. However, the relatively small outcrops of marine deposits remaining in West Cornwall are not always associated with a particular erosion surface, and Tertiary marine planation probably also incorporated residual fluvial deposits. It is possible that phased emergence of the land mass allowed a series of marine benches to be cut, but undoubtedly the St. Erth deposit still remains the best evidence of marine submergence to the 45 m O.D. level. This submergence has been correlated with the Coralline Crag marine phase, (Mitchell, 1973b).

It seems likely that much of West Cornwall owes its morphological features to long continued sub-aerial weathering and fluvial erosion, for the remaining relic deposits at St. Agnes, Polcrebo, and Crousa Common can best be explained as fluvial deposits. The limited marine submergence of an essentially fluvial landscape, together with some tectonic instability, may account for much of what we see today above 30 m O.D. In a series of excellent coastal sections below 30 m O.D. we can examine a suite of deposits of Pleistocene age. Raised beaches, submerged forest beds, sandrock (aeolianite), glacial and periglacial (head) deposits, and giant erratic blocks are all present, sometimes resting on well developed abrasion platforms. Great depths of sediments may mantle the coastal slopes, as well as forming a not inconsiderable mantle of largely periglacially derived regolith inland.

There have been many descriptions of these various deposits and many attempts to define their age, none with complete success. It is perhaps appropriate to outline some of the outstanding problems concerned with the Pleistocene history of the area.

Pleistocene problems in West Cornwall

1. Rock Platforms

The age of various wave-trimmed rock platforms which occur below 20-30 m O.D. has not yet been solved, nor the processes determined which may be involved in their development. Some appear to inter-cliff one another (e.g. at Fistral Bay and Pendower), and all are older than the suites of superficial deposits resting upon them. But little is understood of the exact mode of their erosion, nor of the speed at which platforms have been extended across rocks of diverse resistance and varied structure. These rock platforms undoubtedly have their counterparts in Devon, South Wales, Southern and Eastern Ireland, the Channel Isles, and on the Atlantic coast of France (Bowen, 1977; Keen, 1978; Kidson, 1977b; Mottershead, 1977a; Guilcher, 1969, 1976; Stephens, 1970), but their

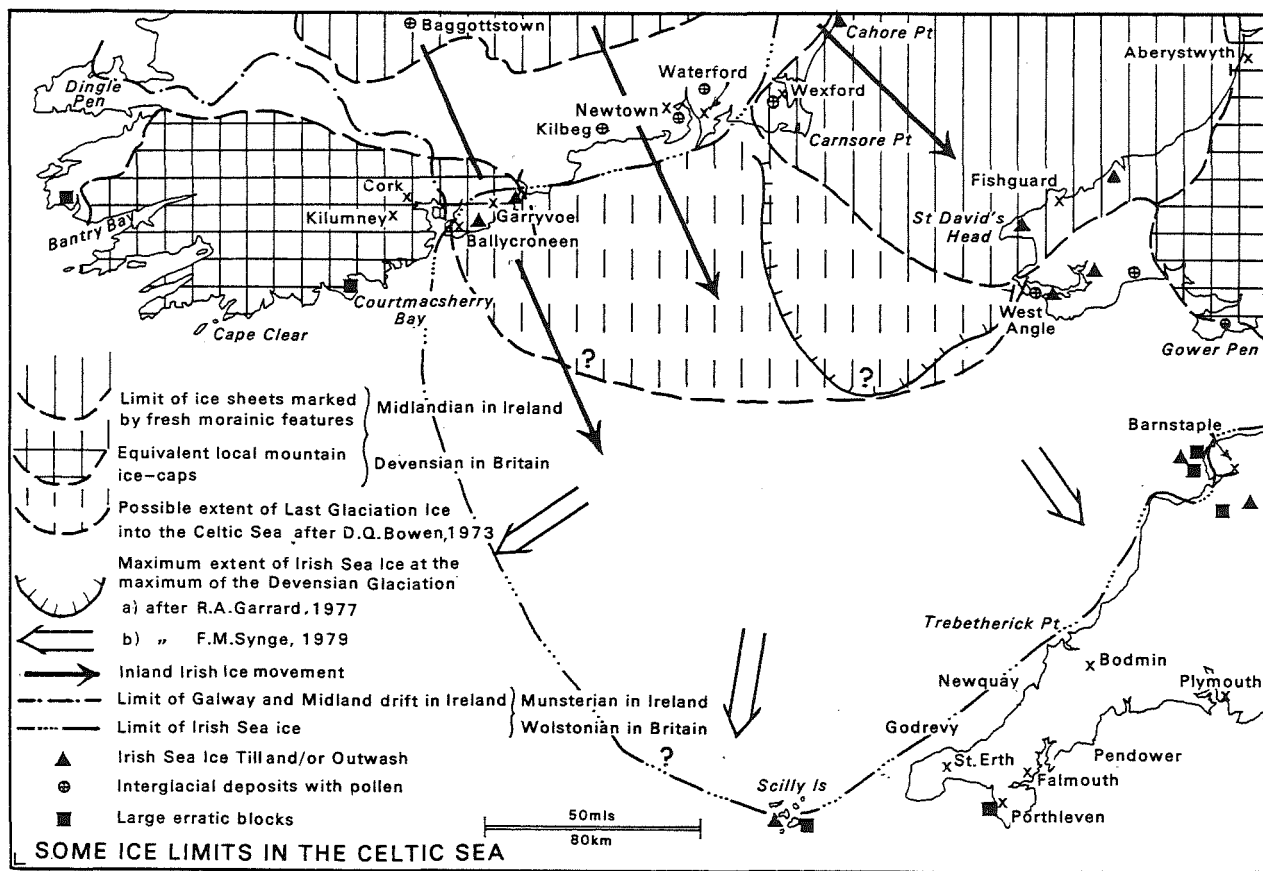


Fig. 2.

correlation still presents difficulties, and strictly altimetric comparisons are at best only tentative.

2. Glacial deposits

Several different types of superficial deposit rest directly upon these wave-trimmed rock platforms. Glacial till has been recorded in the Isles of Scilly (Mitchell and Orme, 1965), and possibly also at Trebetherick (Clarke, 1969). Erratic pebbles and boulders are widespread in the raised and modern beaches of Porthleven, as well as in Barnstaple Bay in North Devon, and as far east as Sussex on the English Channel coast. Tricart (1956) has noted that large erratic blocks also occur in Brittany. The age and manner of their emplacement remains the subject of controversy.

Any glacial till may be Wolstonian and related to the southern limit of Irish Sea ice against the north-facing coast of Devon and Cornwall (Fig. 2), or it may be Anglian till deposited by ice moving either southwards or eastwards according to Kellaway (1971) and Kellaway *et al* (1975).

Alternatively, it has been suggested by Synge (1977, 1979) that the last ice sheets in the Irish Sea, during the mid-late Devensian, may have extended much further south as shelf ice floating in a cold sea, and at a time of high interstadial sea level. He envisaged a floating ice shelf of this type filling most of the Celtic Sea between Ireland, Wales and Cornwall. This raises the interesting possibility that glacial deposits in the Isles of Scilly, at Trebetherick and at Fremington (N. Devon), may be much younger than formerly appreciated.

In West Cornwall, at the sites to be visited, we do not actually see glacial till resting upon an elevated abrasion platform or raised beach, as recorded by Mitchell and Orme (1965) in the Isles of Scilly and by Mitchell (1960), and Stephens (1970) at Fremington, near Barnstaple, although this interpretation has been rejected by Kidson (1977b). The presence of a true till remains to be confirmed at Trebetherick, and, if present, its stratigraphic position determined.

There is clearly controversy concerning the range of possible age(s) for ice advance to West Cornwall (Anglian, Wolstonian or Devensian?), and consequently the age of any underlying rock platform or suite of sediments must also be in some doubt.

3. Raised Beaches

There is a widespread distribution of fragments of raised beach in West Cornwall, with a range of attitude comparable to similar relic deposits recorded in various parts of Devon, South Wales and Southern Ireland (James, 1968, 1976). Temperate conditions are indicated by the included fauna in some raised beach sections, although shells are generally absent in West Cornwall. Correlations using faunal assemblages have proved as unsatisfactory as altitudinal comparisons, and it seems likely that we must await the refinement of the amino-acid or some other dating technique to achieve a more precise chronology, (Holyoak, 1980).

Several particular problems are posed by examination of the various raised beach sections. The incorporation of erratic pebbles and cobbles in profusion in some beaches and not in others, the relationship of the

beaches to the giant erratic blocks and the presence of considerable quantities of angular rock fragments and blocks, all require explanation. The relationship of the beaches to overlying sandrock (aeolianite) and head deposits requires further elucidation, and especially there is the problem of exactly how many raised beaches of different (interglacial?) age are present on these coasts. We have not yet solved the problem of the correct assignment of each raised beach deposit to a particular interglacial, nor indeed, of the correct sea level to be accorded to the last (Ipswichian) interglacial. The evidence has been reviewed a number of times by responsible authors in recent years, but there remain differences of opinion (John, 1968b; Bowen, 1977; Hollin, 1977; Kidson, 1977a; Mottershead, 1977b; Stephens, 1977; West, 1972). No doubt these differences will form the basis for some discussion during the field meeting.

4. Head deposits

Everywhere copious quantities of periglacially derived head deposits (de la Beche, 1839) overlie the raised beaches, the latter frequently containing suites of erratic pebbles. The stratigraphy of the head deposits varies considerably from site to site and it is by no means certain that the sediments as a whole can be regarded as belonging to the Devensian Cold Period, although this would be the interpretation of Bowen (1973) and Kidson (1977b).

Papers by Bowen (1977a), Kidson (1977b), Mottershead (1977a), Synge (1977, 1979) and Stephens (1974) illustrate some of the possibilities of interpretation of the Pleistocene sections in Wales, England and Southern Ireland around the Celtic Sea, but much remains unproven and there is clearly scope for much more research.

At many sites the head shows a series of depositional layers, often extending from 1-2 metres below the surface, and the character of the head varies considerably from site to site. Silty layers or lenses are sometimes found within the head, and in the Isles of Scilly Barrow (1906) recorded the presence of a relatively stoneless, silty layer between the Main and Upper Heads. He regarded the silt as representing a wind blown limon or loess, comparable to that seen on the Brittany coast. Similar layers and lenses have been recorded elsewhere, and some of the colluvium capping the head deposits is probably of loessic origin.

Many sections in head also display a marked discontinuity some 50 cms below the surface, where upper layers with friable consistency and crumb or blocky structure give way to lower layers of extremely compact or indurated material with a marked platy structure (Clayden, 1964). Indurated layers contain stones with silt layers on their upper surfaces only, and may result from a phase of periglacial activity. The upper layer may represent the active layer where seasonal thawing occurred while the lower layer attained its structure under permanently frozen ground conditions as thin laminae of ice melted slowly between layers of mineral matter.

Narrow vertical and branching clay-filled cracks and fissures are also developed in some sections and have been described, for example, by Stephens (1970) in North Devon head deposits. Sometimes the cracks have a filling, or margins of light-grey clay and sometimes iron

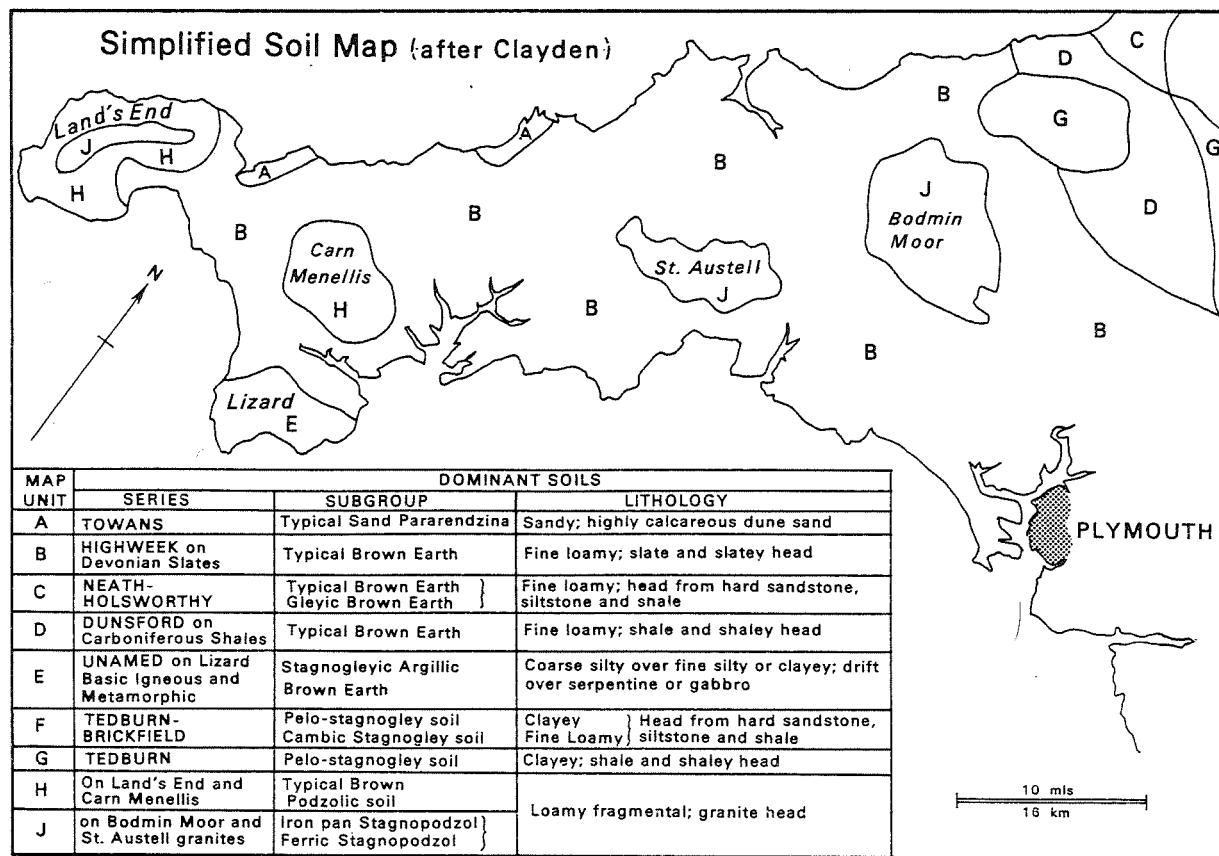


Fig. 3.

7
accumulation occurs at their outer margins (e.g. Prah Sands).

Thus there remains much of interest to study and understand about the formation of the head, the climatic conditions involved, the manner in which movement took place, and the explanation of the various internal structures which have been observed.

5. Post-glacial deposits

Post-glacial submerged sediments and organic deposits occur in a variety of situations in the West Country. Estuaries and sheltered bays often provide examples of submerged peats and tree stumps which have enabled reconstruction to be made of the progress of the Flandrian transgression (Kidson & Heyworth, 1973; Mottershead, 1977a). Submerged forests have been recorded in Daymer Bay, near Trebetherick (Clarke, 1965), which we are unlikely to see, and at Prah Sands, peat descends below modern beach level (Fig.10).

Other organic sediments, especially peats, occur at inland sites, and will be examined on Bodmin Moor at Hawk's Tor (Brown, 1977; Conolly et al, 1950), and at Colliford near St. Neot (refer to pages 9, 37).

DAY 1

BURIED SOIL FEATURES AND PALAEOENVIRONMENTAL RECONSTRUCTION

AT COLLIFORD, BODMIN MOOR

Site characteristics

The site is located on the southern flanks of Bodmin Moor in the St. Neot valley north of East Colliford Farm (GR.SX181709). It is included in an area of some 400 ha. which will be flooded to a level of approximately 255 m by the Colliford Reservoir presently under construction. A number of Bronze Age barrow and stone clearance features occur on both sides of the valley (Fig. 4). These have been fully excavated and the barrows CRII and CRIV have yielded C^{14} dates of 3500±100b.p. and 3600±90b.p. (both uncalibrated) respectively. CRII produced a large number of flints including a barbed and tanged arrowhead beneath the barrow. CRII consisted of a double ring structure of local granite stones and boulders whilst at CRIV a smaller barrow was located eccentrically within an outer ring and the intervening area was filled with turf removed from the surrounding Bronze Age land surface. CRIV stands in acid grass-heath moorland associated with a distinctive stagnopodzol comprising a thin peaty surface and a variable iron pan. CRII occupies a slope which was enclosed and improved probably in the 17th century and now consists of pasture and a brown podzolic soil, although around the barrow margins a thick (2-5mm) iron pan has developed.

Buried features

The stripping and excavation at CRIII revealed an underlying mass of granite boulders and stones apparently imbricated and of conglifractate origins - possibly a stone stripe. Soil profiles on both slopes exhibit distinctive boulder-sized angular stone lines in mid-profile positions suggesting significant periglacial effects. Soil profiles have been buried and locally preserved by the Bronze Age constructions and they reveal a number of intriguing characteristics. Investigations and analyses are most complete for CRII.

Sub-barrow soil CRII

The soil comprised three morphologically distinct mineralogenic horizons. Unlike the profile developed within and at the margins of the barrow, there is no iron pan, bleached Ea or peaty surface horizon (Fig. 5).

Of particular morphological interest in the profile is the occurrence of channels or tubes ramifying not only the buried profile (Figs.5 and 6) but also lower horizons (B and Bs) of the surrounding soil. These are remarkable for a number of reasons:

1. They contain black peaty infill with bleached mineral grains.
2. They vary little in cross-sectional diameter (mean 9.84, standard deviation 1.12).
3. Where channels split or bifurcate they occasionally do so in an upwards direction.

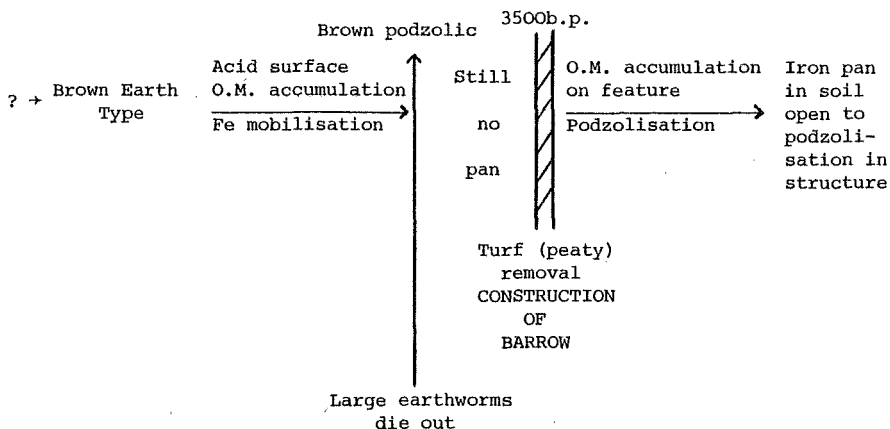
4. The internal walls are in places clearly smoothed.

Thin section examination by Petter Bullock, Rothamsted, revealed abundant casts within the organic material of the channels and evidence for considerable small animal activity.

The features are interpreted as earthworm channels. Notwithstanding the effects of wear and tear on burrows one of the larger species would have to be responsible and the size makes Lumbricus terrestris a strong candidate.

Very different ecological conditions are thus indicated with a resident large earthworm population persisting until such times as the surface character of the soil changed to a degree that mor humus began to accumulate. It is this which now fills the channels and not mineral-ogenic A material. The development of horizon I with its finer texture than II or III may be related to early earthworm activity or is simply a result of enhanced chemical weathering at the surface. Following the argument of Bascomb (1968) the relatively high and consistent values for dithionite extractable Fe suggests a strong affinity, if not genetic link, between the buried soil and a brown earth type profile. The pattern contrasts most strongly with the contemporary profiles of the surrounding soils (Fig. 7) although similar values have resulted from subsequent soil improvement (Fig. 8).

Hypothetical soil events at CR11



Large organic pockets comprising loosely packed humose material occur extensively in soil profiles on both sides of the valley. They are common under mid-profile stones or boulders and may represent top-soil infill in lacunae left by tree roots - cleared or, less likely, dying out naturally.

CR1V

The soil profile beneath the north-east facing barrow contains large humose pockets at depths up to 80 cm, but otherwise demonstrates features

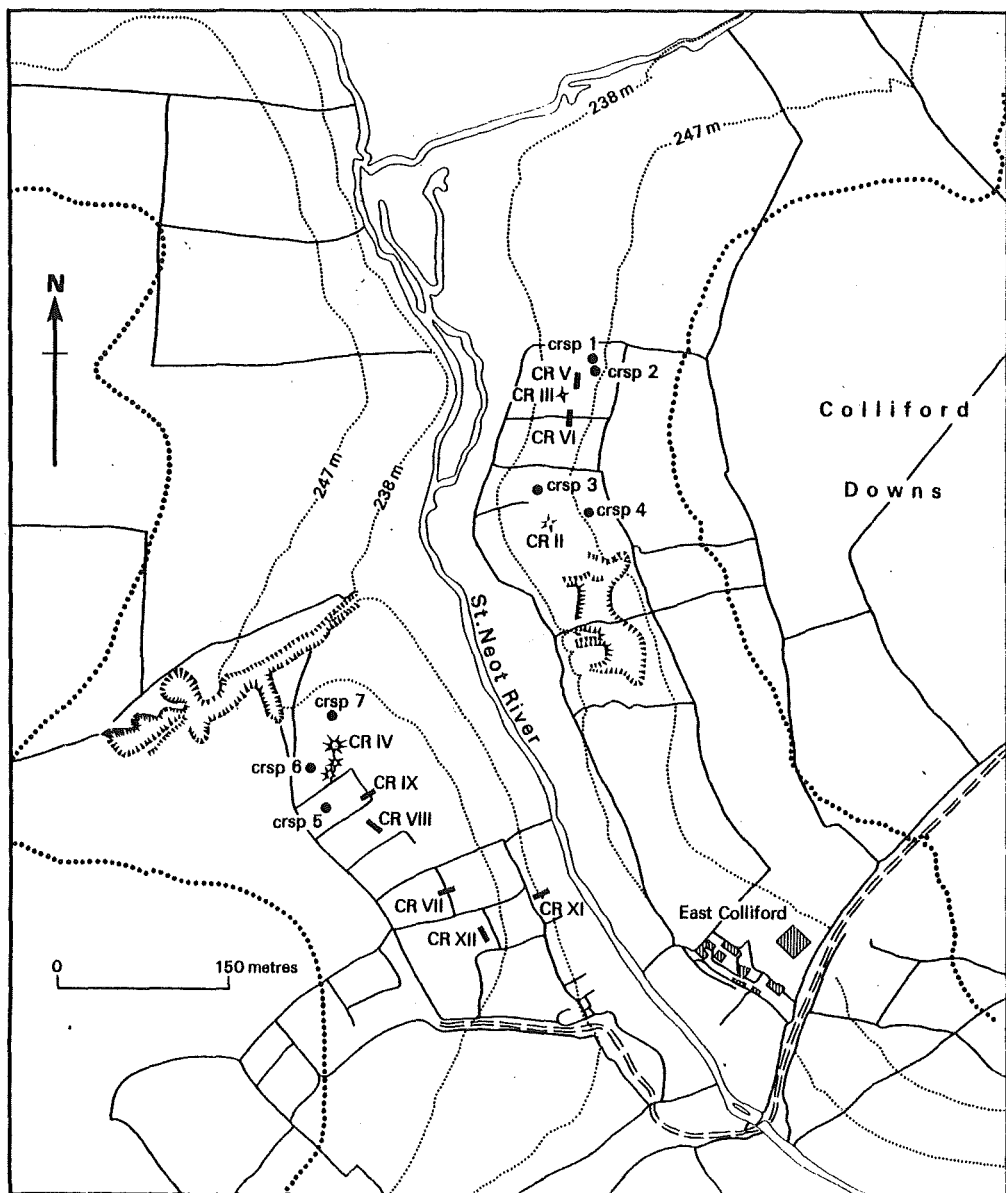
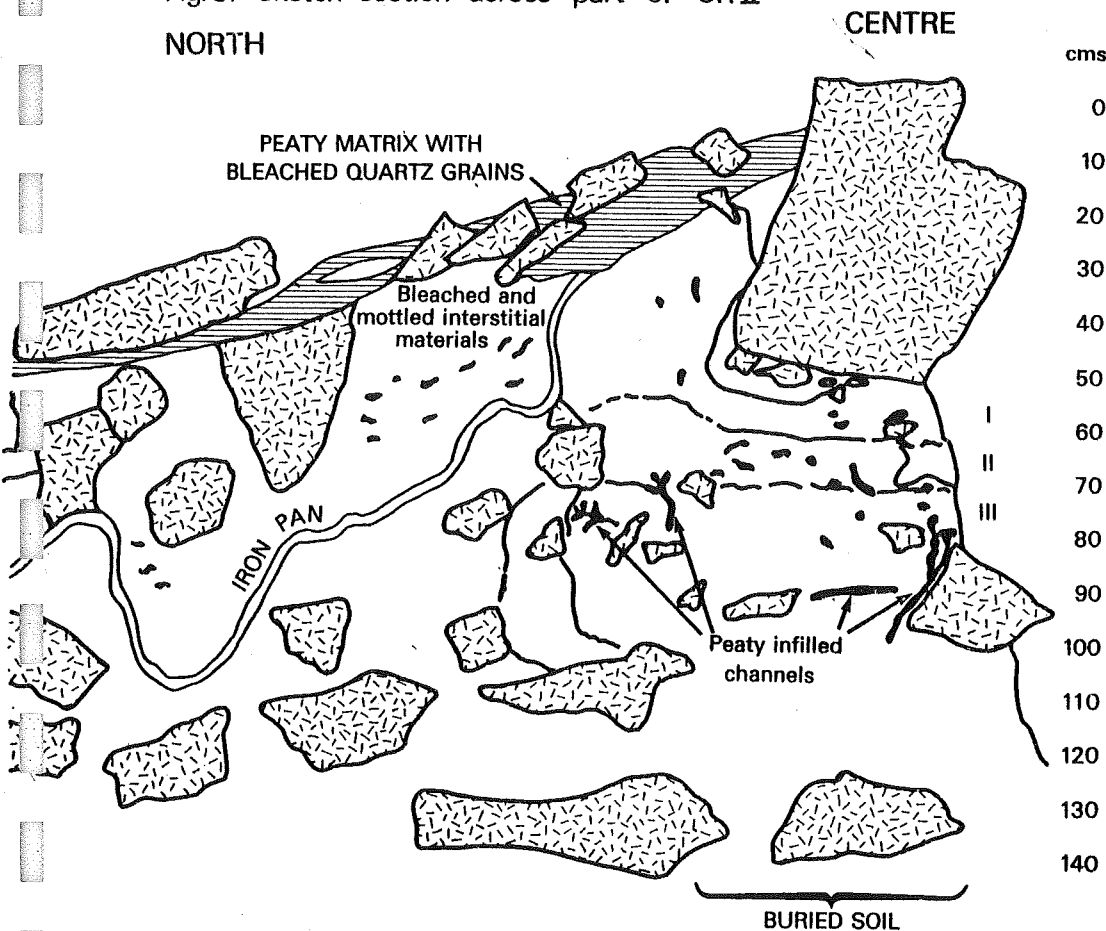


Fig. 4. Location map of archaeological, pollen and soil profiles

Fig.5. Sketch section across part of CR II
NORTH



Buried Soil

		Clay ($<2\mu$)	Silt ($2-63\mu$)	Sand ($63-200\mu$)	pH S.pt. CaCl_2
I	Dull brown 7.5 YR5/3 silt loam	17.73	53.24	29.03	4.08
II	Brown 7.5YR4/4 silt loam	9.95	55.56	34.49	4.19
III	Dull yellowish brown 10YR5/4 silt loam	11.30	48.83	39.86	4.18

COLLIFORD CR II

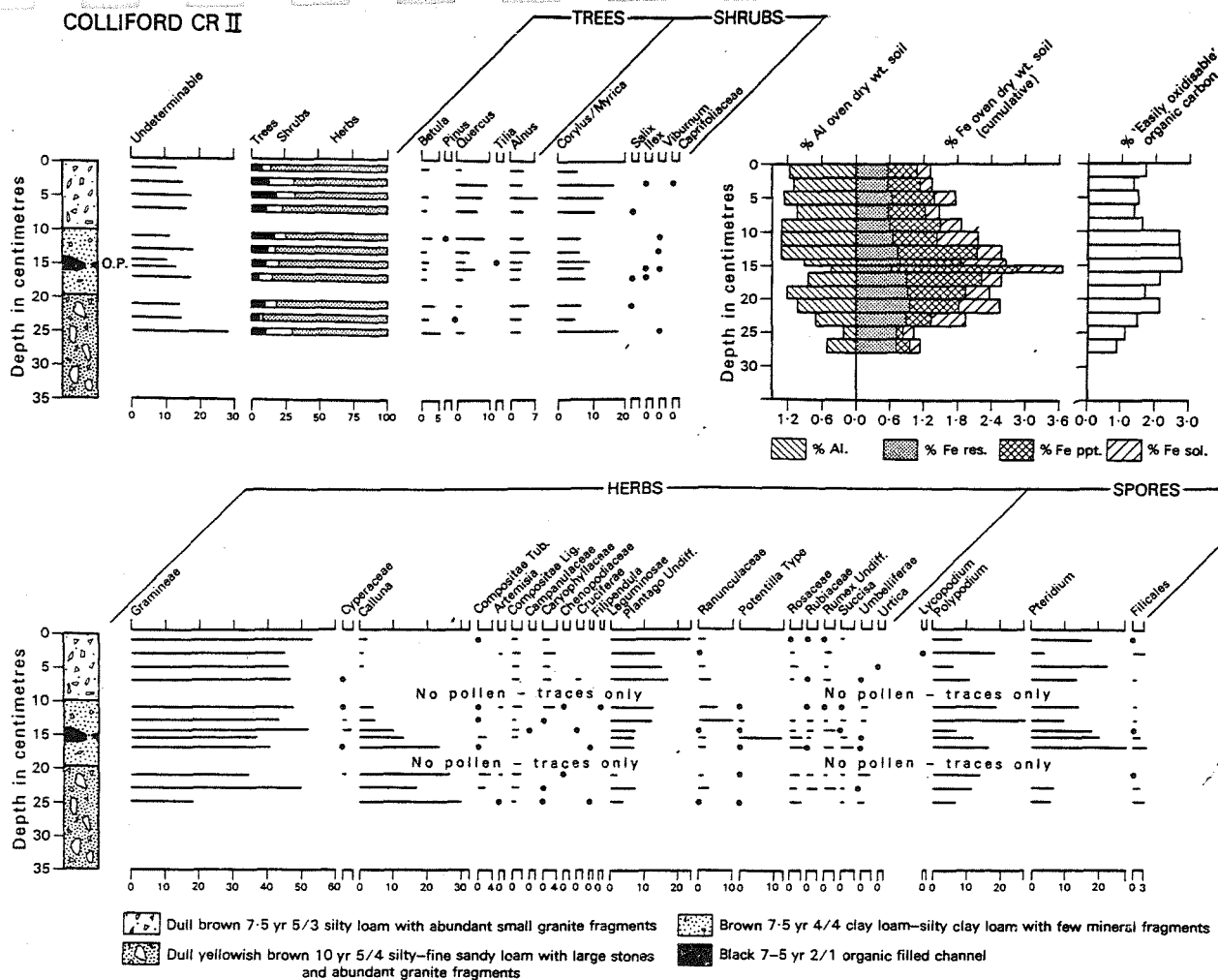


Fig. 6. Pollen and analytical details of buried profile at CRII

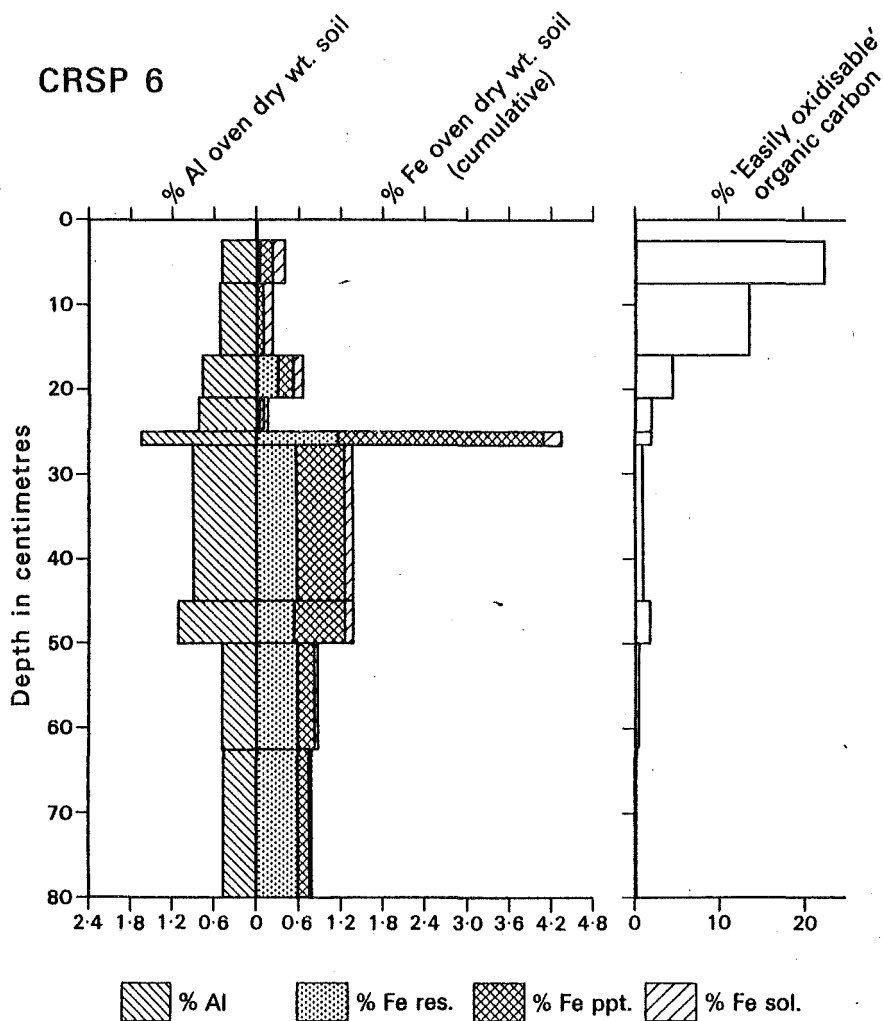


Fig. 7. Distribution of pyrophosphate extractable iron and aluminium, dithionite extractable iron and 'easily oxidisable' organic carbon (Walkley-Black) in moorland profile adjacent to CRIV.

CRSP 4

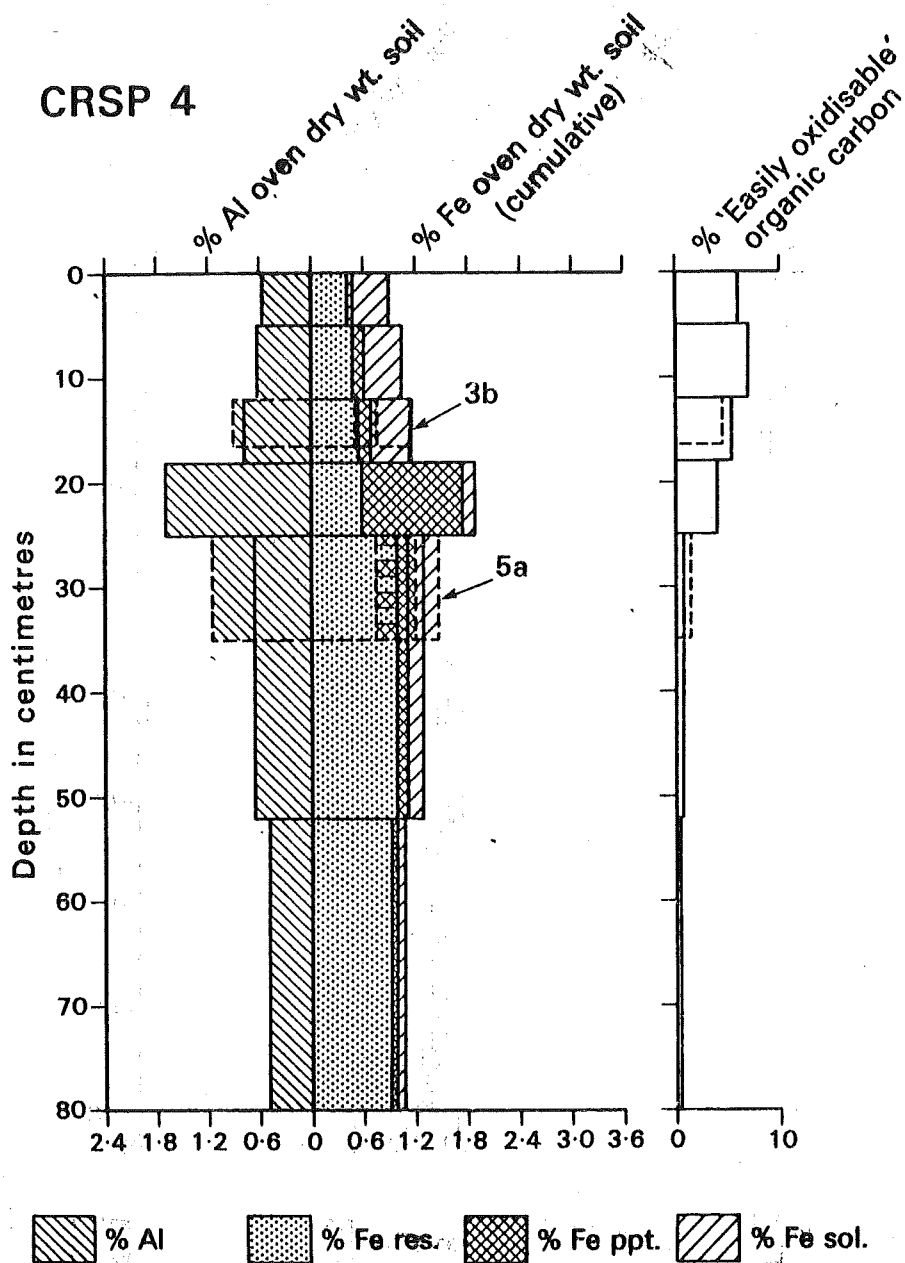


Fig. 8. Distribution of pyrophosphate extractable iron and aluminium, dithionite extractable iron and 'easily oxidisable' organic carbon (Walkley - Black) in profile improved by recent cultivation on west-facing slope adjacent to CR11

characteristic of a thin iron pan stagnopodzol. The old land surface is intact at the base of the turf infill. Already at CRIV pedogenesis may have been further advanced than at CRII at the time of barrow construction. A difference in date of some 100-200 years would be quite sufficient to allow such differentiation on the basis of evidence from elsewhere in the South West (Maltby and Crabtree, 1976). Alternatively, the possible importance of aspect and local variations in slope hydrology and soil moisture regimes influencing the rate and direction of profile development should not be ignored. It would be oversimplistic to assume that any Bronze or pre-Bronze Age changes in soil conditions were independent of subtle landscape details even in the uplands.

Pollen analyses from CRII and CRIV

The analysis of pollen from the buried soils at CRII and CRIV proved difficult because of their poor state of preservation. Diagrams have been prepared for both soils, as well as for other profiles elsewhere in the Colliford area but at CRII only relative counts were made. Because of the poor preservation and the problems involved in interpreting pollen assemblages from soils, only major changes in the assemblages are considered significant in the interpretation of vegetational and environmental change. At CRII the uppermost horizon, I (Fig. 6), is dominated by Gramineae with significant counts for Plantaginaceae and the presence of Compositae lig., Caryophyllaceae, Ranunculaceae, Rosaceae and Rumex. Horizon II has a similar assemblage but with increased Calluna with depth and horizon III shows even higher Calluna, as well as higher relative values for Corylus/Myrica. Overall the pollen record appears to agree with the pedological evidence for the development of a brown podzolic soil under grassland within quite an open environment and suggests that the soil probably had the uppermost turf removed upon the construction of the barrow. The increasing values of Calluna found down the profile however are interesting and indicate either that the soil did not develop directly from a brown earth type, or that Calluna was an important component of the local vegetation communities prior to the development of grassland. Heather may have comprised the understorey of a community dominated by hazel or oak. Birch and alder are relatively sparsely represented in the profiles. Brown (1977), from his more general study of the vegetation history of the moor, has suggested that hazel was found widely along intermediate slopes with heath communities on exposed moorland summits and oak in the valley floors.

Pollen from the pocket found within the CRII profile was not dissimilar to that in the surrounding matrix but was generally better preserved, which is not surprising considering the more acid nature of the material. The difference in preservation probably indicates that the pollen was transported with the infill and if this is so then the pollen assemblage with up to 15% Calluna would agree with the idea of infilling taking place after large earthworms had died out and when a peaty turf layer had developed. The general homogeneity of the pollen record in horizon I also lends support to the view that this horizon owes much to mixing by earthworms for its character.

The thin iron pan stagnopodzol below CRIV produced a more straightforward pollen diagram than CRII which showed the decrease in pollen concentration with depth characteristic of podzols and which showed also the change from a grassland with a variety of N.A.P. taxa in lower horizons to a less diverse Calluna-dominated community in the uppermost mor horizon. This pattern of change agrees well with the pedological evidence and is repeated in the turves which form the fill of the barrow above the former land surface.

The pollen evidence in general complements the soil analyses and emphasises the trend of increasing acidification and podzolisation seen throughout the Colliford area. Because of the variability inherent in the pollen assemblages found in soils, and also because of the low values for A.P. in general, it is not possible to use the pollen evidence to answer questions raised by the status of the buried soils as regards the role of man and the rate of change. Nevertheless the pollen profiles, even at such a poor level of resolution, provide a useful mirror against which the pedological analyses can be evaluated.

DAY 2

GODREVY

Green (1943) comments: "When complete, the Raised Beach (i.e. the 10, 15 and 25 foot raised beaches) in Cornwall is usually composed of pebbles, often with large boulders, resting on a solid platform, and overlain by marine sands. This is covered by thick head. Between the head and the raised beach may be old blown sand". The sequence of Pleistocene deposits exposed at Godrevy conforms to this general model and has been described in detail by Robson (1946) and Stephens (1966a, 1970).

Between the Red River, north of the Towans sand dune complex, and up to the sand covered slopes inland of Godrevy Point, a broad shallow valley has been infilled with head deposits, overlying beach gravels and 'fossil' or cemented sand dunes. Outcrops of these sections are clearly seen along the low coastal cliffs north of the Red River. Stephens (1966a) presents seven sections (Fig. 9) and suggests that three separate cold phases can be distinguished represented by the deposition of (1) the upper head, (2) the main head and (3) frost shattering and weathering of the marine cut rock platform (Table 1).

The upper head is best seen towards the northern end of the small cliff sections where fresh, angular slate and quartz fragments form a distinct layer 0.6 m to 1.2 m thick over the weathered and highly convoluted head deposits below.

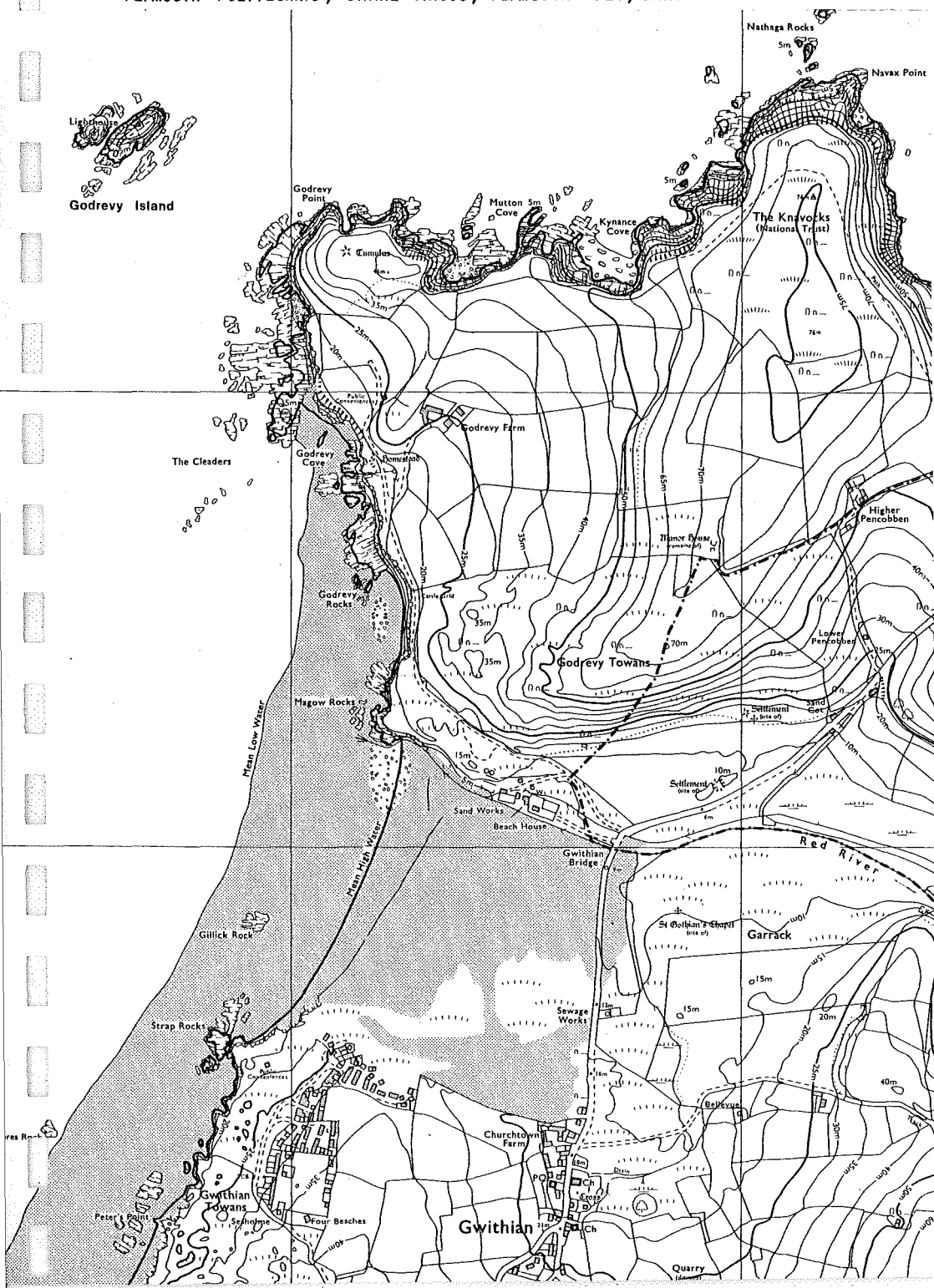
Much of the main or lower head is composed of quartz rock fragments in a fine matrix of sandy clay, thought to have been derived from the weathering of shales and slates. Stephens (1970) suggests that although weathering would have occurred subsequent upon deposition of the solidified material, there may have been some incorporation of previously weathered fine materials during the downslope movement process.

Erratics are recorded in the beach gravels which rest on the rock platform. Frost shattered bedrock in contact with the coastal platform suggests a cold phase prior to the deposition of the raised beach sediments. This could indicate the existence of a pre-Hoxnian platform only a few metres above the present beach.

Table 1. A CORRELATION OF SUPERFICIAL DEPOSITS AND PLEISTOCENE EVENTS AT GODREVY.

Age	Deposit
Flandrian	Blown sand and sand wash.
Devensian	Upper head (fresh with small convolutions) 0.6 to 1.2 m thick.
Ipswichian	Weathering of Main head.
Wolstonian	Deposition and extensive cryoturbation of Main head into festoons. Predominance of large angular fragments of slate and shale in a sandy, clay matrix, 1.5 to 2.4 m thick.
Early Wolstonian	Sand dunes formed overlying raised beach deposits now indurated and cemented into sand rock.
Hoxnian	Raised beach of shingle and cobbles, mainly flint, quartz, sandstone and slate, cemented by manganese in places.
Anglian? and Early Pleistocene	Frost shattering of rock platform and deposition of an early pre-raised beach head. Formation of wave-cut planation surface.

Source: Stephens (1966a, 1970)



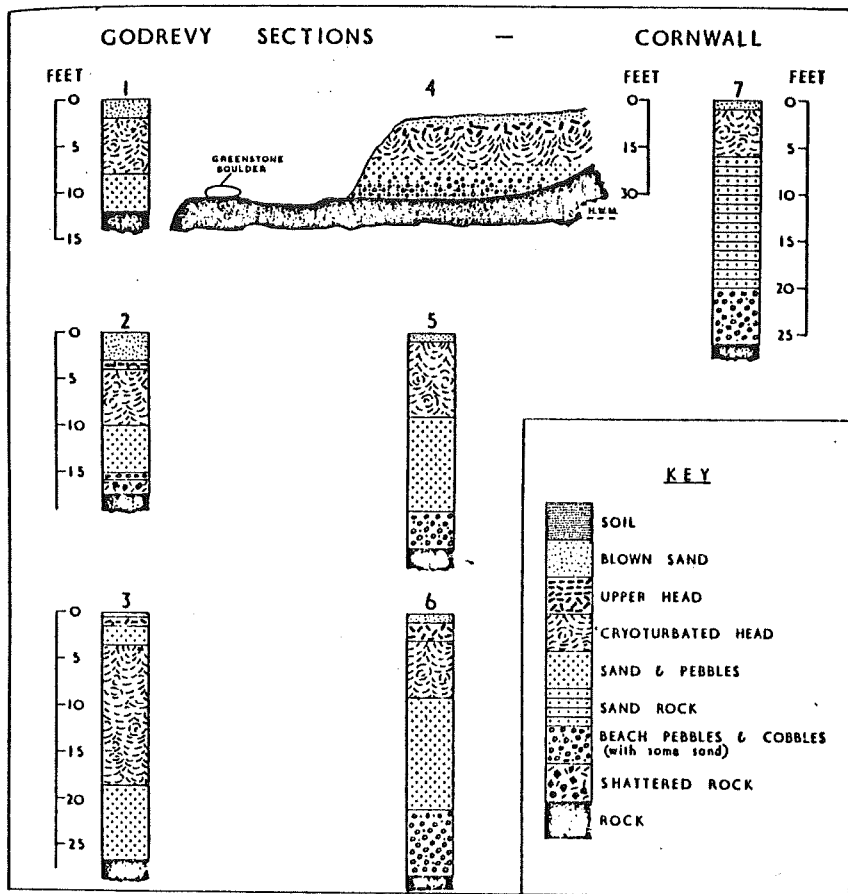
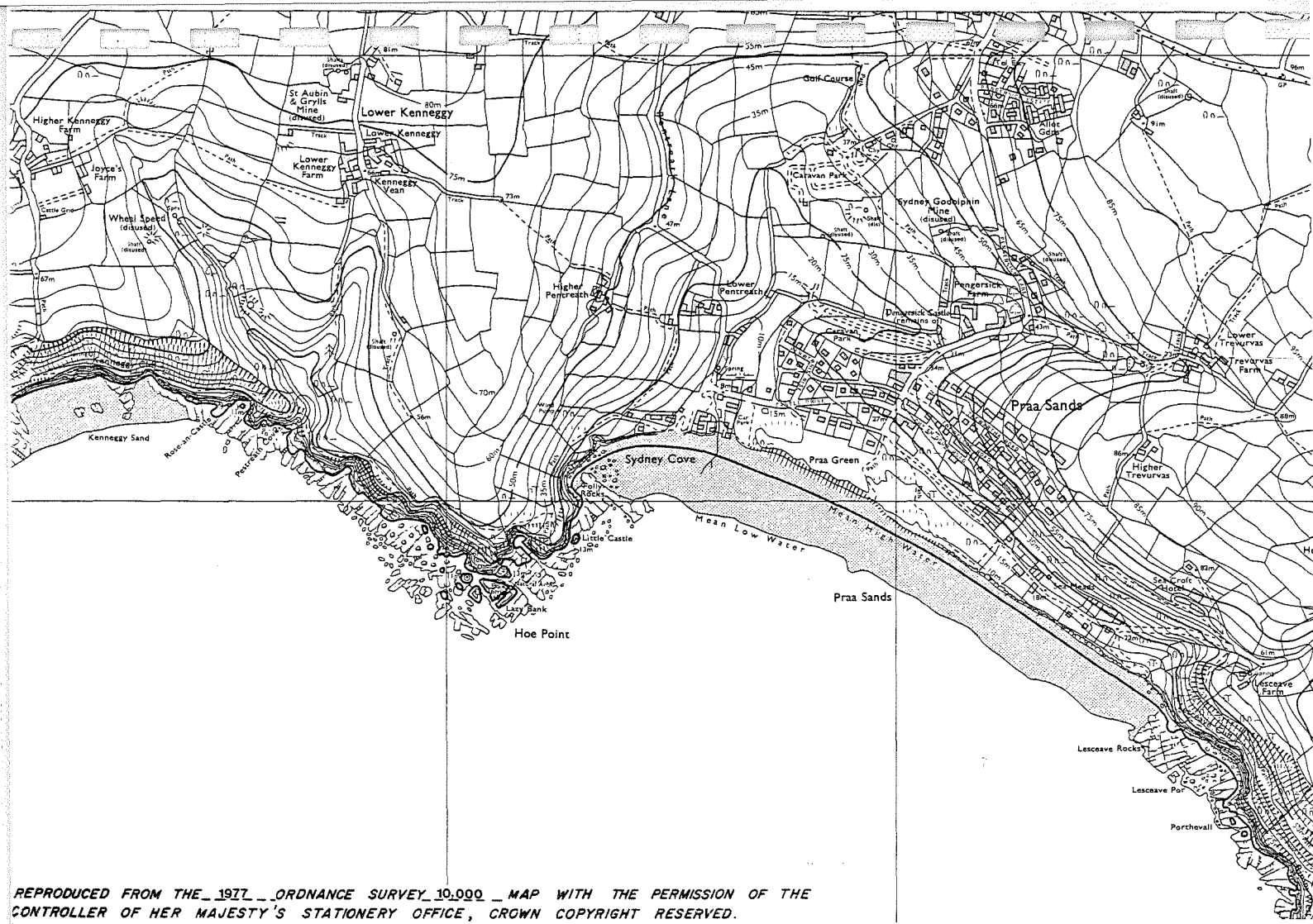


Fig. 9. Source: Stephens, 1966a



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PRAH SANDS

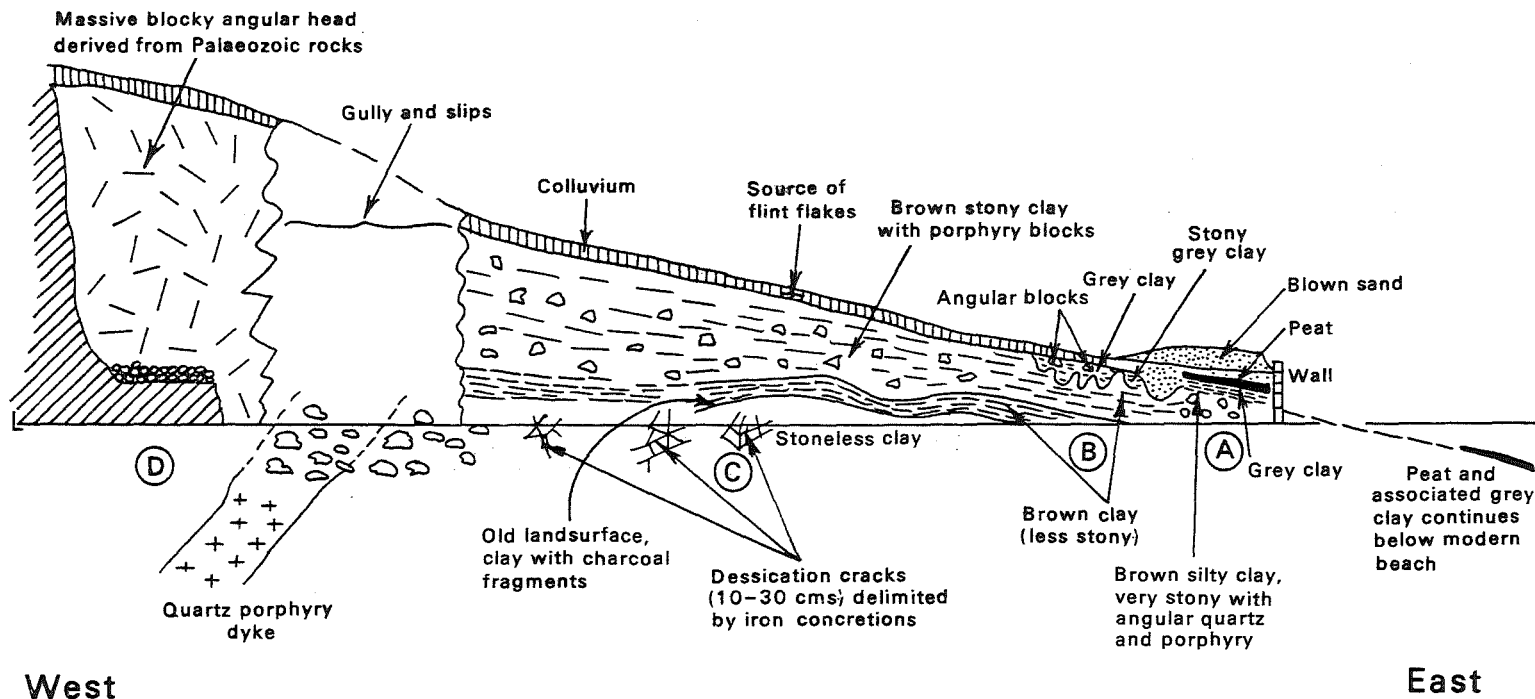
At the western end of Prah Sands Beach (G.R. 575280), a large continuous section extends for several hundred metres, becoming progressively higher westward along the beach. A composite section is illustrated (Fig. 10) and four sketches attempt to show certain important stratigraphical changes along this section.

At site A, near the access point to the beach, black peat is seen below blown sand, and overlying a light grey stoneless clay. Below this clay a brown silty clay with angular stones, including especially quartz and stones derived from a quartz porphyry dyke nearby passes below modern beach level. The peat has been given a C-14 date of 1805 ± 100 B.P. (Kidson, 1977b) and can be seen to extend south-eastwards below the modern beach, and the dunes. At site B, some 40 to 50 metres west of site A, the peat is no longer present but the grey stoneless clay rests upon a strong grey clay (with frost convolutions of the stones in places), and probably two distinct brown clays form the rest of the section. The brown stony clays thicken along the section towards site C, and are seen to overlie a mainly stoneless brown clay, and a clay with lenses and layers of small angular stones. Well-developed desiccation cracks are present at the base of the section. Slumping of the cliff-forming clays, head and colluvial deposits, often obscure the sections, but at one point near site C a dark coloured horizon occurs, a metre or so above the modern beach (Robson, 1944). The dark material is in part charcoal and Reid *et al* (1904) reported the presence of "small splinters of carbonised bone and fragments of burnt earth". This may indicate the existence of an exposed land surface before the massive thicknesses of head were deposited - an interpretation supported perhaps by the presence of the desiccation cracks. The brown clays with stones also contain angular and sub-angular blocks of the quartz porphyry dyke rock (elvan) outcropping on the foreshore at the western end of the section. This dyke also supplies the large piles of quartz porphyry boulders on the modern beach.

Towards Hoe Point massive blocky and stony head, derived largely from the highly contorted Devonian slates with many quartz veins, mantles the coastal slope at site D. This overlies a raised beach and platform, elevated several metres above the modern notch. The raised beach is well-developed in places and is seen to contain a substantial number of angular and sub-angular blocks of the country rock near the old mine adit.

The superficial deposits have been described by Reid (*et al*, 1904), Flett and Hill (1912) and Robson (1946), but there has not been a full description and explanation of the various stony and stoneless brown clays, nor of their relationship to the blocky head overlying the raised beach. The bulk of the clay is probably derived from the country rock and perhaps accumulated as mudflows swept seawards along shallow valleys extending back from the coast.

PRAH SANDS



West

East

Fig. 10.

PRAH SANDS SECTIONS

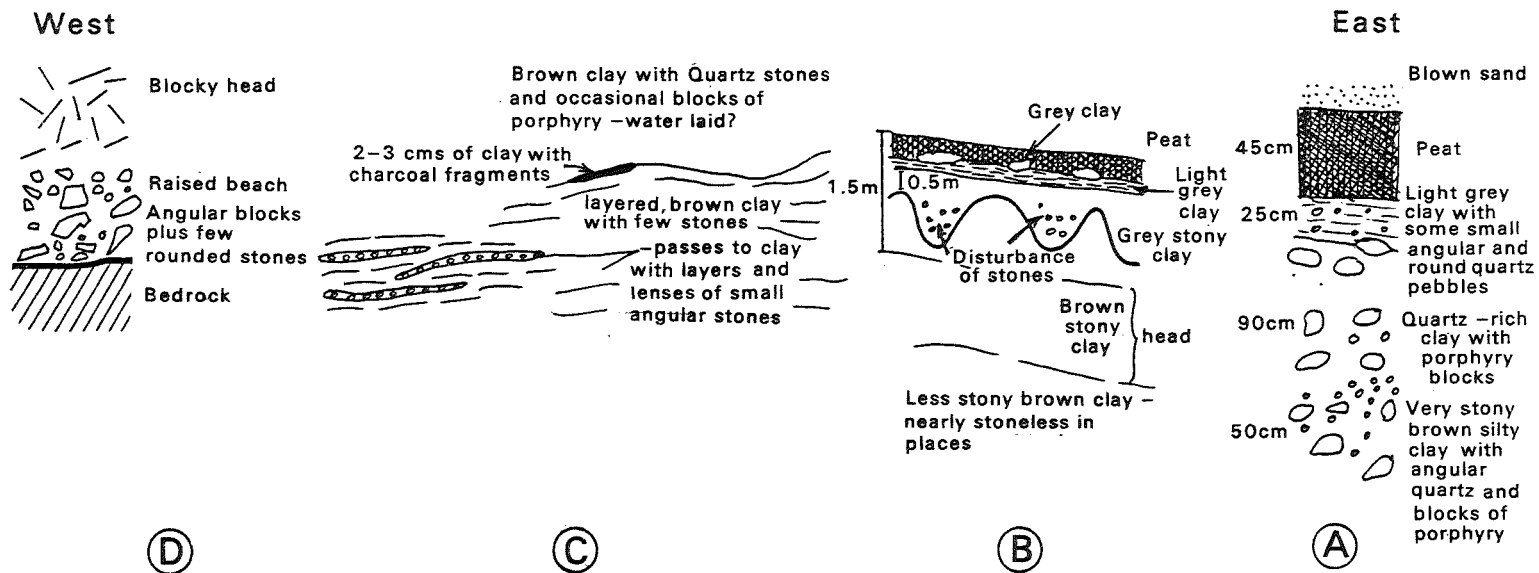
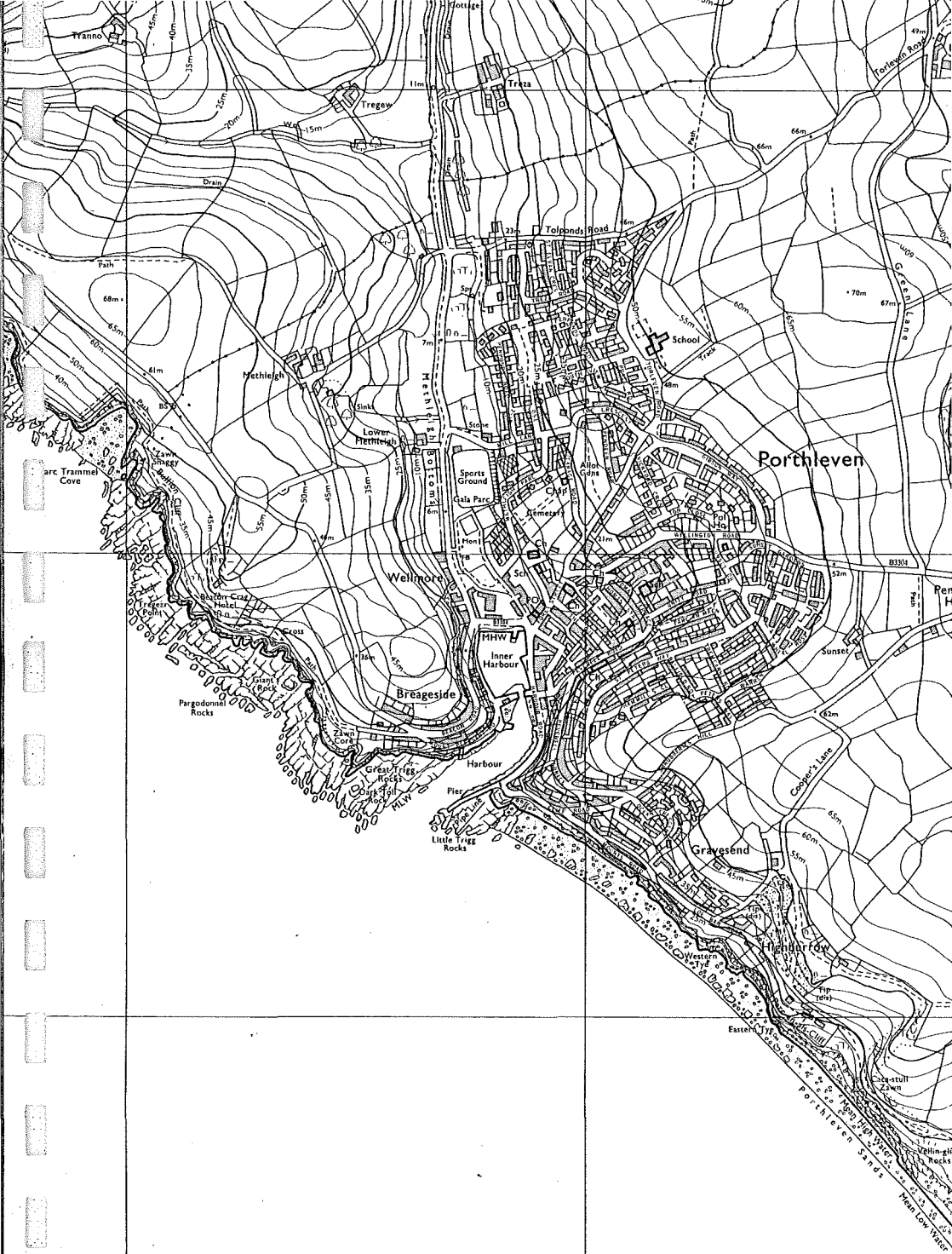


Fig. 11.

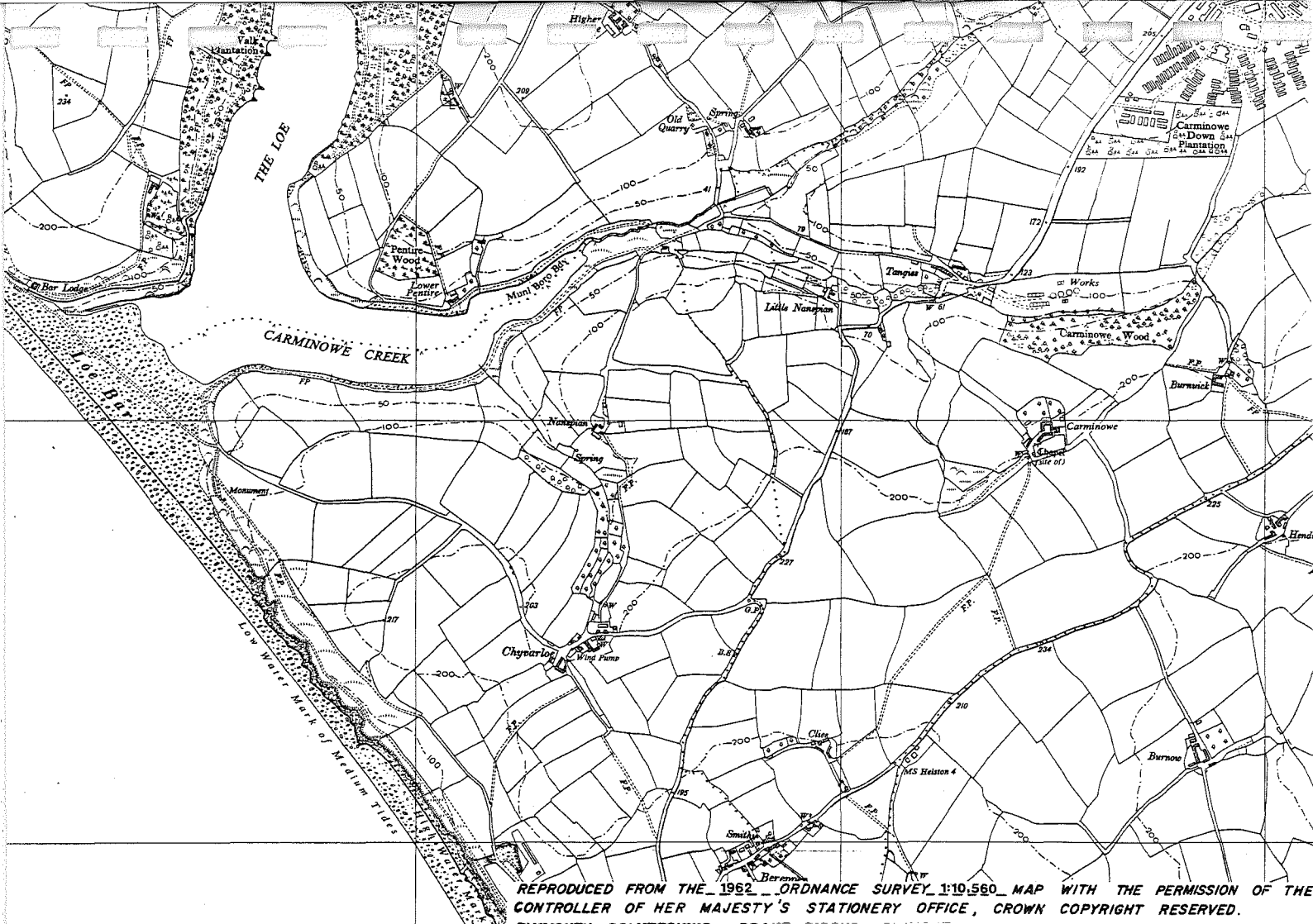


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PORTHLEVEN

The Mylor Beds of the Devonian Series are well exposed near Porthleven Harbour, and consist mainly of slates and siltstones with occasional sandstones and numerous quartz veins. Repeated folding and faulting has occurred, and relationships with the older Gramscatho Beds and younger Veryan Beds are ill-defined. The Porthleven beach is composed of small chert pebbles which may have derived from Cretaceous and Eocene deposits outcropping on the sea-floor some 50 km to the south (Reid, 1904).

Some 400 metres north-west of Porthleven Harbour a cliff-top path leads to Pargodonnell Rocks, where a wide abrasion platform is exposed at low tide. The Giant's Rock rests in a large pool on the abrasion platform. It is about 3 m long, weighs some 50 tons, and consists of a garnetiferous gneiss, of a type unknown elsewhere in Britain.



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LOE POOL AND LOE BAR

Together, Loe Pool and Loe Bar represent the largest of a number of lagoon and bar features found on either side of the Lizard Peninsula. These are also common elsewhere in South-West England, the most celebrated example probably being Slapton Ley in East Devon. The bars all appear to be Holocene in age, but beyond this, it does not seem possible to say whether they record a phase of widespread aggradation in response to rising post-glacial sea level, or represent individual episodes of bar formation.

For example, Little, Barnes and Dorey (1973) suggested a late glacial origin for the Swanpool near Falmouth, whereas at the other extreme, Crabtree and Round (1967) found that sediment in a core from Slapton Ley began to accumulate in Pollen Zone VIII (i.e. any time during the last 2500 years). More recently, Morey (1976) has found that the freshwater sediments of the Ley all post-date c. 2900 BP.

Pollen-analytical evidence (O'Sullivan unpublished) shows that freshwater sedimentation at the Swanpool, and also at nearby Maenporth, began in the period preceding the Alnus-rise. According to Brown (1977) this may mean that those bars were formed before c. 6450 BP. However, at Mawgan Porth on the north Cornish coast, Alnus pollen is present throughout the period of freshwater sedimentation (Lennon, unpublished).

Documentary evidence indicates that Loe Bar was in existence by the late thirteenth century, when a charter of Edward I mentions "the lake of Helston" (Turk and Turk, 1976). Subsequent references to the silting up of the port of Helston in 1301 (Toy, 1936) may not in our opinion preclude the existence of the Bar. Various nineteenth century authors (e.g. Rogers, 1865) record that during excavations in the Cober Valley immediately below the town, freshwater peats and remains of Oak and Hazel were found at c. 2 m O.D. Above these deposits are c. 7 m of silt presumably deposited by the River Cober. There is strong evidence from numerous documentary sources of silting being associated with mining activities in the area inland from Helston (Toy, 1936; Coard, unpublished).

By 1800 AD, spontaneous outbreaks of winter flood water from the Pool had ceased. By the mid-nineteenth century it was necessary to break the Bar to release excess water. In 1857 the adit which presently drains the Pool was rediscovered and employed for this purpose (Toy, 1936). Map and documentary evidence (Coard, unpublished) indicates that the Bar attained its present height and shape about then, but that it is still undergoing rapid change and landward movement.

The material of which the bar is composed is mainly fragments of flint thought to originate offshore (Turk and Turk, 1976). There are occasional boulders of local slate (Killas). During the storm of February 1979 which inflicted much damage on the coast of S.W. England, a cut made by the South West Water Authority to drain away excess flood water clearly showed that the Bar was composed of alternating coarse and fine layers, perhaps related to incidence of stormy and quiet episodes of deposition.

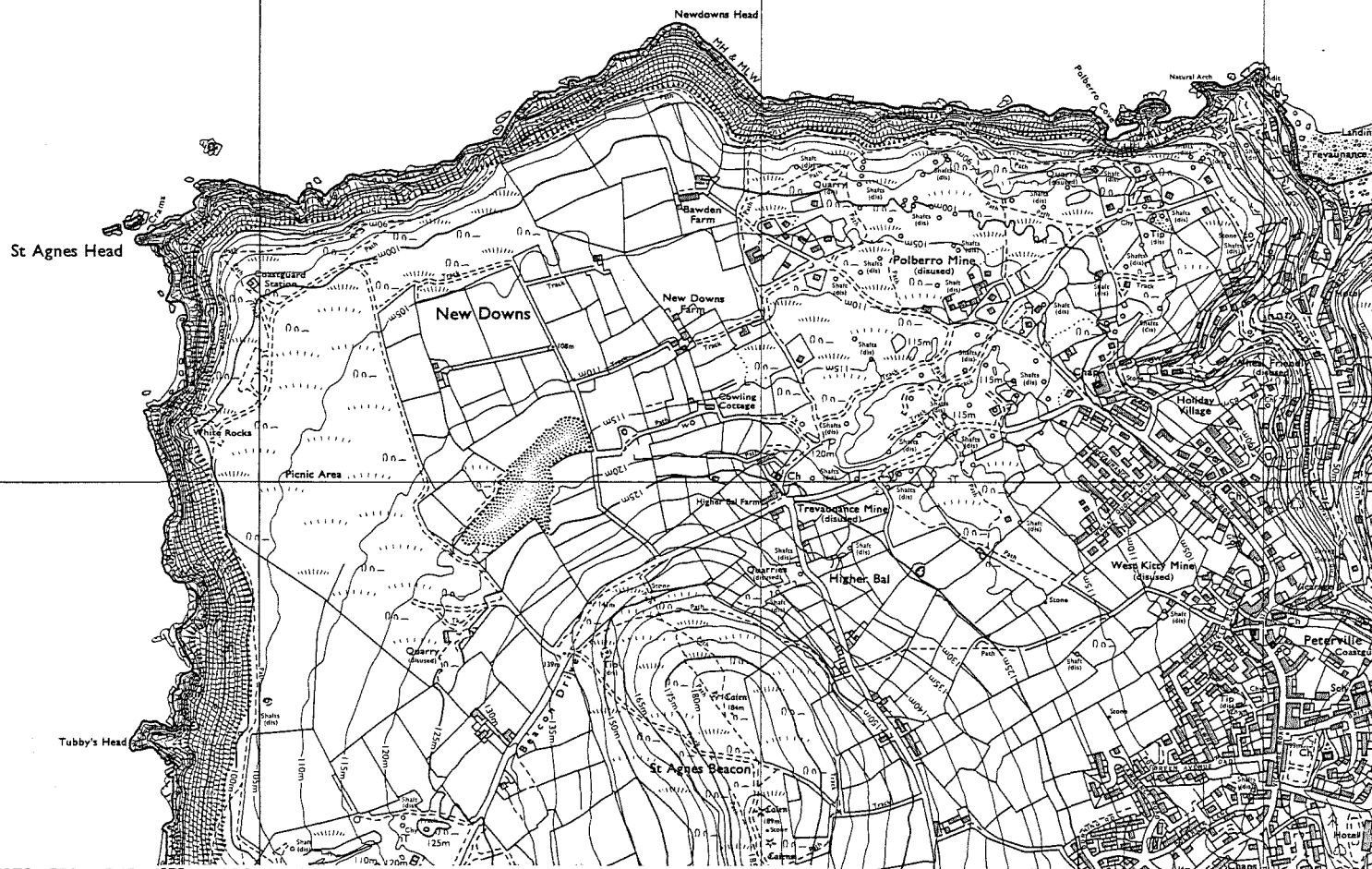
At least three studies of the size range of the material of the Bar are being conducted but at present no details of conclusions are available.

CROUSA COMMON

The B.3293 road from Helston leads south-eastwards across Goonhilly Down (on Serpentine or Peridotite and Gneiss), where the Space Satellite Tracking Station is sited. Goonhilly Down is an excellent example of the 85-112 metre planation surface, and its eastwards extension towards St. Keverne is impressive. At Crousa Common (G.R. 776201) cross roads (on Gabbro) there are a series of small exposures of yellow clay with copious quantities of water-worn quartz pebbles. These range from pea-size to cobbles, and occur both within and upon a stiff, stony clay, apparently derived from weathering of the country rock. Large rounded boulders litter the plateau surface on Crousa Common, and have been cleared from many of the fields, but the true profile of the bedrock surface is unknown. The pebbles and clay may form part of the so-called 'Tertiary deposits' mantling an old pre-Pleistocene erosion surface or surfaces, which at Crousa Common occur at about 112 metres.

The plateau area of the Common supports paleo-argillic brown earth soils and paleo-argillic stagnogley soils, and there is usually a thin or discontinuous veneer of loess present. The loess has an extensive distribution on the serpentine outcrop in the Lizard Peninsula (Coombe and Frost, 1956) and is probably of granitic origin. The deepest deposits occur near the south coast, and there are close similarities with loess found in the Isles of Scilly. In general, depths greater than 1 metre are very restricted and most is found as a silty loam on the 'flat' erosion surfaces in association with a 'short heath' vegetation. It is generally absent from slopes and valley bottom sites. At Crousa (G.R. 772 197) a silt loam forms the uppermost 29 cms of the soil profile, and has 51-64% silt content (20-31% sand and 16-25% clay).

DAY 3



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THE ST. AGNES BEDS

Introduction

The sands and clays of the St. Agnes area occur in a crescent-shaped outcrop on the north side of the St. Agnes Beacon (Fig.12). These deposits were discovered in 1758 and cover an area of approximately 2 sq. km. though the exposure is restricted to a few, much overgrown, partially back-filled pits. The best sections at present visible occur in the working operations of Doble's Sand Pits (SW 7065 5110).

The sediments vary greatly in thickness up to approximately ten metres with considerable lateral variation in lithology (Fig. 13).

They rest on metamorphosed Devonian slates (locally called 'killas') or on the St. Agnes granite. The clays and sands have been worked for several hundred years. Initially the clays were used for tobacco pipes, crucibles, in pottery and in brickmaking. Increasing competition caused a decline in these outlets and the plastic clays were then used for candle clay. The term 'candle clay' was applied to a particularly unctuous blue-grey clay which was sold by past owners of the Beacon Cottage Farm Pits (Balandeeze Mine) (7059 5007) to the mines of Cornwall particularly to those of the Camborne-Redruth area, for fixing candles to the underground mine walls and to miners' hats. The candle clay was also used as a grouting or puddling medium where drainage problems were severe. The candle clay trade gradually declined and died out about 1940. The shed where the clay was stored, now derelict, is still in the Beacon Cottage Farm yard.

The fine white sand in the deposit has been used extensively as a garden potting sand. At present the clean pure silica sand is used for moulding and the grey clay is used in pottery and in furnace linings.

The Succession

a) The basal pan

The basal deposits sit on a surface of deeply weathered, stained 'killas' where they are exposed in Dobles Pits. Here the rock shelf below the sediments is a relatively level surface.

Reid and Scrivenor (1906) record a bed of pebbles, often containing tinstone, at the base of the sediments. This basal conglomeratic layer is frequently referred to in the literature, but is not visible in Dobles Sand Pits where the contact between the sediments and bedrock is marked by a layer of cemented sand (Atkinson 1975). This iron pan at the bottom the deposit has an average thickness about 0.5 metre, it is ubiquitous in the lower, eastern pits but is thinner and less extensively developed in the upper western pits. The iron pan is variegated in colour from black, through dark blue to various shades of brown and yellow. The iron content of this pan is in excess of 10% by weight in certain areas. Certain sections of the pan contain

angular pieces of decomposing 'killas' up to 100 mm long. Contained in the basal pan are large concretions up to 2 m long and 0.3 m across which have tubular structures within them containing soft, unconsolidated yellow sand (Atkinson et al 1974). The majority of these tubes lie with their long axes sub-horizontal trending 035°.

b) The lower sand

At the north end of Dobles Pit is exposed about 4 to 6 metres of yellow or buff coloured sands which grade up into about 3.5 m of grey-white silty sands which are presumed to pass up into the clay member which overlies the basal sands (Fig.14). Although, as mentioned above, the rockshelf below the sediments is relatively level in Dobles Pits, geophysical evidence suggests that the base of the deposit lies on a very irregular surface beyond the confines of the existing pits.

The basal sands may then represent channel fills in the irregular floor. Field evidence demonstrates that the area of the St. Agnes Granite Quarry (7042 5074) was an area of non deposition during the formation of the lower sand horizon. In boreholes drilled at Beacon Cottage Farm, (7059 5007) south of the Granite Quarry, the sand horizon appears again and is at least 1.5 metres thick (Fig.14). There appeared to be a basal rudaceous layer in the Beacon Cottage Farm boreholes but the presence of the basal pan could not be proved.

Away from Doble's Pits in the other direction, eastwards, the lower sand horizon with the basal pan is exposed in the Polberrow Mine openwork (7121 5123). East of this the outline of the St. Agnes beds difficult to define and in the neighbourhood of St. Agnes village no outcrops occur. Davies and Kittor (1878) show the beds crossing the Truro - St. Agnes road near (7168 5004).

c) The clay horizon

There is a transitional junction between the lower sands and the overlying grey and white clays. The silty sand visible in the topmost sections of Dobles lower (eastern) pits passes upwards into a sandy silt, recorded from auger holes in the upper pits but not currently exposed. Approximately 3 metres of uniformly pale grey silty clay with occasional quartz pebbles towards the top is present in the pits. The overlying sands sharply truncate the grey clays in the Dobles Pits (Fig.14).

At Beacon Cottage Farm the clays are about 4 metres thick where penetrated by boreholes (Fig.14). Here again grey white silty clays predominate while towards the top the clays become slightly reddened, and they are overlain by the so called 'Red Blush' clays.

There are no definite records of the clays to the east of Dobles Sand Pits but the present owner of these pits has reported similar clays in the foundations of new bungalows on the outskirts of St. Agnes village.

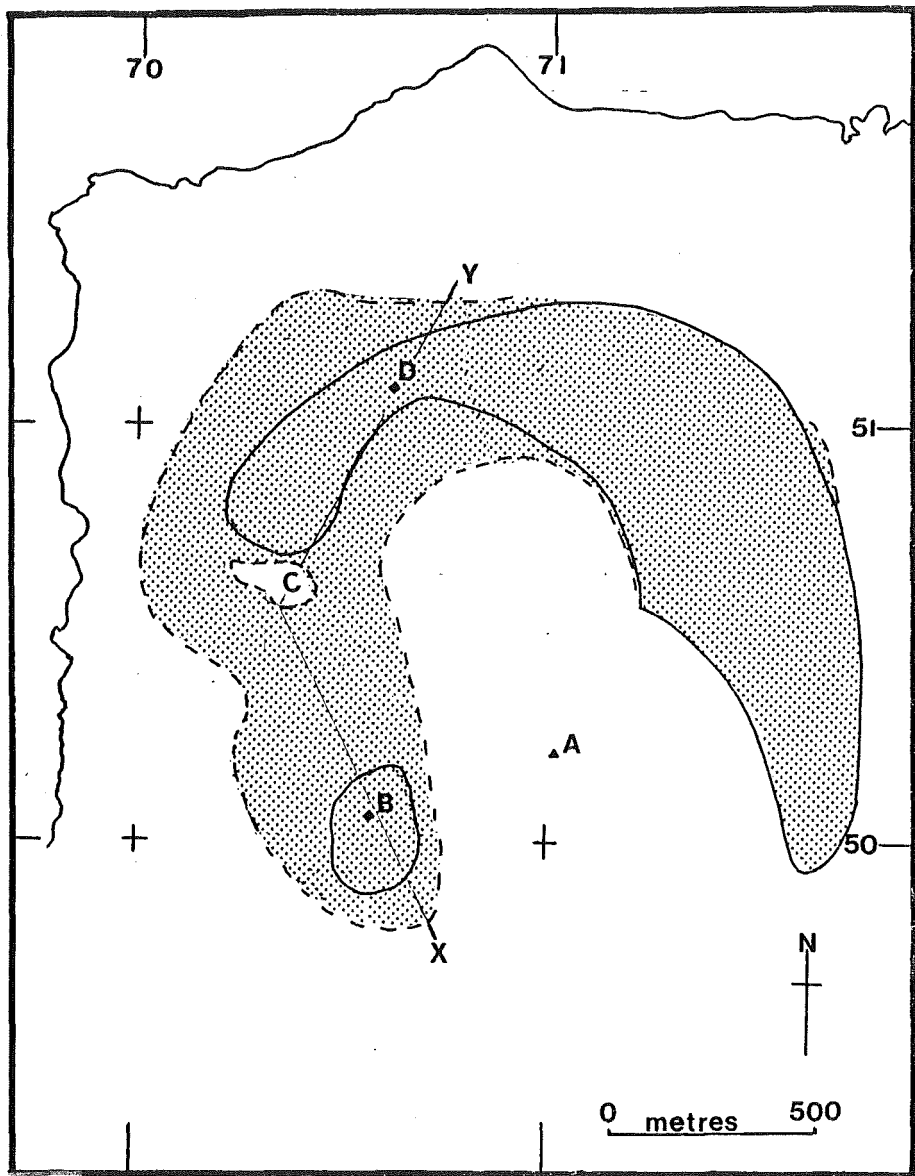


Fig. 12.

Outcrop pattern of the St. Agnes Beds; solid outline according to Davies and Kitto (1878), dashed outline based on geophysical evidence and borehole data. X - Y approximate line of section shown in Figure 2. A = St. Agnes Beacon, B = Beacon Cottage Farm Pits, C = St. Agnes Granite Quarry, D = Doble's Sand Pits.

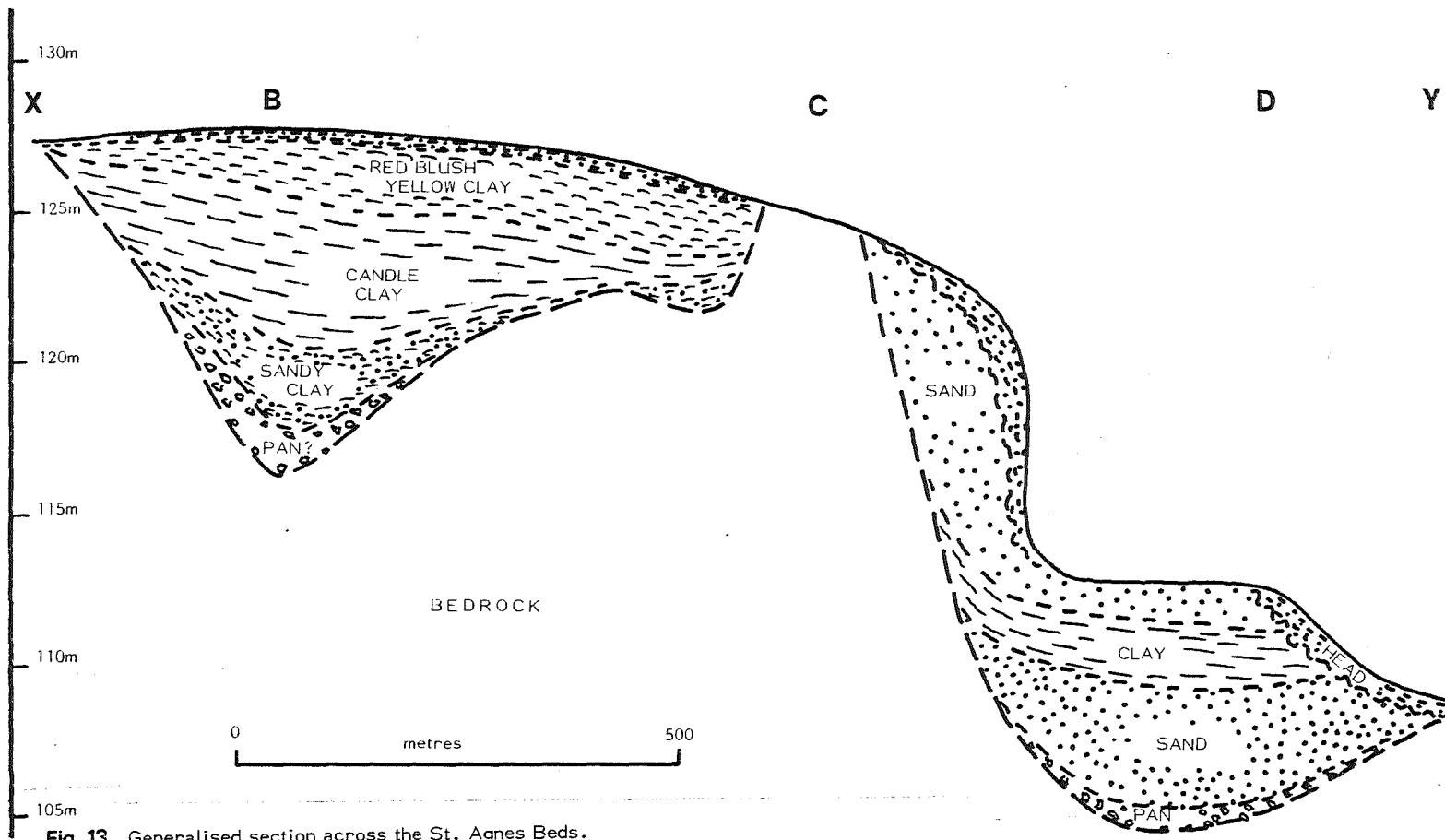


Fig. 13. Generalised section across the St. Agnes Beds.

Successions based on borehole data, bedrock profile based on geophysical evidence and borehole data.

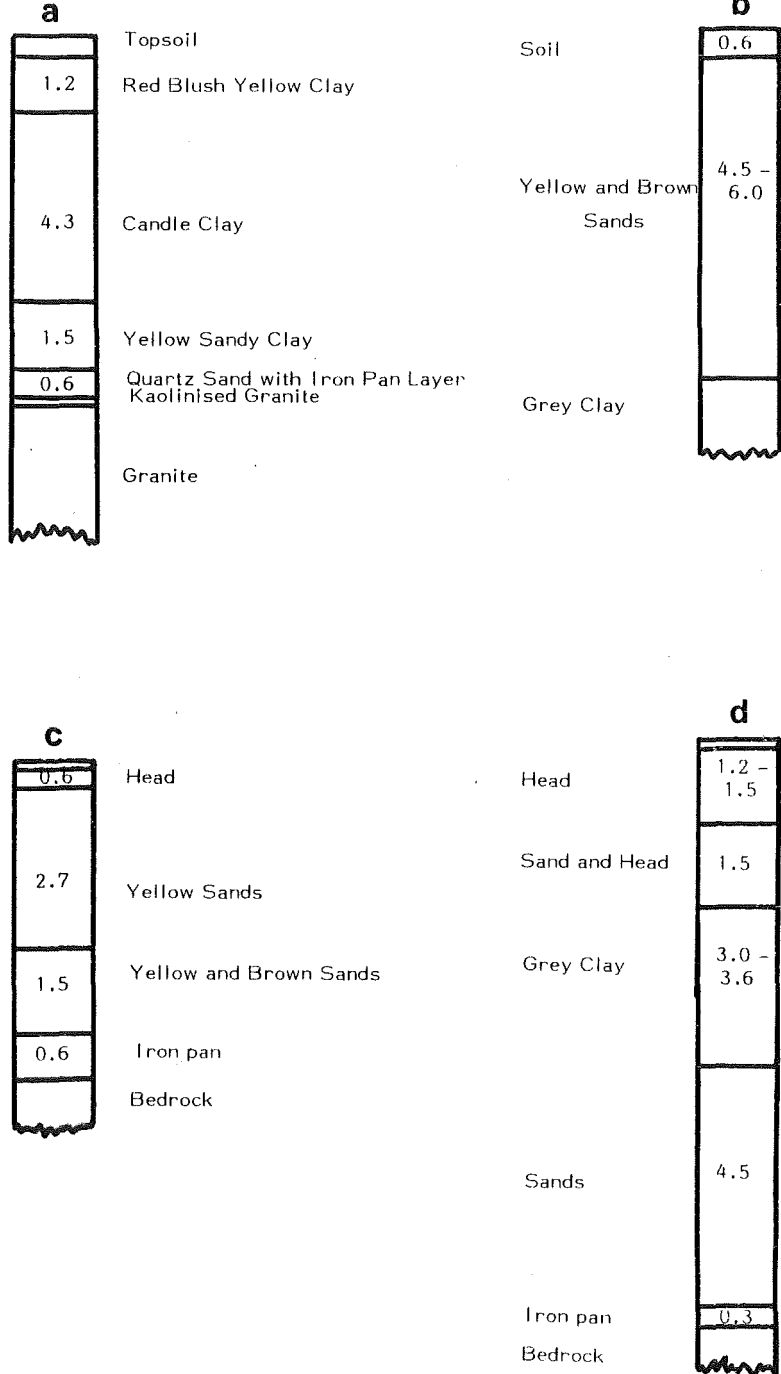


Fig. 14. Sections from the St. Agnes Beds.

(a) from Beacon Cottage Farm Pits; (b) from Doble's Sand Pits, upper pit;

(c) and (d) from Doble's Sand Pits, lower pit. Thicknesses in metres throughout.

d) Upper sand/clay

i) Sand facies

In the area of Dobles Sand Pits the uppermost part of the St. Agnes deposits is formed of fairly thick, around 3 metres, yellow and buff sands showing evidence of marked current bedding. Exposed sections are much affected by permafrost action and the contact with the overlying Head is much convoluted.

ii) Clay facies

In the sections at Beacon Cottage Farm, now badly overgrown and built upon, and in the boreholes drilled there the uppermost representative of the St. Agnes beds is argillaceous and mottled red-yellow. These clays were known as 'Red Blush' when these pits worked for candle clay and they are at least 4 metres thick. This change in facies may be very sharp and may be related to the rise in the level of bedrock near the St. Agnes Granite Quarry (7042 5074).

The form of the sub-St. Agnes Beds surface

Within the immediate vicinity of the Dobles Sand Pits the exposed sub-St. Agnes Beds surface is relatively flat and even. Outside the pits deductions have to be made based on geophysical evidence and sporadic boreholes. This evidence suggests that there exists a series of sub-parallel ridges and depressions in the rock head aligned ENE/WSW or NE/SW, one such ridge trends through the St. Agnes Granite Quarry.

The age of the St. Agnes Beds

Until 1960 the St. Agnes beds were thought to be unfossiliferous for dating purposes.

In investigation of the St. Erth beds Mitchell noticed on display in the south west England regional cabinet at the Museum of Practical Geology, South Kensington, a specimen of apparently lignitic clay. The specimen was reported to have derived from the Beacon Cottage Farm Pits. In his notebook for the year of collection, 1932, Dewey is not specific as to the exact location of the lignite when collected from the Pits. Mitchell 1965, records Oligocene elements in the preserved microfauna, matching that of the Oligocene of the Isle of Wight. "The pollen of the temperate genera that are characteristic of the late Tertiary appear to be completely absent. Though the possibility that the lignite at St. Agnes is derived from some earlier deposit cannot at present be overlooked, the Pliocene age of the deposit and platform can no longer be assumed" (Mitchell 1965). The lignite sample has been examined by Boulter and a list of the flora is given in Atkinson et al (1975). Boulter's examination led to the conclusion that the material is of Middle-Upper Oligocene age, and that the sediment must now be considered a basal remnant of a late Oligocene continental mainly fluvial deposit of currently unknown extent. Wilson (1975) states that the Palaeogene

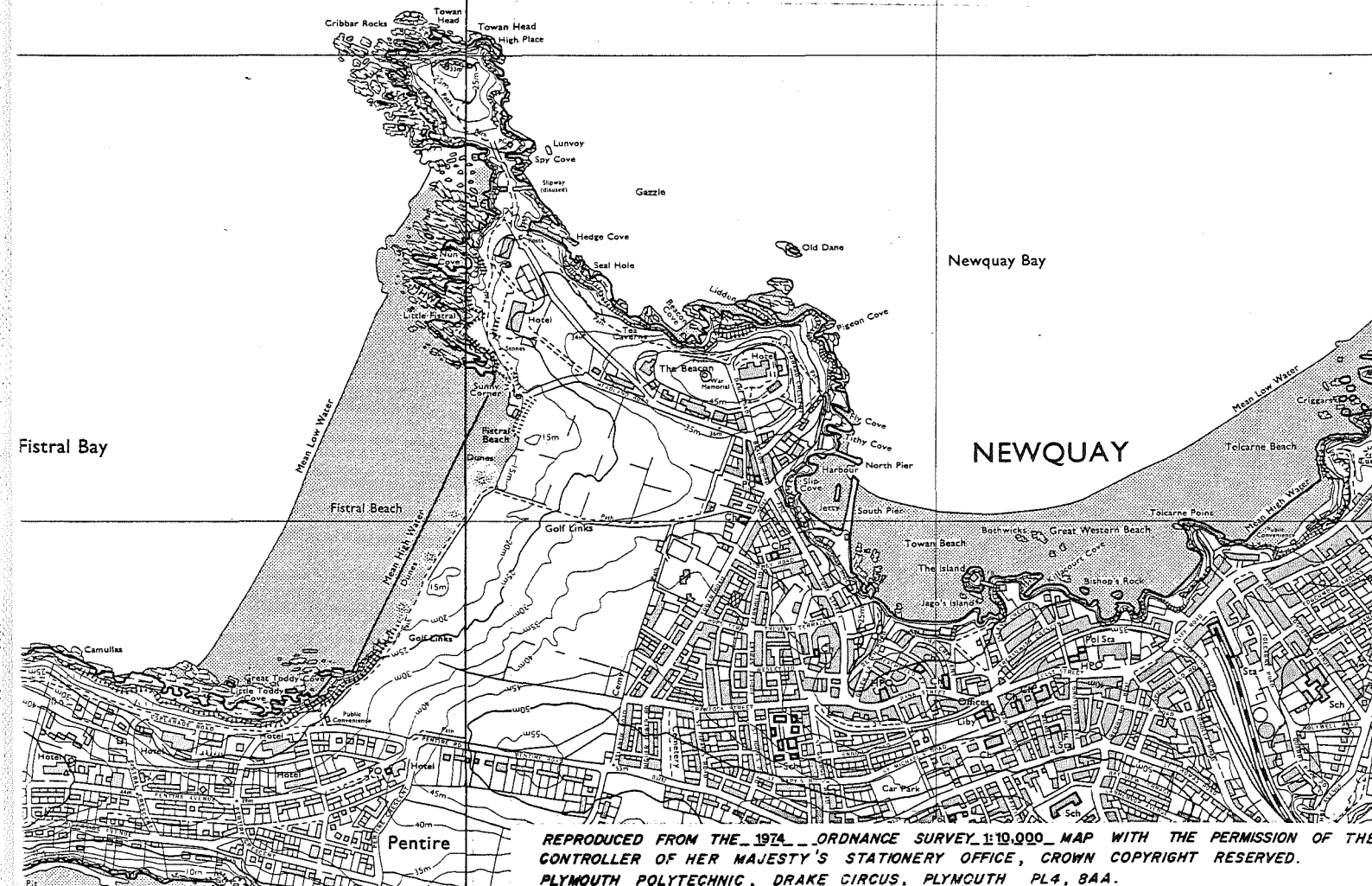
St. Agnes Beds were extensively eroded by marine action in the Late Pliocene. Despite many boreholes in the outlier, some in the Beacon Cottage Farm area, no further samples of the lignitic clay, with a comparable flora, have been recognised.

Until more pollen-bearing lignitic clay is found in situ the question of the age of the St. Agnes Beds cannot be satisfactorily answered. If the lignite is in situ and the underlying sands are marine as believed by many earlier authors, then the beach is much older than the nearby St. Erth Beds (551 350) with which they have considerably mineralogical affinities. If, as already suggested (Atkinson *et al* 1975), the beds are middle to Upper Oligocene and fluvial in origin, this fluvial phase could have considerably contributed to modification of the pre-submergence landscape.

The third possibility would arise if the lignite was derived elsewhere and washed into the St. Agnes Beds which could be of Coralline Crag age as previously accepted. In this final interpretation there would appear to have been an early Tertiary land surface near St. Agnes with environmental conditions suitable for the Oligocene deposit to survive until late Pliocene.

Acknowledgements

Many of the observations made in this description arise from work carried out jointly by the author and Dr P.T.Walsh of the City University with the assistance of students from the Camborne School of Mines and the City University. Dr Walsh and the author hope to publish a full description of the beds and their interpretation in due course.



FISTRAL BAY, NEWQUAY

Sections of Pleistocene deposits, resting on a 1.8 to 3 m wave-cut platform are exposed at either end of the beach. To the north, there are small cliff sections below and to the west of the Headland Hotel and in the south, more substantial cliff sections appear below and to the north of the St. Rumons Hotel. These sections have been referred to and described in part by Reid and Scrivenor (1906), Guilcher (1949) and Stephens (1966).

Northern sections: Along the cliff path moving north from the Fistral Bay carpark, the following sections can be seen.

	<u>Unit</u>	<u>Thickness</u>	<u>Description</u>
1.	E	0.3 m	Sandy modern soil
	C	0.15 m	Small angular stony fragments (mainly slates and quartz) in a sandy soil matrix
	B	0.15 - 0.2 m	Small stony fragments (as in C, but less angular) in a sandy matrix passing down into
	A	0.8 m	Sand
<hr/>			
2.	E	0.3 m	Sandy modern soil
	B/C?	0.15 m	Stony layer with larger angular fragments passing downwards into sand
	A	0.8 m	Sand
(See also Fig.15)			
<hr/>			
3.	E	0.15 m	Sandy modern soil
	D	up to 1.5 m	Blown sand
	C	0.15 m	Stony layer with angular fragments
	B	0.2 m	Small angular stones in a sandy matrix
	A	1 m	Sand
(See also Fig.15)			
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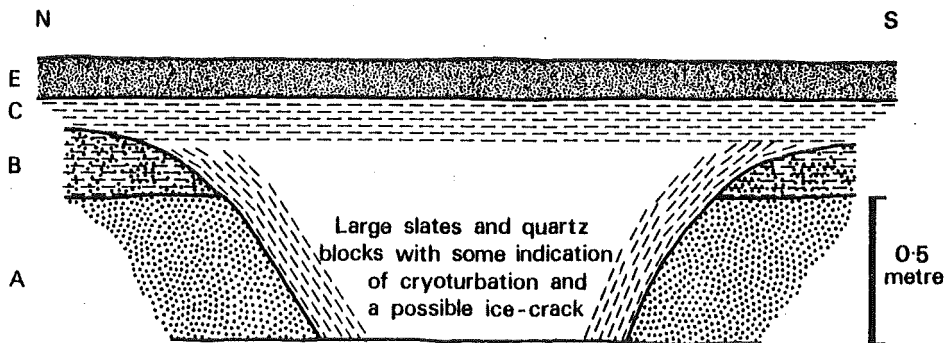
4.	0.3 m	Modern Soil
	0.2 m	Blown sand
	0.15 m	Old soil
	0.2m	Stony layer with small angular fragments
	1m	Quartz, granite and slate fragments <1 cm dia. in a sandy clay matrix. Towards base, stone fragments become very well rounded.
	4 m	Sand rock, gross-bedded at base
	0.6m	Raised beach. Well rounded pebbles 2 to 5 cms dia. mainly of quartz but with some sandstones cemented by lowest layers of overlying sandrock, resting on and let down into pockets on the rock platform below.
Wave-cut rock platform		

Southern sections: North of the life-guards huts, good sections are exposed of deposits resting on a well defined rock platform. As Guilcher noted, much of the upper cliff sections are hidden by slips and cliff falls, so only the lower deposits are described here.

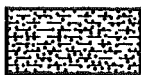
5.	0.6 m	Modern soil
	10 -15 m	Cliff, deposits not seen
	4 m	Sand rock
	0.6 m	Raised beach, composed of very well rounded quartz pebbles cemented in a manganese stained matrix. Set in the base are some large rounded quartz and granitic blocks c. 0.6 m dia.
Wave-cut rock platform		

6.	0.6 m	Modern Soil
	10 - 15 m	Cliff, deposits not seen
	4 m	Sand rock

SECTION 2



Modern soil



Head in sand matrix



Head



Sand

1 metre

SECTION 3

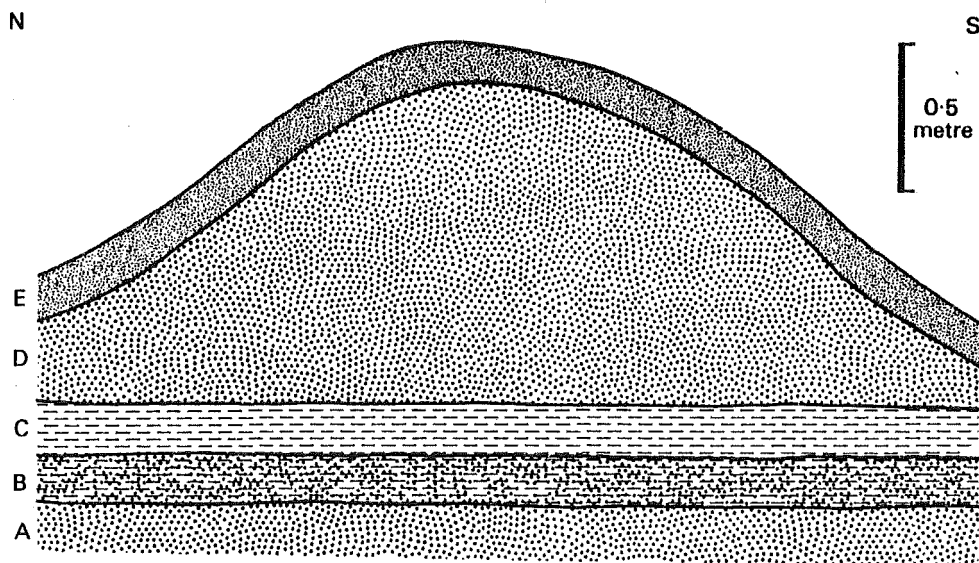


Fig. 15. Fistral Bay, northern end

2 m Raised beach. Many well rounded
c. 2cm quartz pebbles in a grey
sandy matrix, uncemented. Thin
layer (0.1 m) of manganese
stained and cemented material at
base.

Wave-cut rock platform

- 7.
- | | |
|-----------|--|
| 0.6 m | Modern Soil |
| 10 - 15 m | Cliff, deposits not seen |
| 3 - 4 m | Sand rock with thin bands of
small quartz pebbles. Sand rock
with some incorporation of
angular slaty material (Head?)
apparently in bands up to 0.6 m
thick. |
| 1 m | Raised beach with well defined
manganese stained and cemented
sand layer (0.25 m thick) at base
resting on sloping wave-cut
platform. Angular slate blocks
(broken parts/frost-shattered?
wave cut platform) are incorporated
with the raised beach. At base,
some large c.1m dia. well rounded
boulders. |

Wave-cut rock platform

PENDOWER

A series of previously undescribed coastal sections are exposed to the east of the river at Pendower Beach (G.R. 898382) about 2.5 kms. south-west of the Veryan. (Figs. 16 and 17).

At site 1, the Upper Head mantling the valley side and part of the coastal slope is revealed. The blocky head shows some disturbance, possibly by frost-induced convolutions, and the slaty strata, with prominent quartz veins, is drawn out down slope. Sand containing some angular rock fragments (head?) is sealed by head, and in turn overlies sand with rounded pebbles (raised beach?), and an elevated rock platform. There is much manganese staining of the deposits.

Passing eastwards along the sections at site 2 blocky head is seen in contact with a rock platform and is overlain by sandy-pebbly layers (mostly quartz pebbles) and further head. Site 3 displays a fossil notch near the base of the rock cliff. Here the raised beach with incorporated head is cemented to the rock wall (cf. Porthleven 'fossil' notches). The head is blocky and rests upon a raised beach, usually well-cemented with manganese. An elevated rock platform is present and the modern beach appears to coincide with a lower rock platform. The age relationships of these platforms and the raised beach are open to different interpretations.

At site 4 the thickness of sediments has increased, with considerable head deposits overlying a substantial raised beach of sands and pebbles, and an elevated rock platform. The separation of the elevated rock platform from that at modern beach level is clear, and at site 5 contemporary notching of the bed rock can be observed. The deposits here consist of two heads separated by sands with occasional rock fragments.

At the eastern access point to the beach (site 6) some 3 metres of head rests upon sand and a well-exposed raised beach containing many highly rounded boulders. Between sites 5 and 6 there are a number of large blocks and boulders, apparently 'stranded' upon the lower of the two rock platforms, and below high water mark. Some of these boulders may be 'erratics', but others are perhaps derived from the Gramscatho Beds and consist of local cherts, conglomerates and spilitic lavas. Work is in progress to investigate the possible 'erratics'.

Western End

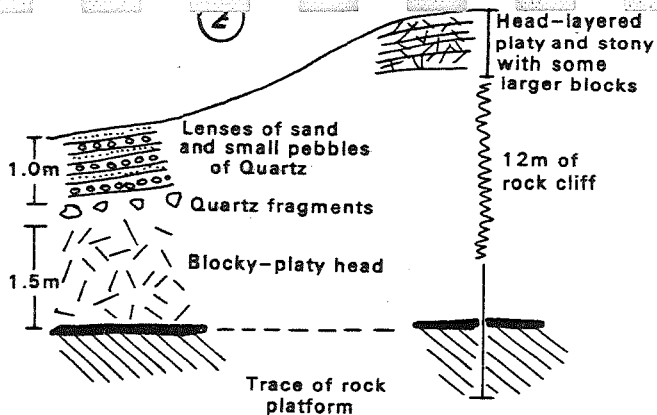
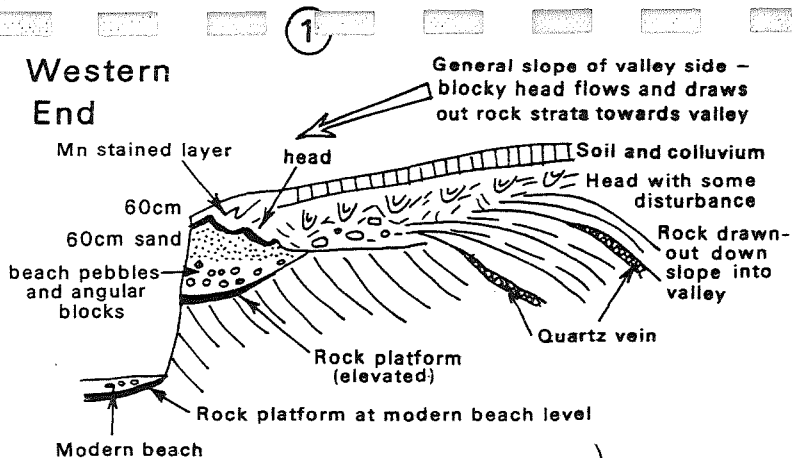
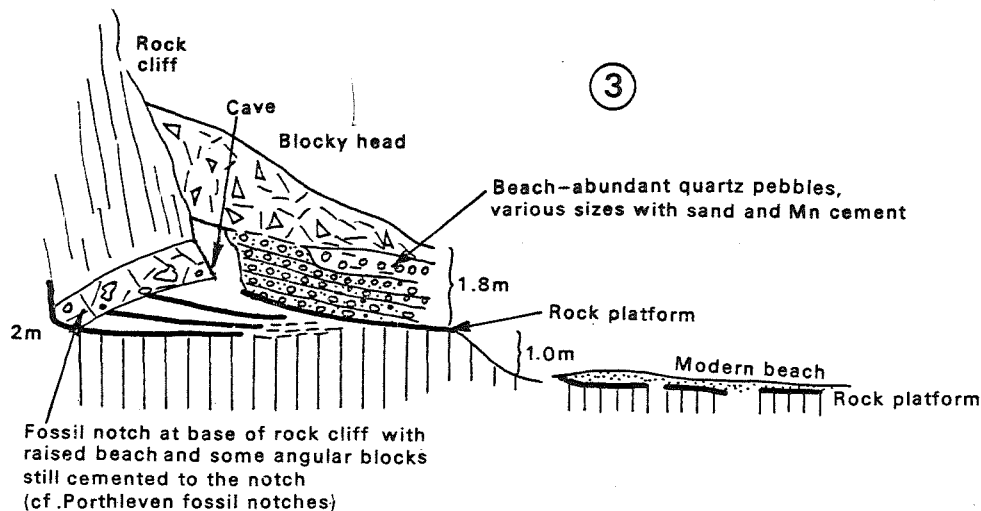


Fig. 16. PENDOWER SECTIONS



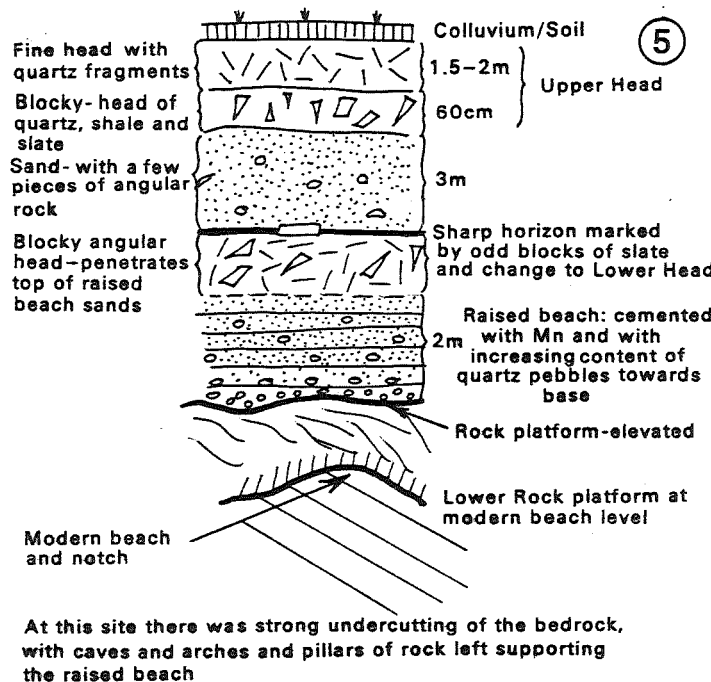
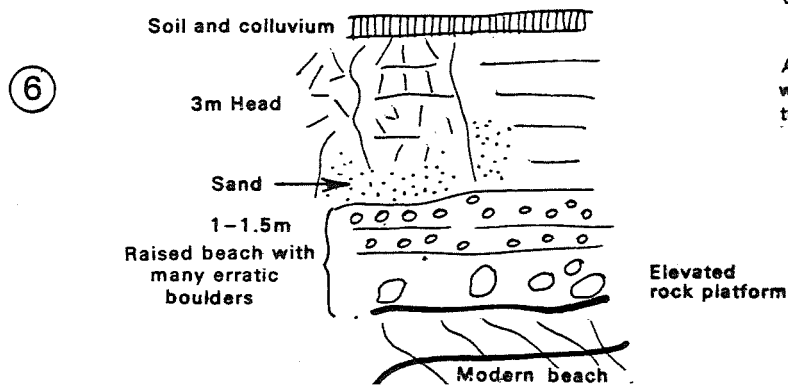
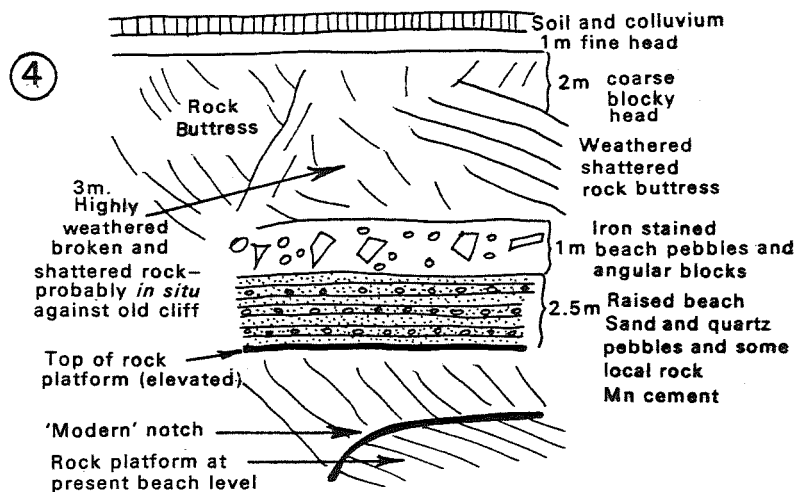


Fig.17. PENDOWER SECTIONS
(continued)

Eastern End

DAY 4

TREBETHERICK

"A coast exposure of raised beach and later deposits, the best and probably the most important Pleistocene occurrence in Cornwall." (Macfadyen, 1970). Superficial deposits rest on wave-cut platforms along both sides of the Camel estuary for some 2½ km north of Padstow. The best exposures occur on the eastern side of the river, north of Rock in the area between Daymer Bay and Trebetherick Point. The sections have been described in detail by Ussher (1879), Reid et. al. (1910), Arkell (1943), Clarke (1965) and Stephens (1966, 1970).

Most authors agree that the base of the superficial deposits is a rock platform. However, as is common with so many places in South West England, the platform varies in height from less than 1m above H.W.M.S.T. to some 7m above H.W.M.S.T. Arkell (1943) recognises levels at + 15 ft (4.6m) to + 20 ft (6m), roughly 10 ft (3m) above high water mark; Clarke (1965) notes 15 ft (4.6m) and 25 ft (7.6m) platforms whilst Stephens (1970) notes a lower planation at 10 ft (3m) above the modern beach cutting into a higher level 20-25 ft (6 - 7.6m) platform at the northern end of the exposed sections. It is assumed that the lower platform is younger than the higher one although it is not possible to give a precise date nor to satisfactorily relate the ages of the platforms to the sequence of Pleistocene deposits. There is further disagreement on the dating and origin of the superficial sediments which rest on these platforms.

Stephens (1966) notes the following general sequence:

- (viii) Blown sand and soil formation on top of the Upper frost disturbed head.
- (vii) Frost action during which Upper Head was contorted by frost wedges and cracks.
- (vi) Accumulation of Upper head - sometimes separated by a sand layer from the Main head below.
- (v) Erosion and weathering of Main head.
- (iv) Accumulation of coarse, blocky Main head (and Boulder Bed/gravels of Arkell; 1943) with a sandy-clayey matrix.
- (iii) Sand accumulated or sandrock formed incorporating raised beach pebbles at base.
- (ii) Accumulation of a head on the higher rock platform.
- (i) Wave-cut rock platforms.

Stephens (1970) describes the deposits by reference to two sections (Fig 18 A and B). In section A, blown sand and top soil (1) overlap a dark clay (2) which contains slate and quartz pebbles. This overlies the a coarse slaty head with a sandy-clayey matrix (3) with some sand

and rock fragments at its base (4), all resting on a wave-cut platform some 2.5m to 3m above the back of the modern beach.

Section B shows a sandy soil (1) resting upon an Upper Head (2) overlying a stony head (4) with slates, large quartz fragments, together with pebbles and boulders. This deposit is equivalent to Arkell's Boulder Bed and Stephens comments that it resembles an out-wash deposit which has incorporated some head. The top of this unit is convoluted and contains small fossil ice wedges (3). A considerable thickness of sand and sandrock (5) then overlay a coarse head (6) and shattered bedrock of the higher wave-cut platform.

Macfadyen (1970) attempts a correlation of the deposits largely based on Arkell (1943):

?	Sub-Boreal:	1.5 - 6ft	(1.5 - 1.8m)	Blown Sands
Atlantic	:	0 - 1ft	(0 - 0.3m)	Submerged forest and old soil
Wlrm	:	0 - 1ft	(0 - 0.3m)	Younger head
Eeemian	:	0 - 12ft	(0 - 3.7m)	Trebetherick boulder gravel
Riss	:	0 - 6ft	(0 - 1.8m)	Main head
Hoxnian	:	3 - 45ft	(1 - 13.7m)	False-bedded blown sand and sandrock. Raised beach conglomerate overlying 10ft wave-cut platform.

Clarke (1965) recognises thirteen distinct units in the area:

1. Frost-shattered brash
2. Main head
3. Brown solifluction clay
4. Grey clay
5. Hard sand with marine shells
6. Stratified sands with rounded beach pebbles
7. Boulder gravels
8. A breccia/conglomerate at St. Saviour's Point
9. Stoney clays and sands at St. Michael's Rock
10. Dune sand
11. Sandrock
12. Fossil wood
13. Occasional raised beach pebbles

This list does not constitute a dating sequence, although there are obvious correlations to be made with the deposits described by Arkell (1943) and Stephens (1966, 1970). Unit 1 represents the frost-shattered bedrock of the wave-cut platforms and may in part be an old head with the fines removed (cf. Stephens, 1970 section A, unit 4; section B, unit 6, Fig). Unit 2 - the Main Head, is described by Clarke to be 0 - 11ft (0 - 3.4m) thick and is correlated by him with the Last or Main Irish Sea Glaciation. The surface of this head is extensively weathered. The 2 - 4ft (0.6 - 1.2m) thick Brown solifluction, clay, Unit 3, overlies the Main Head unconformably and extends onto solid rock or the frost-shattered 'brash' of the platforms (cf. Younger Head of Arkell, 1943; Unit 2 of Stephens, 1970, Fig. 18).

The Hard sand with marine shells (Unit 5) overlies the Brown solifluction clay and passes upwards into the modern dune sands. Clarke (1965) notes that this deposit is poorly stratified at Daymer Bay whilst at Trebetherick Point, rounded pebbles of sandrock are present. It is suggested (Clarke, 1965) that the deposit is part wind-blown, part

TREBETHERICK POINT, CORNWALL

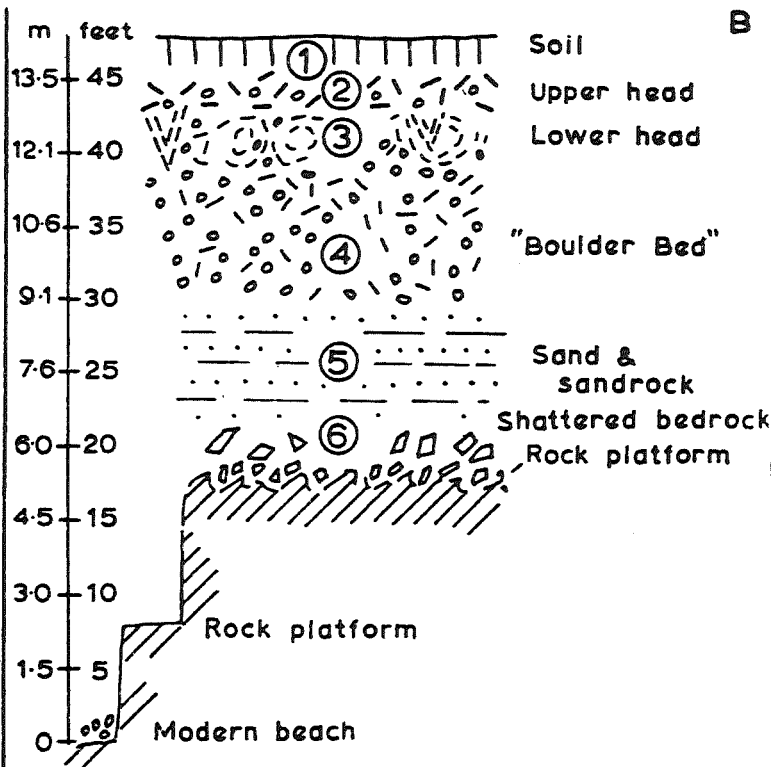
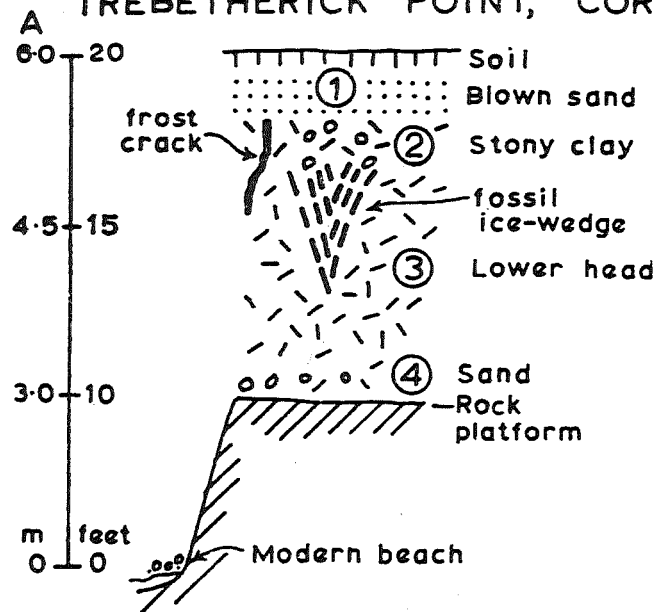


Fig. 18.

storm beach and probably post-glacial in age.

The stratified sands with rounded beach pebbles which constitute Unit 6 occur between the Main Head and the Brown Solifluction clay in Daymer Bay. The deposit is 2 - 5ft (0.6 - 1.5m) thick, lying in pockets on the weathered surface of the Main head. Quartz pebbles are present in sufficient numbers to suggest a beach gravel (Clarke, 1963), although the inclusion of angular slate fragments probably indicates that this deposit represents a transition between the two heads.

Unit 7 constitutes one of the most interesting deposits of the area. Large rounded to subangular stones, to 30cm in diameter, are set in a sandy clay matrix making a 3.7m thick deposit about 7.6m above high water mark. The position of this boulder bed was described as above the Main head of Arkell. Stephens (1966, 1970) considers the boulders and gravels to be contemporaneous with the Main head. The rock types of the stones and boulders are extremely varied. Arkell (1943) noted Bunter quartzites, granites, dolerites, phyllites and aplites. Clarke (1965) records mica schist, rounded flints and dark red grit.

Arkell's view: The Boulder bed represents an interglacial terrace gravel or a shore deposit with much of the material possibly of glacial origin. The deposit was formed when sea-level was about 12 - 13.7m above present, during the Ipswichian interglacial.

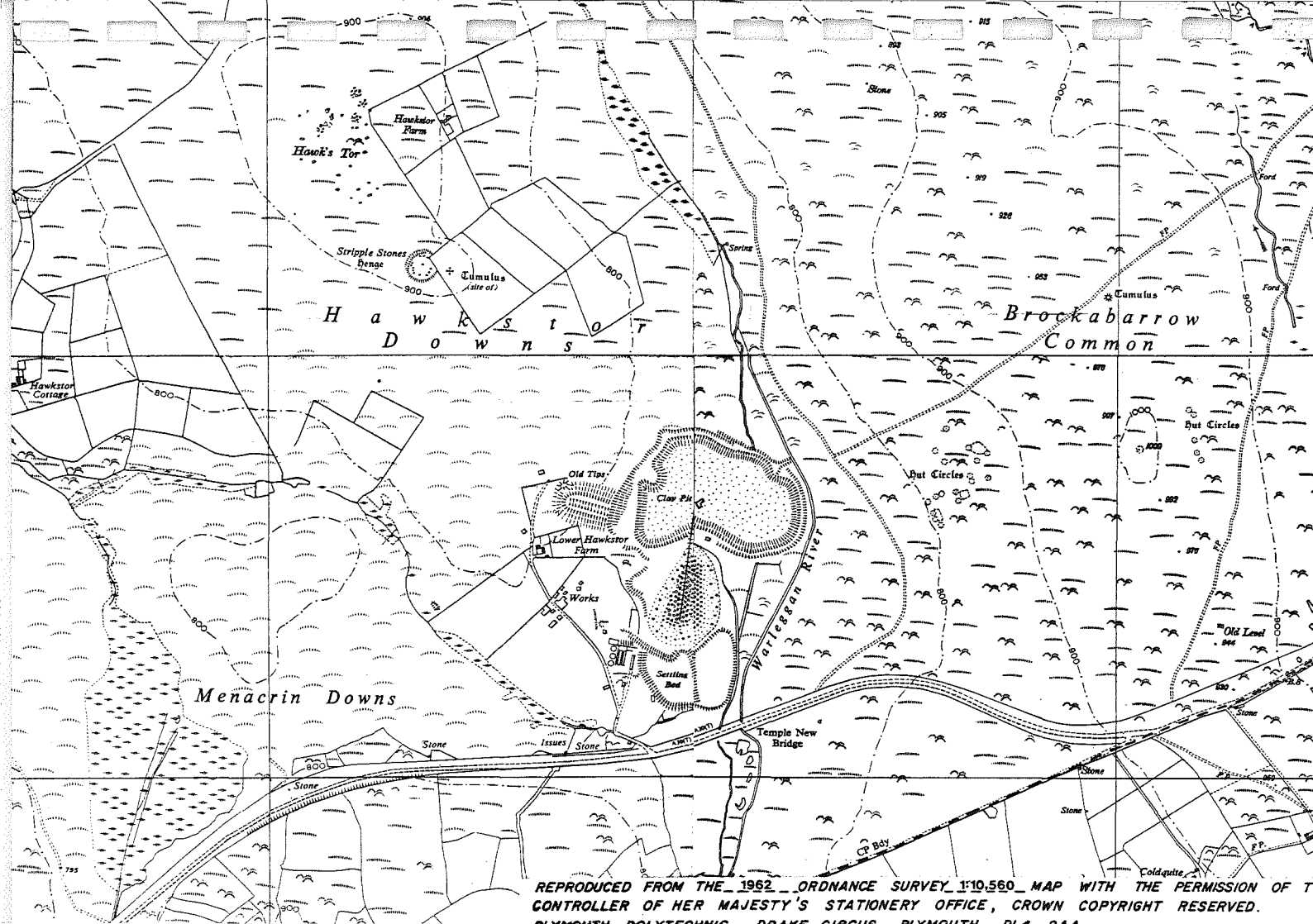
The erratics are derived either from ice-rafting, the Irish Sea ice itself or the River Camel. Arkell seems to favour the latter although there is no positive corroboration.

Clarke's view: Marine erosion of a Bristol Channel moraine deposited at Trebetherick as a beach gravel during the Ipswichian interglacial. Some incorporation with the Devensian Younger head has occurred. A possibility that the deposit is a glacial till.

Stephens' view: The Boulder bed is unlike any other raised beach deposit of South West England. It contains angular slate pieces within the matrix and no marine shells. He concluded that the deposit is a mixture of the Main head and glacial outwash gravels or a mixture of outwash gravel and Irish Sea ice till (cf. Fremington till, Barnstaple Bay) which has been subjected to later frost action.

Clarke's Unit 10 represents the youngest of the superficial deposits in the area attaining a considerable thickness up to 50ft (15.2m). These cross-stratified, wind blown, post-glacial sands have formed a large and extensive vegetated dune system between Rock and Polzeath.

Similar, but older and cemented deposits form the sandrock of Unit 11. Good exposures are seen north of Trebetherick Point. Arkell (1943) records the deposit as being current-bedded with a general dip to the north. This sandrock attains a thickness of 25ft (7.6m) in places, is generally overlain by the Main head or the Boulder bed and rests on the wave-cut platform (Fig. 18, Section B).



REPRODUCED FROM THE 1962 ORDNANCE SURVEY 1:10,560 MAP WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE, CROWN COPYRIGHT RESERVED.
PLYMOUTH POLYTECHNIC, PLATE 1, PLYMOUTH, PL1 8AA

DEPOSITS AT HAWKS TOR, BODMIN MOOR

1. Introduction

This account is based on the observations and work of Conolly, Godwin and Megaw (1950) and Brown (1977). The sedimentary record at Hawks Tor is discontinuous and additional records from Parsons Park china clay quarry as well as the mire at Dozmary Pool are necessary to provide a complete record of Late-Devensian and Flandrian vegetational history and climate on Bodmin Moor.

2. Hawks Tor Sediments

2.1 General description

Up to 2.5m organic sediment is exposed at the edge of the present workings in the valley bottom, thinning to less than 0.5m on the surrounding hillsides. Greater depths may have existed at the centre of the area before its excavation for kaolin and it is possible that these sections had been already reduced by peat cutting in historic times. In the longest profiles the upper 1.5 - 2.0 m sediment is peat of varying degrees of humification, all attributable to the Flandrian. The lowest sediments are generally silty or gravelly, although superficially they may look organic, and are attributable to the Late-Devensian and some, possible, to the full Devensian.

2.2 Deposition and interpretation

2.2 (a) Late-Devensian and earlier (Fig 19)

It is both stratigraphically and biologically probable that, in this section, the earliest sedimentation occurred at the site of monolith HT4 although no dates are available. The lithology and fossil record here suggest cyclical silt and gravel deposition into still water from an area with treeless vegetation. It contains pollen and plant macrofossil indicators of cold climate vegetation including that of hillside snowbeds.

The oldest dated sediment is that from monolith HT3, 13088 ± 300 B.P., and indicates deposition in a shallow mud-bottomed channel filled with clear water which, both on lithological and biological evidence, became shallower converting to sedge mire by about 12600 B.P. All the plant fossils indicate cold-loving treeless vegetation. A transition to woody sedge peat and the pollen record show that development of tall-herb fen and then birch carr followed by about 11500 B.P. This is a clear indication of climatic amelioration. The depositional sequence at HT3 continues with a gravel containing no pollen. The junction between this and the underlying sediment is sharp and unconformable and is a product of solifluxion.

Deposition at monolith HT2 starts with fen peat containing birch wood deposited up to about 11000 B.P. The sediments immediately above this are silty and their pollen record indicates open treeless vegetation with several indicators of cold climate. There is no visible or palynological evidence of an unconformity between this and the succeeding sediment but an unconformity may be inferred from the radiocarbon date for the pollen assemblage zone boundary here (9654 ± 190 B.P.) which is too young for the opening of the Flandrian. Several unconformities of this age have been observed previously and their

origin is discussed in Brown (1977) and Godwin and Willis (1959).

There is abundant visual evidence of solifluxion in the sediments deposited between about 11000 and about 9700 B.P. (Fig. 20). The gravel capping monolith HT3 is solifluxion gravel. Brown (1977) argued that this solifluxion was a product of wet-soil creep under a cold oceanic climatic regime. The banded silts of HT4 may also be ascribed to an earlier period of solifluxion producing a heavy sediment load in the streams feeding the valley pools.

Four botanical records of interest which highlight conditions on Bodmin Moor during the Late-Devensian cold phases are those of Luzula arcuata, Epilobium alsinifolium, Artemisia norvegica and Astragalus alpinus. From the dated profiles L. arcuata is found only after the period equated with the Allerød, that is, after 11069 B.P. The other are found only before the Allerød, that is, before 11553 B.P. However in the undated monolith HT4 L. arcuata and A. norvegica are found together in sediment which almost certainly antedates the Allerød on Bodmin Moor.

L. arcuata is a circumpolar arctic-montane species presently distributed in the Cairngorms, the western fringes of Scotland and the Scandinavian mountains. E. alsinifolium is arctic-montane and is presently distributed through northern England and Scotland. Artemisia norvegica is a eurasiatic arctic-montane species found in the northwest highlands of Scotland, north of Dovrefjellet in Norway, in the Urals and Siberia around the Lena River. Astragalus alpinus is a circumpolar arctic-montane species of base-rich rocks in the eastern Scottish highlands and Scandinavia generally north of 65°N. It is an indicator both of low mean annual temperature and of soil enrichment by solifluxion in this case.

2.2 (b) Flandrian

Flandrian sediments studied by Brown (1977) were represented only in monolith HT2. At the base they are usually highly humified Sphagnum and sedge peats which grade into Sphagnum/Eriophorum peats of decreasing humification. The fossil record indicates coverage of the Late-Devensian sediments by wet Sphagnum mire which are rapidly dried to fen carr followed by raised bog development resulting from impeded drainage. Development of blanket bog at about 1100 B.C. is argued by Brown (1977). Development of pastoral and, later, arable agriculture followed, clearly evident in the pollen record.

2.3 Synthesis of events at Hawks Tor

(See Table 2)

3. Comparison with other sites on Bodmin Moor

3.1 Stannon Down (Dickson, 1965).

Banded silts and gravels (without stratigraphical correlation or radiocarbon dating) revealed pollen and plant macrofossils of snowbed vegetation. Ascribed to the Late-Devensian by Dickson. Very similar to basal undated sediments at HT4.

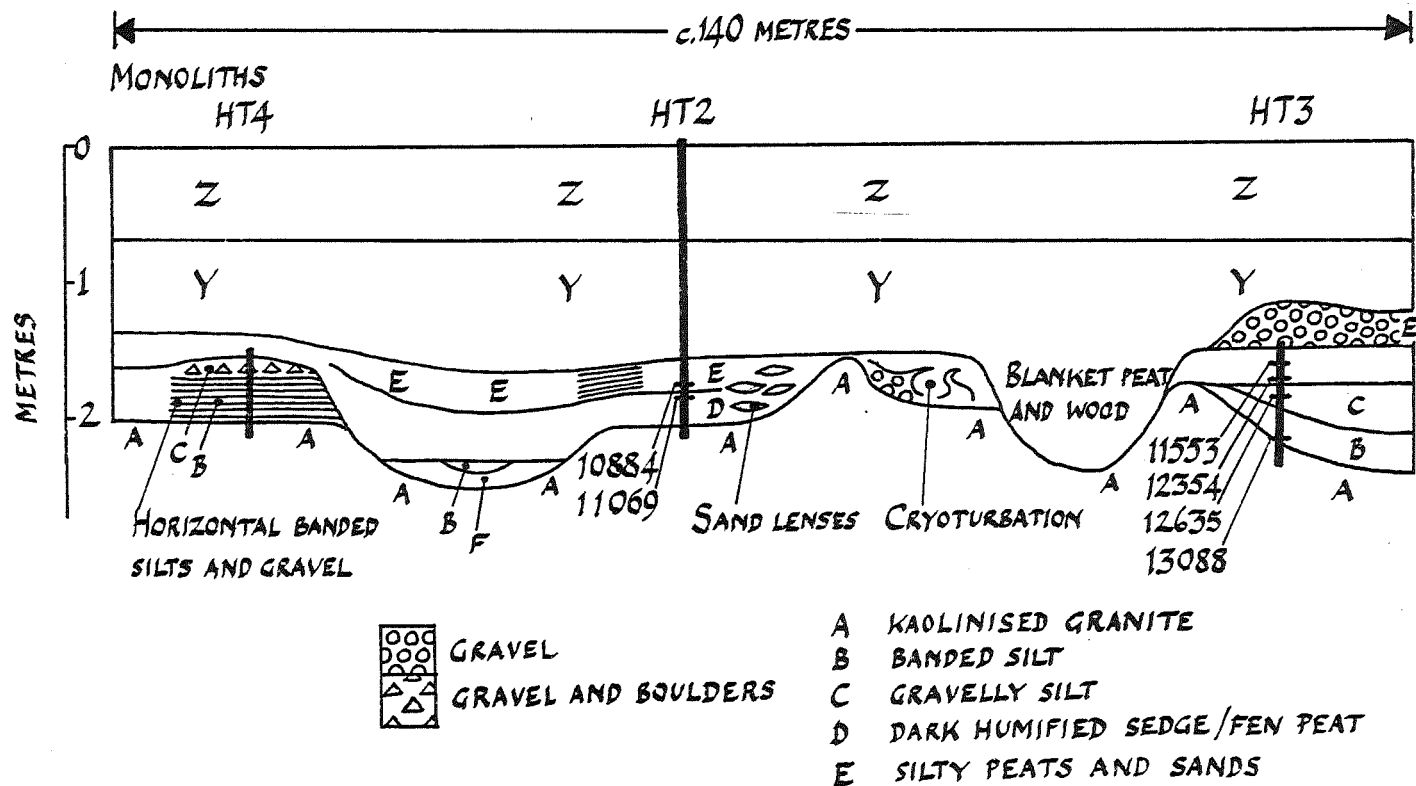


Fig. 19. Composite simplified section of the northeast face of exposures at Hawks Tor 1970-71 (adapted from Brown 1977)

Y HUMIFIED RAISED BOG PEAT
Z UNHUMIFIED SPHAGNUM PEAT

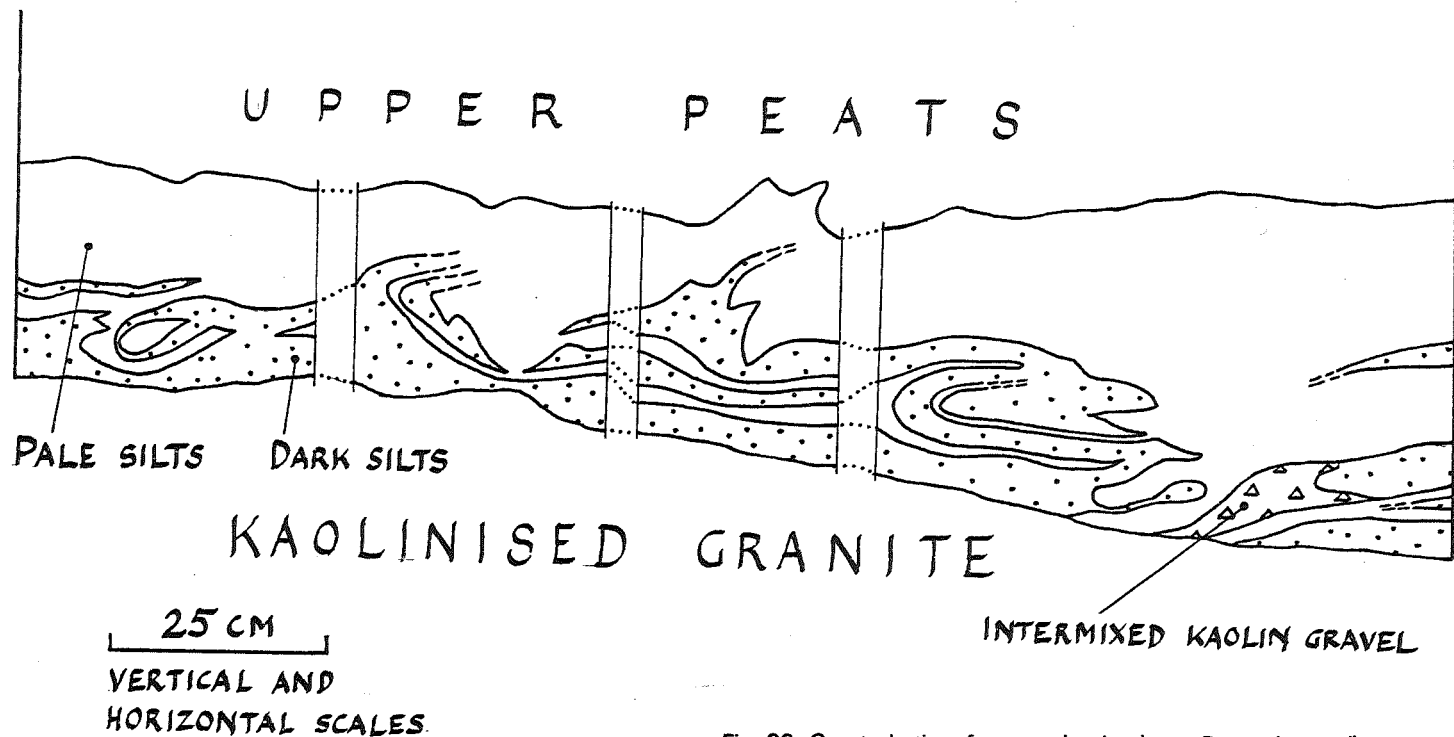


Fig. 20. Cryoturbation features in the Late-Devensian sediments,
east face, Hawks Tor, 1970

2.3 TABLE 2 SYNTHESIS OF EVENTS AT HAWKS TOR

	Regional Pollen Assemblage Zone (Brown, 1977)	Dates *= ¹⁴ C date years B.P.	Number of Distinct Pollen Assemblage Zones in all Monoliths	Remarks
FLANDRIAN	BM7 Birch-Oak zone		4	Blanket bog developed
	BM6 Birch-oak-alder zone	c.3000	3	Climate wetter than previously
	BM5 Hazel-birch-oak zone	*6451±65	1	Dry climate, slow peat deposition and some erosion (continuous record only at Dozmary Pool). Woodland on hillsides after early immigration of oak and hazel
	BM4 <u>Empetrum</u> -juniper zone	*9061±65	2	Climatic amelioration occurs. Dwarf shrub heaths on hillsides
LATE - DEVENSIAN	BM3 Sedge-grass zone	greater than *9654±190	3	Amorphous solifluxion occurring. Open or shrubby vegetation, treeless. Valley mires snowbeds
	BM2 Birch- <u>Empetrum</u> zone	*11069±220	2	Birch woods in valley bottom. Equivalent to Allerød
	BM1	*11553±280		Amorphous solifluxion gives deposition of banded silt in valley pools. Open snowbeds then juniper on hillsides
		earliest date *13088±300		

3.2 Parsons Park (Brown, 1977; Conolly *et al.*, 1950)

Deposits only about 1.3 m deep. Abbreviated sequence with distinct unconformity covering BM5 pollen assemblage zone. BM2 and BM3 represented in basal sediments very similar to those at Hawks Tor except that clear banding of silts is absent.

3.3 Dozmary Pool (Brown, 1977; Conolly *et al.*, 1950)

2.4 m of lake mud, sedge and fen peat topped by decreasingly humified raised bog peats which cover regional pollen assemblage zones BM5, 6 and 7. The sediments investigated by Brown are Flandrian, and deposition started at 9053 ± 120 B.P. There seem to be no unconformities in the sequence, unlike at Hawks Tor. This is almost certainly because, during the climatic optimum (c.7900 to c. 6500 B.P.), the Dozmary water supply was always adequate to allow anaerobic preservation, whereas at Hawks Tor and Parsons Park the mires dried out, fossil preservation ceased and, furthermore, erosion may have taken place.

Thus Dozmary Pool contains, as yet, the only unbroken Flandrian pollen sequence on Bodmin Moor and is a key to the interpretation of the abbreviated sequences of Hawks Tor and Parsons Park. A successful search for a longer profile would be of utmost value.

4. Significance of these events

The dated sequence of pollen assemblage zones provided by Brown (1977) and their interpretation have shown that the vegetation by the 'oceanicity' of local climate and by exposure to wind. As a result the vegetational history shows great similarity to other sites on the western fringes of Britain and, indeed, France.

Climatic amelioration earlier than the "Allerød" birch pollen rise (11553 ± 280 B.P.) is indicated by the pollen record of juniper expansion from 12635 ± 300 B.P. onwards and by the occurrence of *Sagittaria* pollen just before 12635. *Sagittaria* has, essentially, a continental distribution. Investigation of the Coleoptera of Hawks Tor by G. R. Coope (unpublished) confirms the slimmer botanical evidence for this early amelioration.

REFERENCES

- Andrews, J.T. et al., 1979. Amino-acid ratios and the correlation of raised beach deposits in south-west England and Wales, Nature., 281, 556-558.
- Arkell, E.J. 1943. The Pleistocene rocks at Trebetherick Point, North Cornwall, Proc. Geol. Assoc., 54, 141-170.
- Atkinson, K., Eastwood, N.J., and Scott, P.R. .1974. The occurrence and composition of concretionary structures in the Tertiary sands of St. Agnes, Cornwall, J. Camb. Sch. Mines, Vol. 74, 38-45.
- Atkinson, K. et al., 1975. A revision of the geology of the St. Agnes outlier, Cornwall, Proc. Ussher Soc., 3, 286-287.
- Atkinson, K. 1975. Observations on the basal hardpan of the St. Agnes Beds, Proc. Ussher Soc., 3, 288.
- Balchin, W.G.V. The geomorphology of the north Cornish coast, Trans. Roy. Geol. Soc. Cornwall, 17, 317-344.
- Balchin, W.G.V. 1964. The denudation chronology of south-west England, in Present Views on Some Aspects of the Geology of Cornwall and Devon Royal Geol. Soc. Cornwall (Ed. K.F.G. Hosking and G.J. Shrimpton), 267-282.
- Barrow, G. 1906. The Geology of the Isles of Scilly, Mem. Geol. Surv., U.K., 15-31.
- Bascomb, C.L. 1968. Distribution of pyrophosphate, extractable iron and organic carbon in soils of various groups, J. Soil Sci., 19, 251-268.
- de la Beche, H.T. 1839. Report on the Geology of Cornwall, Devon and West Somerset, Mem. Geol. Surv. U.K.

- Bell, R.G. 1888. The Pliocene Beds of St. Erth, Cornwall, Brit. Assoc. Adv. Sci. Rep., 718-719.
- Bell, A. 1898. On the Pliocene shell-beds at St. Erth; Trans. Roy. Geol. Soc. Cornwall, 12, 111-166.
- Boswell, P.G.H. 1923. The petrography of the Cretaceous and Tertiary outliers of the west of England, Quart. Jl. Geol. Soc. Lond., 79, 205-230.
- Bowen, D.Q. 1973a. The Pleistocene Succession of the Irish Sea, Proc. Geol. Assoc., 84, 3, 249-272.
- Bowen, D.Q. 1973b. The Pleistocene History of Wales and the Borderland, Geol. J., 8, 207-224.
- Bowen, D.Q. 1977. The Coast of Wales, in The Quaternary History of the Irish Sea (Eds. C.Kidson and M.J. Tooley), Geol. J., Special Issue 7, 223-256.
- Brown, A.P. 1977. Late-Devensian and Flandrian vegetational history of Bodmin Moor, Cornwall, Phil. Trans. R. Soc. Lond. B 276, 251-320.
- Clarke, B.B. 1963. Erosional and depositional features of the Camel estuary as evidence of former Pleistocene and Holocene strandlines, Proc. Ussher Soc., 1, 58-59.
- Clarke, B.B. 1965a. The Superficial Deposits of the Camel Estuary and Suggested Stages in its Pleistocene History, Trans. Roy. Geol. Soc. Cornwall, 19, 4, 257-279.
- Clarke, B.B. 1965b. The upper and lower surfaces and some structural features of the frost soils of the Camel Estuary, Proc. Ussher Soc., 1, 192-193.

- Clarke, B.B. 1969. The problem of the nature, origin and stratigraphical position of the Trebetherick Boulder gravel, Proc. Ussher Soc., 2, 87-91.
- Clarke, B.B. 1973. The Camel Estuary Pleistocene Section west of Tregunna House, Proc. Ussher Soc., 2, 6, 551-553.
- Clayden, B. 1964. Soils of Cornwall, in Present Views of some aspects of the Geology of Cornwall and Devon, Roy. Geol. Soc. Cornwall (Eds. Hosking and Shrimpton), 311-329.
- Conolly, A.P., Godwin, H. and Megaw, E.M. 1950. Studies in the post-glacial history of British Vegetation XI. Late-glacial deposits in Cornwall, Phil. Trans. Roy. Soc. Lond. B., 234, 397-469.
- Coombe, D.E. and Frost, L.C. 1956. The nature and origin of the soils over the Cornish Serpentine, Journ. Ecol., 44, 605-615.
- Crabtree, K. and Round, F.E. 1967. Analysis of a core from Slapton Ley. New Phytol 66, 255-270.
- Curry, D., Hamilton, D. and Smith, A.J. 1971. Geological evolution of the western English Channel and its relation to the nearby continental margin in The Geology of the East Atlantic Continental Margin (Ed. F.M. Delany) Inst. Geol. Sci., 2, Europe, 1-170.
- Davies, A.T. and Kitto, B.K. 1878. On some beds of sand and clay in the parish of St. Agnes, Cornwall, Trans. Roy. Geol. Soc. Cornwall Vol. 9., 196-204.
- Davies, G.L.H. and Stephens, N. 1978. Ireland: The geomorphology of the British Isles, 250 pp. Methuen, London.

- Dearman, W.R. 1963. Wrench-faulting in Cornwall and South Devon, Proc. Geol. Assoc., 74, 265-287.
- Dearman, W.R. 1971. A general view of the structure of Cornubia, Proc. Ussher Soc., 2, 220-236.
- Dickson, J.H. 1965. Historical biogeography of the British moss flora. Ph.D. dissertation, University of Cambridge.
- Donovan, D.T. and Stride, A.H. 1975. Three Drowned Coastlines of probable Late Tertiary age around Devon and Cornwall, Marine Geol., 19, 35-40.
- Edmonds, E.A., McKeown, M.C. and Williams, M. 1975. South-West England: British Regional Geology 4th Ed. H.M.S.O. London.
- Everard, C.E. 1977. Valley Direction and Geomorphological Evolution in West Cornwall, England, Occ. Papers 10, Queen Mary College, London. 1-72.
- Exley, C.S. 1965. Some structural features of the Bodmin Moor granite mass, Proc. Ussher Soc., 1, 157-160.
- Flett, J.S. and Hill, J.V. 1946. The Geology of the Lizard and Meneage. (Sheet 359), 2nd Ed. Mem. Geol. Surv. U.K.
- Garrard, R.A. 1977. The sediments of the South Irish Sea and Nymphae Bank area of the Celtic Sea, in The Quarternary History of the Irish Sea (Eds. C. Kidson and M.J. Tooley), Geol. J. Special Issue, 7, 69-92.
- Godwin, J. and Willis, E.H. 1959. Radiocarbon dating of the late-glacial period in Britain, Phil. Trans. Roy. Soc. Lond. B., 150, 199-215.
- Goode, A.J.J. and Wilson, A.C. 1976. The geomorphological development of the Penzance area, Proc. Ussher Soc., 3, 367-372.

- Green, J.F.N. 1843. The age of the raised beaches of south Britain,
Proc. Geol. Assoc., 54, 129-140.
- Guilcher, A. 1949. Aspects et problèmes morphologiques du massif de
Devon-Cornwall comparés à ceux d'Amérique, Rev.
Geog. Alpine., 37, 689-717.
- Guilcher, A. 1969. Le Quaternaire littoral et sous-marin dans
l'Atlantique (Côtes françaises), in Etudes françaises
sur le Quaternaire, VIII Congr. INQUA., 33-41.
- Guilcher, A. 1976. L'Âge des plages anciennes de bas niveau dans le
Nord-Ouest de l'Europe dans son intérêt morphologique,
Mem. Della Soc. Geogr. Italiana., 283-295.
- Gullick, C.F.W.R. 1936. A physiographical survey of West Cornwall.
Trans. Roy. Geol. Soc. Cornwall, 16, 380-399.
- Hall, A. 1974. West Cornwall, Geol. Assoc. Guide No. 19, 1-39.
- Hancock, J.M. 1975. The petrology of the Chalk, Proc. Geol. Assoc.,
86, 499-536.
- Hendriks, E.M.L. 1923. The physiography of south-west Cornwall, the
distribution of chalk flints and the origin of the
gravels of Crousa Common, Geol. Mag., 21-31.
- Hill, J.B. and MacAlister, D.A. 1906. The Geology of the Falmouth,
Truro, and the Mining District of Camborne and Redruth.
Mem. Geol. Surv., U.K.
- Hitchcock, H.D. 1970. The origins of the surface relief in the area of
Carnmenellis, Cornwall. Trans. Roy. Geol. Soc.
Cornwall, 20, 152-161
- Hollin, J.T. 1977. Thames Interglacial Sites, Ipswichian sea levels
and Antarctic ice surges, Boreas, 6, 32-52.

- Holyoak, D.T. 1980. Shell Structure and Amino Acid Racemization, Quat. Newsletter, 30, 17-24.
- James, H.C.L. 1968. Aspects of the Raised Beach of South Cornwall, Proc. Ussher Soc., 2, 55-56.
- James, H.C.L. 1975a. A Pleistocene section at Gunwalloe Fishing Cove, Lizard Peninsula, Proc. Ussher Soc., 3, 294-298.
- James, H.C.L. 1975b. An examination of recently exposed Pleistocene sections at Godrevy, Proc. Ussher Soc., 3, 299-307.
- James, H.C.L. 1976. Problems of dating raised beaches in South Cornwall, Trans. Roy. Geol. Cornwall.
- Jardine, W.G. 1979. The Western (U.K.) shore of the North Sea in Late Pleistocene and Holocene times, Acta. Univ. Ups. Symp., 2, 159-174 Ann. Quinq. Cel.
- John, B.S., 1968a. Directions of ice movement in the Southern Irish Sea Basin during the Last Major Glaciation: an hypothesis, J. Glac., 7, 507-510.
- John, B.S. 1968b. Age of Raised Beach Deposits of South-Western Britain, Nature, 218, 665-667.
- Keen, D. H. 1975. Two aspects of the Last Interglacial in Jersey, Ann. Bull. Soc. Jer., 21, 392-396.
- Keen, D.H. 1978. The Pleistocene deposits of the Channel Islands, Inst. Geol. Sci., Rep. 78/26, 1-14.
- Kellaway, G.A. 1971. Glaciation and the Stones of Stonehenge, Nature, 232, 30-35.
- Kellaway, G.A. et al, 1975. The Quaternary history of the English Channel, Phil. Trans. Roy. Soc. Lond., A. 279, 189-218.

- Kendall, P.F. and Bell, R. G. 1886. On the Pliocene Beds of St. Erth,
Q.J. Geol. Soc. Lond., 41, 65-73.
- Kidson, C. 1971. The Quaternary History of the Coasts of South-West
England, with special reference to the Bristol
Channel Coast, in Exeter Essays in Geography, 1-22.
(Ed. K. J. Gregory and W. Ravenhill).
- Kidson, C. and Heyworth, A. 1973. The Flandrian sea level rise in the
Bristol Channel, Proc. Ussher Soc., 2, 565-584.
- Kidson, C. and Wood, R. 1974. The Pleistocene Stratigraphy of
Barnstaple Bay, Proc. Geol. Assoc., 85, 223-237.
- Kidson, C. and Heyworth, A. 1976. The Quaternary Deposits of the
Somerset Levels, Q. Jl. Engng. Geol., 9, 217-235.
- Kidson, C. and Tooley, M.J. (Editors) 1977. The Quaternary History of
the Irish Sea, Geol. J. Special Issue, 7, 345 pp.
- Kidson, C. 1977a. Some problems of the Quaternary of the Irish Sea,
in The Quaternary History of the Irish Sea (Eds.
C. Kidson and M.J. Tooley), Geol. J. Special Issue, 7,
1-12.
- Kidson, C. 1977b. The Coast of South West England, in The Quaternary
History of the Irish Sea (Eds. C. Kidson and
M.J. Tooley), Geol. J. Special Issue., 7, 257-298.
- King, C.A.M. 1963. Some problems concerning marine planation and the
formation of erosion surfaces. Trans. Inst. Brit.
Geogr. 33, 29-43.
- King, W.B.R. 1954. The geological history of the English Channel,
Q. Jl. Geol. Soc. Lond., 110, 77-101.

- Little, C., Barnes, R.S.K. and Dorey, A.E. 1973. An ecological study of the Swanpool, Falmouth. 3. Origin and history. Cornish Studies 1, 33-48.
- MacAlister, D.A. 1906. in The Geology of Falmouth and Truro and the Mining District of Camborne and Redruth, Mem. Geol. Surv. U.K.
- Macfadyen, W.A. 1970. Geological Highlights of the West Country. Butterworths.
- Maltby, E. and Crabtree, K. 1976. Soil organic water and peat accumulation on Exmoor: a contemporary and palaeo-environmental evaluation. Trans. Inst. Brit. Geogr. New Series 1. 259-278.
- Milner, H.B. 1922. The nature and origin of the Pliocene deposits of the county of Cornwall and their bearing on the Pliocene geography of the south west of England, Q. Jl. Geol. Soc. Lond., 78, 348-377.
- Mitchell, G.F. 1960. The Pleistocene history of the Irish Sea, Adv. of Science, 17, 313-325.
- Mitchell, G.F. and Orme, A.R. 1963. The Pleistocene Deposits of the Scilly Isles, Proc. Ussher Soc., 1, 190-192.
- Mitchell, G.F. 1965. The St. Erth Beds - an alternative explanation, Proc. Geol. Assoc., 76, 345-366.
- Mitchell, G.F. and Orme, A.R. 1967. The Pleistocene Deposits of the Isles of Scilly. Q. Journ. Geol. Soc. Lond., 123,
- Mitchell, G.F. 1972. The Pleistocene History of the Irish Sea: Second Approximation. Scient. Proc. Roy. Dubl. Soc. A., 4, 181-199.

- Mitchell, G.F. et al. 1973a. A Correlation of Quaternary Deposits in the British Isles, Geol. Soc. Lond. Special Report No. 4, 1-99.
- Mitchell, G.F. et al. 1973b. The Late Pliocene marine formation at St. Erth, Cornwall, Phil. Trans. Roy. Soc. Lond., B., 266, 1-37.
- Morey, C.R. 1976. The natural history of Slapton Ley nature reserve. IX - the morphology and history of the lake basins. Field Studies 4, 353-368.
- Mottershead, D.N. 1976. Quantitative aspects of periglacial slope deposits in south-west England, Biuletyn Periglacialny, 25, 35-57.
- Mottershead, D.N. 1977a. The Quaternary evolution of the south coast of England, in The Quaternary History of the Irish Sea (Eds. C. Kidson and M.J. Tooley), Geol. J. Spec. Issue 7. 299-320.
- Mottershead, D.M. 1977b. South West England, Guide Book for 10th INQUA Excursions A6 and C6. 1-60.
- Orme, A.R. 1966. Quaternary Changes of Sea Level in Ireland, Trans. Inst. Brit. Geogr. 39, 127-140.
- Prestwich, J. 1892. The raised beaches and 'head' or rubble drift of the south of England: their relation to the valley drifts and to the glacial period; and on a late post glacial submergence, Q.J. Geol. Soc. Lond., 48, 263-343.
- Reid, C. 1890. The Pliocene Deposits of Britain, Mem. Geol. Surv., U.K.

- Reid, C. and Reid, 1904. On the probable occurrence of an Eocene outlier off the Cornish Coast, Q. Jl. Geol. Soc. Lond., 60, 113-119.
- Reid, C. and Scrivenor, J.B. 1906. The Geology of the Country near Newquay, Mem. Geol. Surv., U.K.
- Reid, C., Barrow, G. and Dewey, H. 1910. The Geology of the Country around Padstow and Camelford, Mem. Geol. Surv., U.K.
- Robson, J. 1944. The Recent Geology of Cornwall, Trans. Roy. Geol. Soc. Cornwall., 17, 132-163.
- Rogers, J.J. 1865. Strata of the Cober Valley, Loe-Pool, near Helston. Royal Geological Society of Cornwall Transactions, Vol. 7., 352-354.
- Round, E. 1944. Raised Beaches and Platforms of the Marazion Area, Trans. Roy. Geol. Soc. Cornwall, 17, 97-108.
- Shearman, D.I. 1967. On Tertiary Fault Movements in North Devonshire, Proc. Geol. Assoc., 78, 555-566.
- Smith A.J. and Curry, D. 1975. The structure and geological evolution of the English Channel, Phil. Trans. Roy. Soc. Lond. A, 279, 3-20.
- Smith, W.E. 1961a. The Detrital minerology of the Cretaceous rocks of south-east Devon, with particular reference to the Cenomanian, Proc. Geol. Assoc., 72, 303-332.
- Smith, W.E. 1961b. The Cenomanian deposits of south-east Devonshire, Proc. Geol. Assoc., 72, 91-134.
- Stephens, N. 1961. Re-examination of some Pleistocene sections in Cornwall and Devon, Abstr. Proc. Conf. Geomorph. S.W. England, Trans. Roy. Geol. Soc. Cornwall, 21-23.

- Stephens, N. 1966a. Geomorphological studies in Ireland and western Britain with special reference to the Pleistocene Period. Unpublished Ph.D. thesis. The Queen's University, Belfast.
- Stephens, N. 1966b. Some Pleistocene Deposits in North Devon, Biul. Peryglac., 15, 103-114.
- Stephens, N. 1970. The West Country and Southern Ireland, in Glaciation of Wales and adjacent regions (Ed. C. Lewis), 267-314. Longmans.
- Stephens, N. 1974. Contributions to the Quaternary Research Association Guide to the Exeter Field Meeting, 25-29 and 35-42.
- Synge, F.M. 1970. The Pleistocene Period in Wales, in The Glaciations of Wales and Adjoining Regions (Ed. C.A. Lewis), London, 315-350.
- Synge, F.M. 1977. The Coasts of Leinster, in Quaternary History of the Irish Sea (Eds. C. Kidson and M.J. Tooley), Geol. J. Special Issue, 7, 199-220
- Synge, F.M. 1979. Quaternary Glaciation in Ireland, Quat. Newsletter, 28, 1-18.
- Toy, W.S. 1936. The history of Helston. Cambridge University Press.
- Tricart, J. 1956. Cartes des Phenomenes Periglaciares Quaternaires en France, Mem. Carte Geol. Détaillée Ministre de l'Industrie et du Commerce, 1-40.
- Turk, F.M. and Turk, S.M. 1976. A Handbook to the natural history of the Lizard peninsula. Dept. Extra Mural Studies, Univ. of Exeter.

- Ussher, W.A.E. 1879. The Post-Tertiary geology of Cornwall. Hertford.
- Ussher, W.A.E., Barrow, G. and MacAlister, D.A. 1909. Geology of the Country around Bodmin and St. Austell, Mem. Geol. Surv., U.K.
- Weller, M.R. 1959. Erosion of Bodmin Moor, Trans. Roy. Geol. Soc. Cornwall, 19, 233-242.
- West, R.G. and Sparks, B.W. 1960. Coastal interglacial deposits of the English Channel. Phil. Trans. Roy. Soc. Lond., B243, 95-133.
- West, R.G. 1972. Relative land-sea level changes in south-eastern England during the Pleistocene. Phil. Trans. Roy. Soc. Lond. A, 272, 87-98.
- Whitley, N. 1882. The evidence of glacial action in Cornwall and Devon. Trans. Roy. Geol. Soc. Cornwall, 10, 132-141.
- Williams, R.E.G. 1965. Permafrost in England during the Last Glacial Period, Nature, 205, 1304-1305.
- Wilson, A.C. 1975. A Late-Pliocene marine Transgression at St. Erth, Cornwall and its possible geomorphic significance, Proc. Ussher Soc., 3, 289-292.
- Wooldridge, S.W. 1950. The Upland Plains of Britain: their origins and geographical significance. Adv. Science., 7, 162-175.
- Wood, S.V. (Jnr) 1885. On a new deposit of Pliocene age at St. Erth, near the Land's End, Cornwall, Q.J. Geol. Soc. Lond., 41, 65-73.

- Wood, A. 1974. Submerged platform of marine abrasion around the
coasts of south-western Britain, Nature, 252 563.
- Wood, A. 1976. Successive regressions and transgressions in the
Neogene, Marine Geol., 22, 23-29.

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