

**QUATERNARY
RESEARCH ASSOCIATION**

**FIELD HANDBOOK
EASTER MEETING 1974**

EXETER

QUATERNARY RESEARCH ASSOCIATION

EASTER FIELD MEETING, 1974

EXETER

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(THIS HANDBOOK CONTAINS UNPUBLISHED MATERIAL WHICH SHOULD NOT
BE QUOTED WITHOUT THE CONSENT OF THE AUTHOR).

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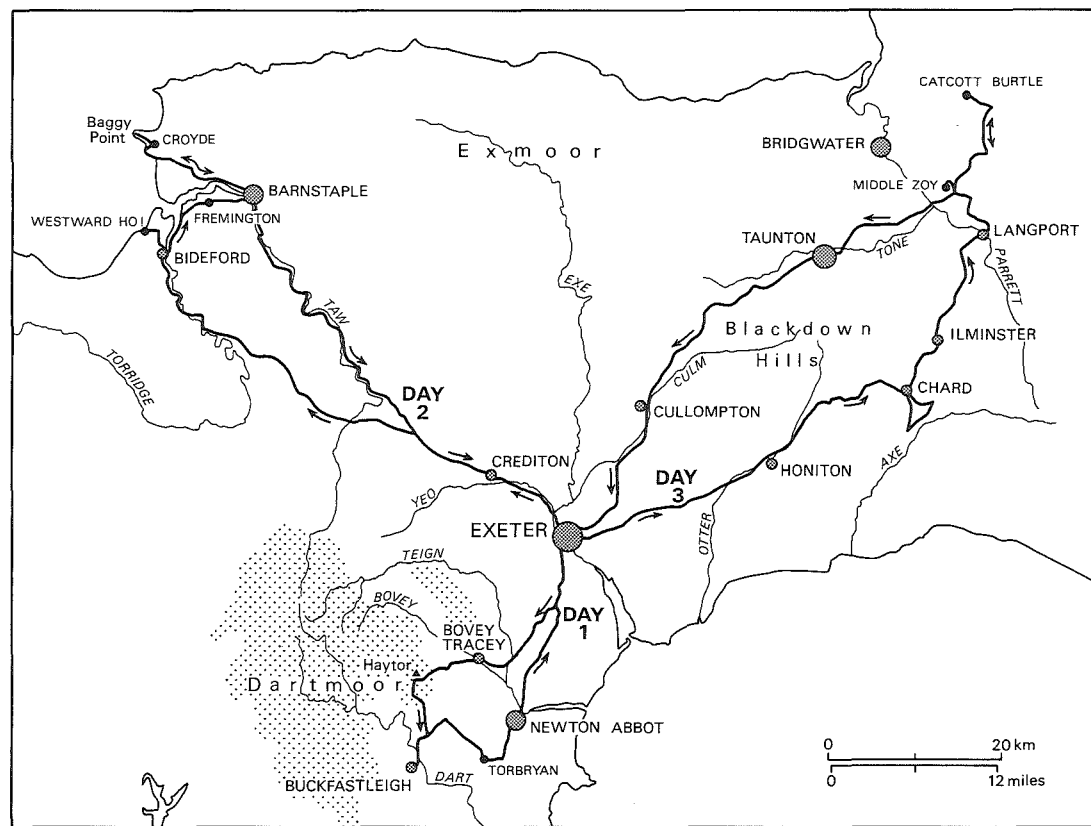


Fig. 1 - Excursion routes and location map.

INTRODUCTION

The South-West of England has an interesting location in relation to the extents of the various glaciations of the British Isles. It is widely believed that ice reached the north coasts of Devon and Cornwall at certain times during the Quaternary, but did not overspread the inland areas. Rather the latter experienced a succession of periglacial phases, and periglacial phenomena, quite well known around the coasts and in Dartmoor and other hill areas, are certainly not lacking from lowland areas.

Geological, biological and geomorphological interest pertains to a large number of inland localities, and to innumerable sites around the coasts. Contributions to the Handbook confirm this range of interest, providing detailed descriptions and interpretations of localities to be visited on the excursions, as well as general reviews and interpretations of the Quaternary history of South-West England.

An 'excursions subcommittee' comprising Q.R.A. officials, prospective field leaders and the Local Organizer decided on a 3-day programme, and on the general areas to be visited. The Local Organizer is particular grateful to Professor C. Kidson, Professor N. Stephens, and Dr. A.J. Sutcliffe for undertaking to plan and direct substantial parts of the field programme.

The routes of the excursions are illustrated on Figure 1, and in the limited time available, it is hoped on the first day to introduce Conference members to the Haldon Hills, Dartmoor environs, and bone-caves to the south-west of Exeter. On the second day, interest focuses on the glacial, periglacial and coastal features around Barnstaple Bay in north Devon. On the third day, opportunity is taken to examine deposits in the Chard area to the east of Exeter, and in south Somerset, which have a bearing on glacial and interglacial events in these regions.

Finally, on the evening of Monday, April 8th, members can take advantage of the generous offer by Mr. S. Locke, Director of the Royal Albert Memorial Museum, Exeter, to examine Quaternary material and artefacts from the Museum's collection.

(A. STRAW)

THE QUATERNARY OF SOUTH-WEST ENGLAND

Deposits of Pleistocene Age are sparse in South-West England. They group themselves into two classes, coastal and cave deposits.

Coastal sections in South-West England show a characteristic stratigraphy of raised beach sands and gravels and/or old blown sand overlain by head and/or till capped by modern blown sand or a colluvial layer. In many places the raised beach incorporates erratic material, including the 'giant erratics'. Most frequently the latter are to be found resting on the shore platform in front of the other deposits exposed in the coastal sections but at Saunton one such erratic is 'cemented' to the shore platform by the overlying beach material. At Trebetherwick Point in Cornwall, Arkell (1943) suggested the possibility of more than one raised beach. More recently Mitchell and Orme (1967) have described two raised beaches, in the Isles of Scilly, the lower of which underlies and pre-dates glacial deposits. All the coastal sites are capable of more than one interpretation largely because the deposits do not include any organic material dateable by any known technique, but also because the stratigraphical relationships are frequently obscure and questionable.

The South-West is particularly rich in caves containing stratified deposits. Kent's Cavern, near Torquay, has long been known and has recently been re-examined (Campbell and Sampson 1971). Although it contains a last glaciation fauna and Upper Palaeolithic artifacts and a Lower Palaeolithic industry, which may be of Hoxnian or earlier, it lacks a fauna from the Ipswichian. The most important sequence of Upper Pleistocene cave deposits in the British Isles is found in Tornewton Cave, Torbryan (Sutcliffe and Zeuner 1962). Fauna of Wolstonian and Devensian age are separated by the "Hyaena stratum" which contains a rich Ipswichian fauna. Indeed it is the only site in Britain where Wolstonian and Devensian deposits are separated by an interglacial stratum containing hippopotamus. Studies of rodents among the Wolstonian and Devensian faunas are of great significance for the separation of the two glaciations. The Joint Mitnor Cave, Buckfastleigh, has a very rich Ipswichian fauna typical of the warmest part of the interglacial.

In addition to the coastal and cave deposits, a number of significant but widely scattered Pleistocene beds occur inland. The Fremington Clay, The Burtle Beds of Somerset and The St. Erth beds are among the best documented. Motorway sections are revealing other sites. These include the section in the Honiton By-Pass excavated in 1965 which has come to be known as the Honiton Hippopotamus Site. This yielded a fauna, probably of Last Interglacial age, the significance of which is not yet fully understood.

Despite the fact that Maw (1864) recognised the Fremington Clay as probably a till more than 100 years ago, there followed a long period during which almost any other origin was attributed to it. Thus, for example, Balchin (1952) suggested a fluvial derivation. Mitchell (1960) revived Maw's ideas and the Fremington Clay is now generally accepted as a true glacial deposit. Discussion now centres on its relationship to the raised beaches. Some workers (Mitchell 1960, Stephens 1966) have suggested that the glacial deposits including the Fremington Clay, overlie the adjacent raised beach and therefore antedate them. Others (Zeuner 1959, Kidson 1971) hold that the reverse is the case. Recent work (Kidson and Wood 1974) seeks to demonstrate that the gravels beneath the Fremington Clay are not raised beach gravels, as interpreted by Mitchell and Stephens, but fluvio-glacial deposits of the same ice sheet which laid down the Fremington Clay.

The Burtle Beds of Somerset have long been regarded as a marine interglacial deposit (Bulleid and Jackson 1937). The included faunas, largely marine but with washed in terrestrial tests and mammalian bones, could give either an Ipswichian or a Hoxnian age. Kidson (1971) has argued that the more probable age is last interglacial. Kellaway (1971) has stated that the Burtle Beds are of glacial origin, possibly of Wolstonian or Anglian age, a view contested by Kidson and Haynes (1972) who support the marine interpretation.

The St. Erth Beds, between Hayle and Penzance, together with the 'marine gravels' at Polcrebo and Crousa Common were long held to be of middle or later Tertiary age. Reid (in Reid and Flett 1909) described them as Pliocene marine gravels resting on a marine cut surface 'probably in part Miocene'. His views were dominant for half a century despite doubts expressed from time to time (Wooldridge 1952). More recently, Mitchell (1965) has re-examined the St. Erth Beds, with which he had earlier (1960) correlated the Hele Gravels near Fremington, and has suggested that they are early Pleistocene marine deposits related to a sea level of +185 (55m) (compared to the 430 feet (131m) suggested by Reid). His original view of their age (Cromerian) was subsequently modified (in Mitchell and Watt 1970) to pre-Cromerian (Antian). Mitchell also suggested that the deposits had subsequently been disturbed by ice of Lowestoft age. It is probable that many of the superficial deposits of East Devon, when subjected to similar re-examination may yield significant evidence of Pleistocene events.

If the deposits of the Pleistocene are difficult to interpret in South-West England, the erosional legacy is even more difficult. High level surfaces have been attributed to marine erosion not only in the Pleistocene but also in earlier periods (Wooldridge 1954). The surface at 600-690 feet, formerly

described as the Pliocene marine bench (Wooldridge and Linton 1939), on the basis of the Red Crag faunas in the Lenham Beds of South-East England, has been traced into the South-West. It must now, of course, be referred to as the early Pleistocene bench. Many surfaces have been described at lower levels, notably the 430 feet surface to which Reid referred the St. Erth Beds. There is no general agreement on these surfaces and until additional evidence is forthcoming, further discussion is likely to be unprofitable.

Of more particular interest at the present time are the shore platform(s) which may be regarded as the lowest member(s) of the erosional staircase and on which the coastal Pleistocene deposits rest. Discussion centres on whether there is one platform (usually misleadingly referred to as the '25 ft.' platform) or whether there are a number, the heights of which have significance in terms of Quaternary history. They are held by some (Zeuner 1959) to date from the last interglacial, and by others (Mitchell 1960) to originate much earlier. They have been fully discussed by Everard et al (1964) and Kidson (1971).

In the light of the complexities of the depositional and erosional records summarised above, it is not surprising that there are still major problems to be resolved in relation both to ice limits and to the chronology of the Pleistocene in South-West England. There is general agreement that Devensian ice did not reach the peninsula. There is growing evidence (Mitchell 1972) that Wolstonian ice pushed into the flanks of the peninsula and left depositional evidence as far south as the Isles of Scilly. Suggestions of an Anglian glaciation of Southern England and the English Channel (Kellaway 1971) await detailed supporting evidence.

Views on the chronology of the Pleistocene in the area can be summarised as follows :

	<u>Arkell, Mitchell, Stephens</u>	<u>Zeuner, Kidson</u>
Devensian	Upper cryoturbated Head	Single Head
Ipswichian	Upper raised beach sometimes represented by a weathering horizon/sand layer.	Single raised beach
Wolstonian	Till/Lower Head (inc. Fremington Clay)	Giant erratics and Fremington Clay
Hoxnian	Lower raised beach	
Anglian	Giant erratics	
Early Pleistocene	Shore Platform	Shore Platform

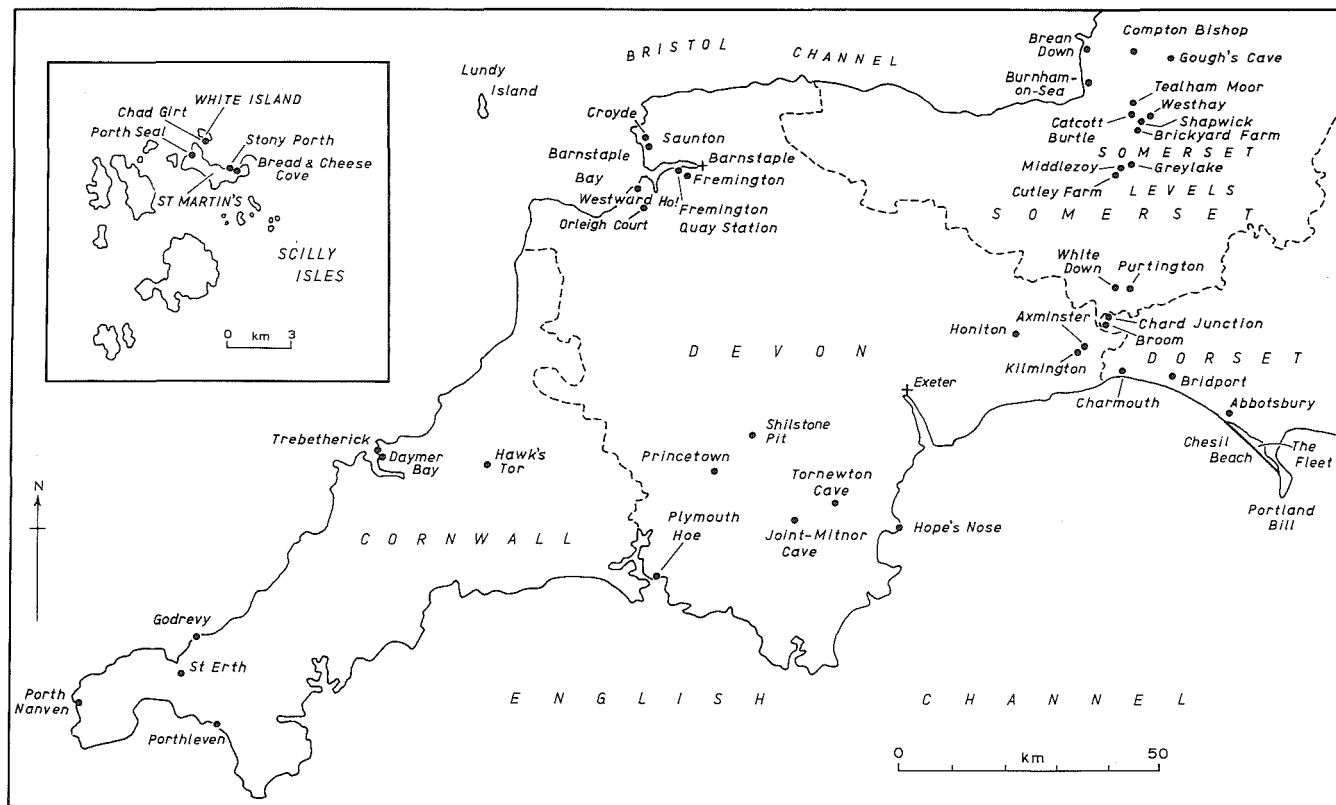


Fig. 2 - Some important Pleistocene sites in the West Country.

Fig. 3 - Pleistocene events in the S.W. British Isles

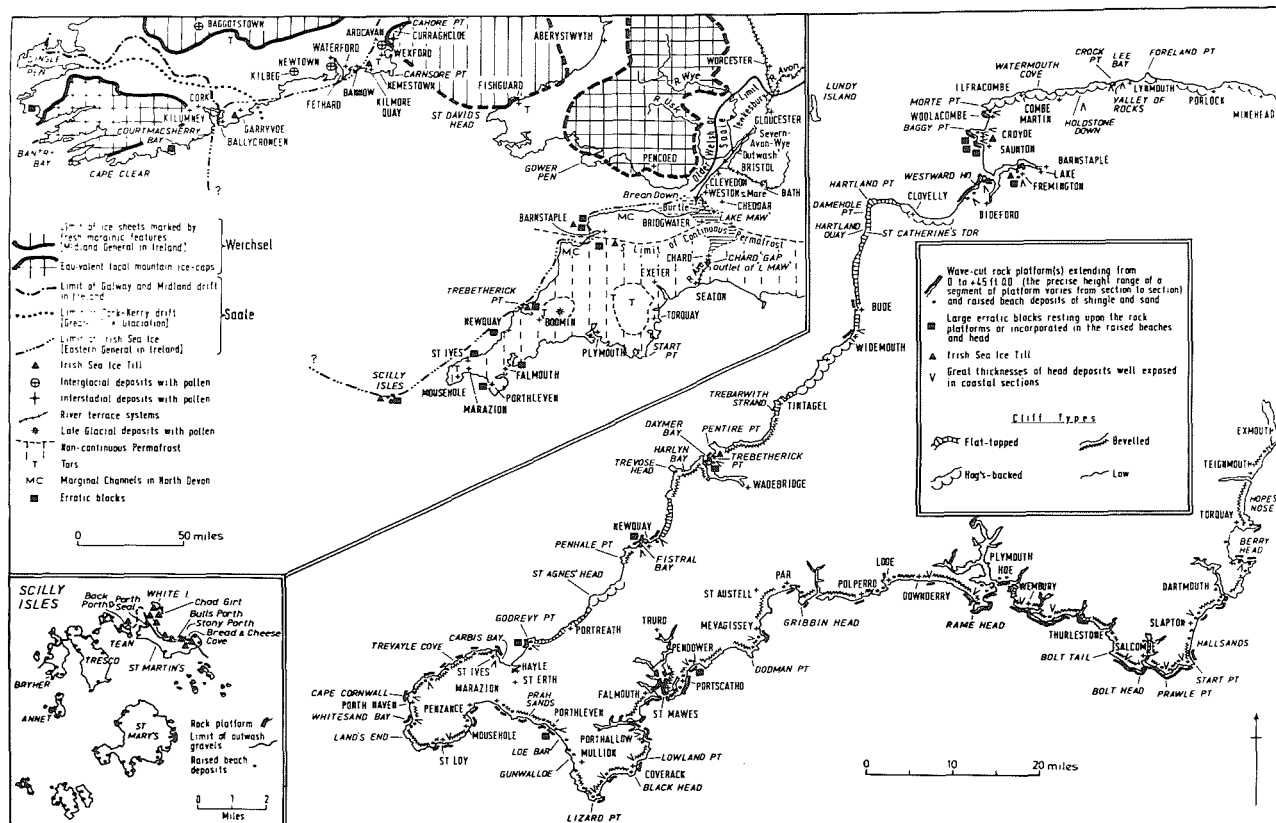


Fig. 4 - Pleistocene marine platforms, coastal deposits, and cliff types

SOME ASPECTS OF THE QUATERNARY OF SOUTH-WEST ENGLAND

During the various cold and temperate periods of the Quaternary an extremely varied series of deposits was laid down, including marine sand, shells, and shingle (now forming raised beaches), boulder clays, periglacial deposits (often called 'head' in the literature), and river terrace gravels, sometimes containing vertebrate remains and human artefacts. In addition, large erratic boulders have been recorded from the Devon and Cornish coasts, their presence having been accounted for by agencies such as regional ice-advances, pack-ice and icebergs (Charlesworth, 1957; Mitchell, 1970; Stephens, 1966). Figure 2 is a general map of some important Pleistocene sites in the West Country.

Although the age of the southern limits of the Pleistocene ice-sheets (Fig. 3) may be disputed it seems that most of the area comprising the lower Severn valley and nearly all of the south-west peninsula of Somerset, Devon and Cornwall and part of South Wales lay within a periglacial zone during the mid-late-Pleistocene. It is not surprising, therefore, to find an abundance of relic periglacial deposits and features well displayed in the present landscape. The thick head deposits of coastal sections, the presence of fossil ice-wedges and involutions in superficial materials, the altiplanation terraces, block fields and tors of some upland areas, including Dartmoor and Bodmin Moor, and the two-storied cliffs (bevelled and hog's-backed), all testify to the action of freeze-thaw processes. It is evident that erosion in interglacial and postglacial periods has been quite incapable of obliterating a relic periglacial landscape of wide extent, where convex slopes (zone of wastage) and concave slopes (zone of deposition) dominate the landscape (Te Punga, 1957). Williams (1965) considers that much of Devon and Cornwall was relatively free of permafrost during the last glacial period, except on high ground, but the Bristol Channel coast east of Barnstaple Bay, and the lower Severn valley are shown to have had extensive permafrost. The line of division of Fig. 3 between extensive and discontinuous permafrost is adapted from Williams's map (1965). In the descriptions which follow it may well seem necessary to consider a greater area as having had active layers over permafrost on the evidence of the existence of fossil ice-wedges. The critical mean annual temperature for extensive continuous permafrost has been given as -6°C (Pewe, 1964). Even if certain areas lay outside this critical limit in the extreme south-west of Cornwall, nevertheless an extremely rigorous periglacial climate must have occurred during the maximum of the last glacial period and, one presumes, during earlier cold periods.

Multiple layers of soliflucted head occur in some coastal sections, and their interpretation presents difficulties (cf.

Watson, 1965), while on Dartmoor two and possibly three periods of cold climate have been recognised by Waters (1964) as responsible for gelification of the sound bedrock and the geliturbation of already weathered material. These cryergic processes have given to the high moorland many of its salient physiographic features, the clitters, valley-side buttresses, terraces of rubble-drift, and smooth slopes on the granite outcrops, as well as altiplanation terraces on the aureole rocks and have contributed to the shaping of the tors (Palmer and Nielson, 1960). There can be little doubt that cryergic action has been equally severe on the other uplands - Mendips, Quantocks, Exmoor, Haldon Hills, Bodmin Moor, and the higher ground of the Penwith (Land's End) peninsula (Guilcher, 1950; Waters, 1961, 1962).

Any consideration of raised beaches and coastal periglacial deposits, which make up a high percentage of the Pleistocene stratigraphy in the area under discussion, directs attention to the composite seacliffs of south-west England, and their counterparts in southern Ireland (Everard et al., 1964). Some of the cliffs are simply abandoned, or relic features, as a result of the growth of shingle spits across the mouths of submerged inlets, or where progradation no longer allows the sea to attack the bedrock of the old cliff line. Elsewhere the cliff profiles reflect the interaction between the efficiency of wave attack and the intensity of periglacial cryergic processes in shaping the cliff.

Three broad divisions have been made in Fig. 4

(a) Flat-topped cliffs occur where wave attack has continued at a rate sufficient to maintain a near-vertical cliff, often in relatively weak rocks, on the seaward edges of plateau-like erosion surfaces. Along segments of coastline, such as between Hartland Point and Bude in north Cornwall, retreat of the cliff-face under wave attack assisted by subaerial weathering of weak shales and slates, is proceeding rapidly today (perhaps even as fast as 0.3m (1 ft) per year in places). There are no traces of any of the Pleistocene raised beaches or elevated wave-cut rock platforms, and it is impossible to say how much of the present intertidal platform below these cliffs is old - considerable portions of it may be the result of Flandrian and recent erosion (L.W. Wright, 1967). Similarly, for some miles north of Godrevy, Cornwall, steep rocky cliffs fall to a shore platform, and there are few reliable traces of raised beaches or elevated platforms. Moreover, at the cliff-top the regional slope is inland, away from the cliff-edge, and in places up to 1.8m (6 ft) of head can be seen capping this south sloping surface. Clearly, the head has been derived from slopes that have now disappeared as a result of cliff recession, indicating that here wave attack has been the dominant process.

(b) Bevelled cliffs occur over long stretches of the coast of Devon and Cornwall, indicating the places where old cliffs have been subjected to cryergic action of perhaps more than one period of periglacial climate. Orme (1962) has illustrated examples of these 'fossil' cliffs from south Devon, where occasionally buttresses and cliff-tors stand out from head-strewn slopes. Good examples occur between Dartmouth and Bolt Tail, where sometimes the base of the old cliff is protected by head. Elsewhere (near Start Point) renewed trimming has occurred, and at Slapton the head has been removed, and the base of the old cliff re-etched, and cut back, by wave attack.

(c) Hog's-backed cliffs are really a special form of bevelled cliff, found best developed where wave-truncated cliffs form the lower element of whale-backed ridges running parallel or sub-parallel to the coast. They are specially well developed between Coombe Martin and Foreland Point, north Devon. Cotton (1951) has referred to these cliffs as 'two-tier cliffs', and the long (often convex) subaerial slope which forms the upper segment of profile (Fig. 4) can be regarded as a periglacially altered 'fossil' cliffline, at one or more former levels. There is considerable variation in the lower part of the profile; for example, on the south-west side of Baggy Point, and at Saunton, raised beach deposits and head form a conspicuous 'apron' or terrace of deposits below a marked convexity of profile developed on rock carrying only a thin skin of head; whereas, on the north-east side of Baggy Point sheer rocky cliffs fall away below the convexity, a type of profile repeated for mile after mile east of Ilfracombe (Fig. 4).

The precise relationship of the wave-cut platforms, and the raised beaches with erratics, to the buried rock channels of the coastal estuaries is unknown at present (Farrington, 1959; McFarlane, 1955). However, the existence of rock platforms at the back of large bays (Barnstaple Bay, Tor Bay, Courtmacsherry Bay), and in some of the larger inlets and rias (Cork Harbour, Waterford, Camel estuary below Wadebridge, and Fal estuary between Falmouth and St. Mawes) indicates that the present coastline was, in large measure, delineated by marine erosion in early Pleistocene times; and that in places the erosion followed a period of valley incision and deepening to levels well below the present base-level of the rivers.

(N. STEPHENS)

THE CAVES OF SOUTH DEVONSome general notes on bone-caves

Caves quite commonly contain great concentrations of fossil mammalian and other remains and thereby provide an important source of evidence in Quaternary studies. Most such concentrations have resulted either from animals falling into open shafts (e.g. Joint Mitnor Cave); or from animals such as bears, hyaenas, bats and Man using caves as places of refuge (e.g. Tornewton Cave) where they have left their own remains and the remains of their prey. Less commonly fossil bones are found in cave stream deposits (e.g. Eastern Torrs Quarry Cave, Yealmpton, near Plymouth). Especially important in Quaternary studies are accumulations of rodent remains carried into caves by birds of prey, since rodents evolve more quickly than the larger mammals and are better stratigraphic indicators. In limestone caves, such as those of Devon, alkaline conditions favour the survival of bone so that even the smallest specimens are frequently magnificently preserved.

Although caves have been places where vertebrate remains have become concentrated since at least Mesozoic times, most caves and the deposits in them are soon destroyed by denudation. In consequence, whilst fossiliferous cave deposits of Upper Pleistocene and Holocene age are numerous, it is unusual to find any which are earlier than Middle Pleistocene. Among the few rare British exceptions are the Mesozoic infillings of Mendip and S. Wales; the silica sand deposits of Derbyshire (probably Pliocene, plants only); Dove Holes, Derbyshire (Lower Pleistocene, probably Crag age); Westbury Fissure, Somerset (Cromerian); and probably the lower part of the sequence in Kent's Cavern, Devon (see below). With the exception of the last mentioned site there is, at present, no evidence of fossiliferous deposits earlier than Wolstonian in any Devon Cave. A second reason probably contributes to the near-absence of any early fossiliferous cave deposits in Devon. None of the caves is situated at a greater altitude than 100 metres above sea level and all have been below the water table as recently as the Lower Pleistocene. Only at a relatively late date have they become drained of their ground water, as we know them today, and have thus become potential bone caves.

History of the study of Devonshire bone-caves

The caves of Devon have been the subject of scientific study for over a century and a half. The first bone cave to be scientifically investigated in Britain was excavated by Joseph Whidbey at Oreston, near Plymouth, in 1816. In 1825 the Revd. J. MacEnery commenced his excavations in Kent's Cavern, later to be continued by

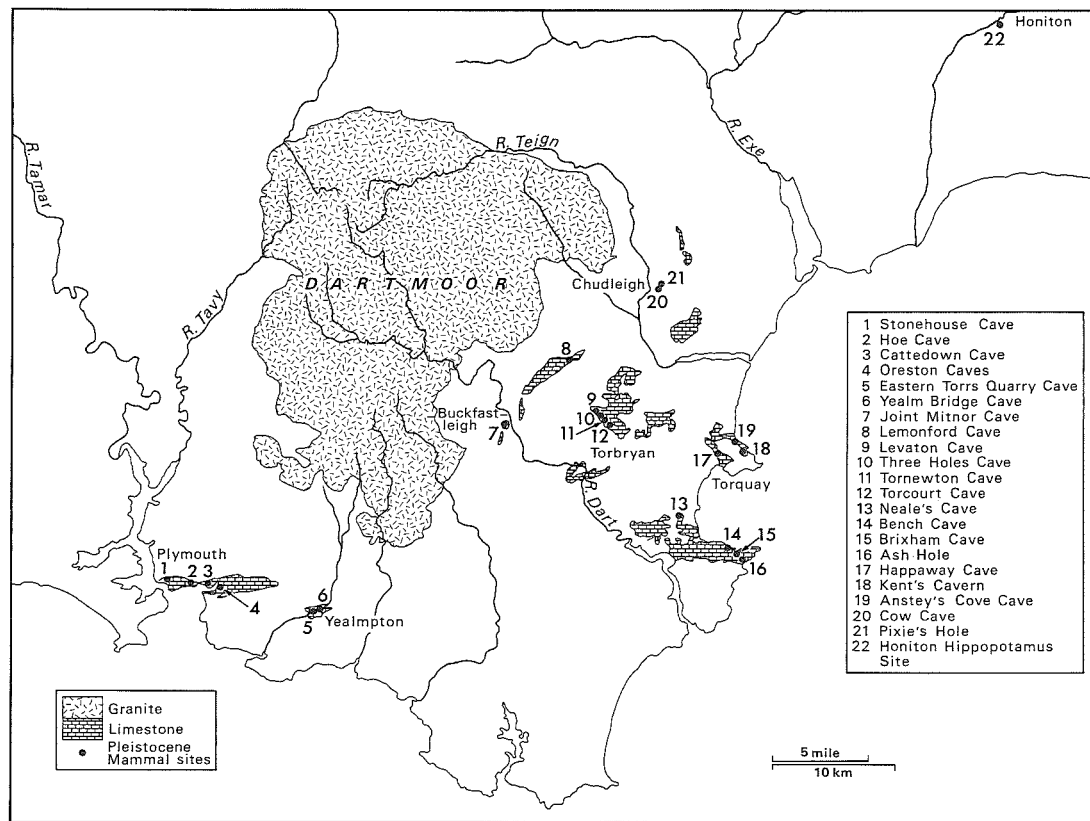


Fig. 5 - Principal localities where remains of Pleistocene mammals have been found in Devon.

STAGE		KENT'S CAVERN	TORNEWTON CAVE	JOINT MITNOR CAVE	OTHER DEVON CAVES	SIGNIFICANT MAMMALIAN SPECIES
HOLOCENE		'Black Mould'	'Diluvium'		?NEALE'S CAVE ?HAPPAWAY CAVE	Domestic animals Wolf Brown bear ?Lynx
UPPER PLEISTOCENE	LAST (DEVENSIAN) GLACIATION	'Granular Stalagmite'	'Reindeer Stratum'		ANSTEY'S COVE CAVE ASH HOLE BENCH CAVE BRIXHAM CAVE CATTEDOWN CAVE COW CAVE LEMONFORD CAVE LEVATON CAVE ORESTON CAVES TORCOURT CAVE YEALM BRIDGE CAVE	Woolly mammoth Woolly rhinoceros Reindeer Horse Brown bear Spotted hyaena Narrow-skulled vole, <u>Microtus gregalis</u>
		'Black Band'				
		'Cave Earth'				
	LAST (IPSWICHIAN) INTERGLACIAL	'Crystalline Stalagmite'	'Hyaena Stratum'	Bone Deposit	EASTERN TORRS QUARRY CAVE	Straight-tusked elephant Narrow-nosed rhinoceros Hippopotamus Red deer Fallow deer Brown bear Spotted hyaena
	WOLSTONIAN GLACIATION		'Glutton Stratum'		?Lower deposits of COW CAVE	Woolly rhinoceros Reindeer Brown bear Glutton (wolverine) Hamsters, <u>Cricetus cricetus</u> & cf. <u>Allocricetus bursae</u> Steppe lemming, <u>Lagurus lagurus</u> Snow vole, <u>Microtus nivalis</u>
MIDDLE-LOWER PLEISTOCENE	HOXNIAN ANGLIAN CROMERIAN	?Breccia				Sabre-toothed cat Cave bear Vole, <u>Pitymys gregaloides</u>

Fig. 6 - Probable stratigraphic range of deposits in principal Devon bone caves.

William Pengelly. William Buckland visited a number of Devon Caves during the 1820's, including Kent's Cavern (where he advised MacEnery); Pixie's Hole, Chudleigh; Oreston; Anstey's Cove Cave and others. Pengelly's excavations in the Brixham Cave in 1859 showed that Man had occupied Devonshire before the extinction of the cave mammals and this discovery was further confirmed by his later work in Kent's Cavern. A remarkable series of excavations was conducted by Mr. J.L. Widger in the Torbryan Caves from about 1865 until about 1880, (see Tornewton Cave, below). From the 1920's until the beginning of the Second War the Torquay Natural History Society excavated in Cow Cave, Chudleigh; Kent's Cavern; Tornewton Cave; and Joint Mitnor Cave. During the years since the War excavations have been carried out by Almy, Cheesman, Neale, Rosenfeld, Sutcliffe, Zeuner and others in Tornewton, Three Holes and Levaton Caves, Torbryan; Joint Mitnor Cave, Buckfastleigh; Eastern Torrs Quarry Cave, Yealmpton (discovered by quarrying in 1954); and Neale's Cave, Paignton (discovered in 1958).

Distribution of Devonshire bone caves

The principal localities where remains of Pleistocene mammals have been found in Devon is shown in Figure 5. With one exception all are caves in Devonian limestone. Also shown is the Honiton Hippopotamus Site where a peaty deposit with a Last Interglacial fauna was found during road works in 1964.

The probable stratigraphic range of the deposits in these caves is shown in Figure 6.

As will be seen from the table, the fossiliferous deposits in most of the caves are of limited stratigraphic extent. Two important exceptions, with long sequences, are Tornewton Cave and Kent's Cavern.

Although time will unfortunately not allow a visit to Kent's Cavern on April 6th the sequence there must be mentioned for the sake of completeness. The chronology of this cave has always presented a problem, since the earliest deposits are apparently of considerably greater antiquity than later deposits. It seems reasonable to accept the 'Cave Earth' and 'Black Band' as being of Last Glaciation age. The fauna, including woolly mammoth, woolly rhinoceros and reindeer, associated with an Upper Palaeolithic industry, is in keeping with such a date. Three mammalian species found in the cave (cave bear, found elsewhere in Britain only in the Hoxnian deposits of Swanscombe; sabre-toothed cat, well known in Cromerian deposits; and the vole Pitymys gregaloides, known from deposits of Cromerian age in East Anglia) nevertheless suggest a Hoxnian or even Cromerian age for part of the deposits. Of these three species the first was found in the 'Breccia', the second (which could be derived)

in the 'Cave Earth' and the provenance of the third is not known. Speculation about the age of the 'Breccia' should not be carried too far but there seems to be good reason for regarding it as of considerable antiquity. The occurrence in it of hand axes of Lower Palaeolithic type further supports this interpretation. If an early date is accepted for the 'Breccia', then it follows that the 'Crystalline Stalagmite' represents a major break in the sequence, covering in part the Last Interglacial, characterised elsewhere by such animals as hippopotamus, straight-tusked elephant and narrow-nosed rhinoceros. These animals are unknown from Kent's Cavern. The cave may have been sealed at the time of accumulation of the 'Crystalline Stalagmite'.

(A.J. SUTCLIFFE)

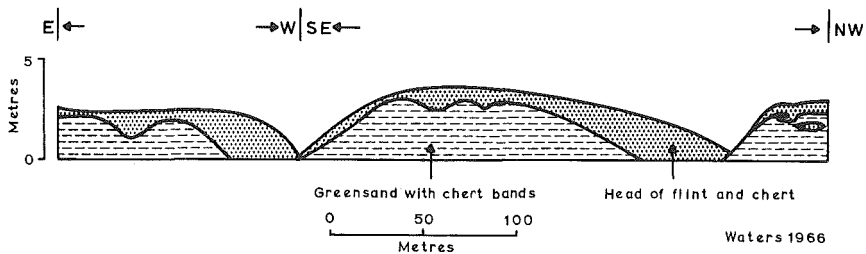


Fig. 7 - Head-filled gullies, Haldon Hills.

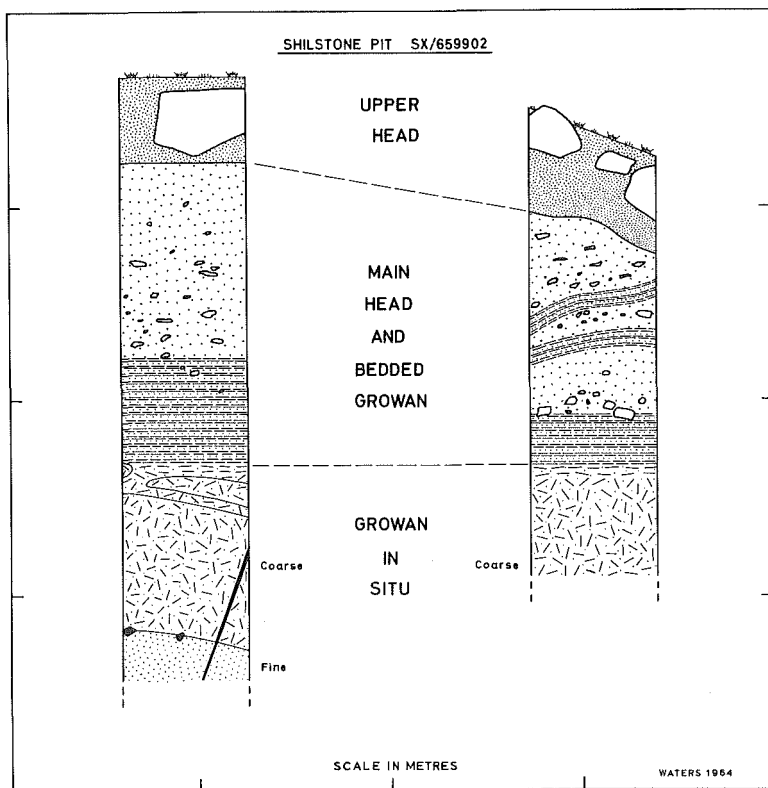


Fig. 9 - Stratigraphy at Shilstone Pit.

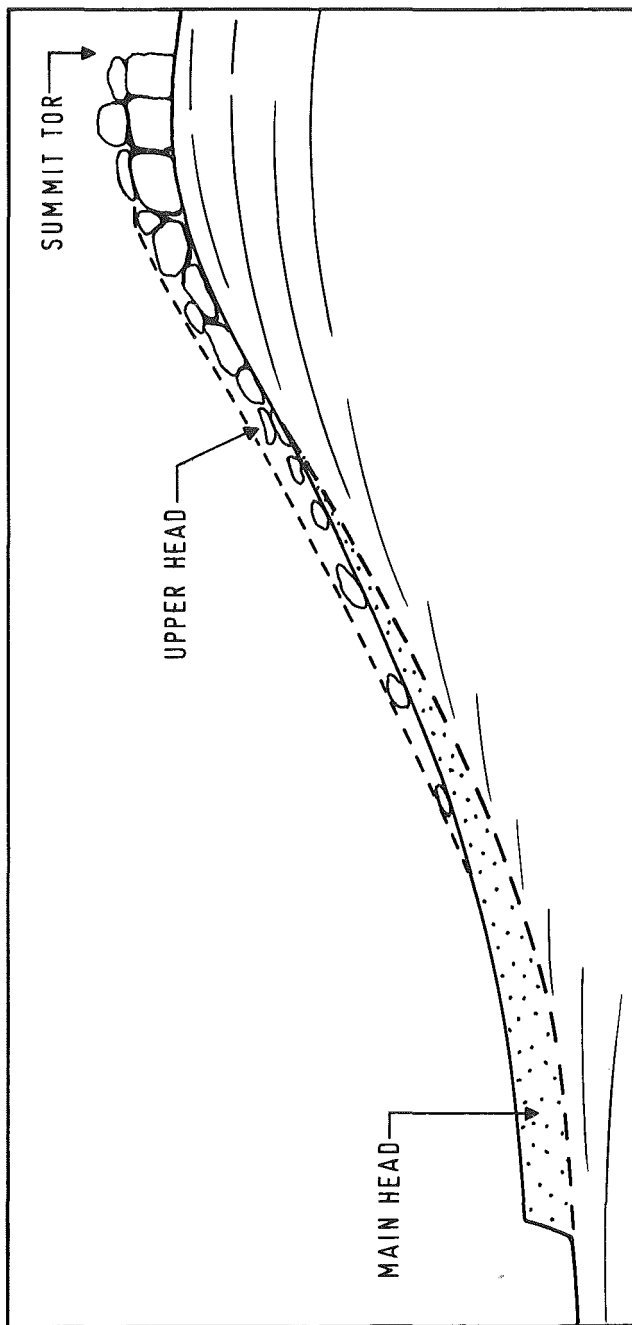


Fig. 8 - Relation of 'heads' on a tor-crowned Dartmoor slope.

HALDON HILLS

Outliers of the Cretaceous plateau of E. Devon, Great and Little Haldon (225-248m) on the Exe/Teign divide are built of Upper Greensand unconformable on the Permian. Representatives of the pre-Pleistocene sub-aerial Lower Surface which encircles (and passes on to) the granite of Dartmoor, they carry a superficial mantle of Early Tertiary gravels and weathering debris, frost-disturbed to a depth of 1m, and show relict patterned ground. Their bounding scarps carry solifluxion spreads of gravels and frost-shattered chips and flakes of flint and chert from the top of the plateau. Road cuttings across spurs show the alternation of soliflual debris and bedrock, e.g. the head-filled gullies north of the A38 (Fig. 7). For a recent account of the gravels on Haldon see Hamblin (1973).

(R.S. WATERS)

TEIGN VALLEY

The upper part of the R. Teign flows generally east from Dartmoor across the Sticklepath fault, and traverses obliquely the metamorphic aureole in a deep gorge. It turns sharply south at Dunsford, and has opened a narrow-floored though broader valley in Culm Measure shales and grits and intruded igneous sills and dykes, parallel to both the crest of the Haldon Hills and the eastern margin of the granite.

East of Chudleigh Knighton, the river crosses onto the Oligocene Bovey Beds. The eastern slopes of the Teign valley carry much 'head' of soliflucted flint gravel and sand from Haldon. The western flank is somewhat steeper and rises quickly onto the granite. The valley floor is bordered intermittently by fragments of Quaternary terraces which pass into broader spreads of sand and gravel toward Kingsteignton. South of Chudleigh Knighton the Teign receives the River Bovey from the northwest, which is aligned close to the Sticklepath fault.

The Quaternary history of both streams would appear to be one of intermittent deepening of their valleys, but detailed mapping of stages of relative base-level stability comparable with that of the Exe basin (Kidson, 1962) and the Dart basin (Brunsden, 1963) has not yet been carried out.

The Tertiary history of the Teign and Bovey, particularly in relation to the formation of the Oligocene basin and the Sticklepath fault zone, would perhaps be of greater interest. In this connection the suggestions by Jukes-Browne (1904) that

the upper Teign once coursed toward Exeter, and that the alignment of the Teign estuary may have been established by an early east-flowing Dart are worth mention.

BOVEY BEDS

Exposures near Newton Abbott, Chudleigh Knighton and Bovey Tracey reveal white, purplish and pinkish lacustrine clays with lignites, that were deposited during the Oligocene in a large brackish-water lake some 10 miles long from NW to SE, by 4 miles wide. Sandier marginal deposits, also derived by weathering and erosion from Dartmoor granite, were aggraded as fluvial deltas and fans, and include pieces of wood and some peats.

The basin was created by localized downwarping of the Eocene surface represented by the Haldon summit, along the line of the important Sticklepath-Lustleigh dextral tear fault which crosses Devon from Barnstaple Bay to Tor Bay.

Existing deposits in the basin are known to be over 750 metres thick and they have been long quarried as pottery clays. On the margins of the basin, the Oligocene beds are overlain by soliflual deposits which on the east flank south of Chudleigh include much flint from the Haldon Gravels.

Along the Bovey and Teign rivers the clays are sharply overlain by variable fluviatile sands and gravels. The latter are most likely to be of late Quaternary age, and generally pass below sea-level in the Teign estuary.

Most Quaternary interest lies in irregularities in the bedding of the clays and lignites which apparently occur to depths of no greater than 8 m from the clay surface.

Dineley (1963) described several of these structures as sharp anticlines and domes, frequently circular or quadrate in plan, and he suggested a periglacial origin, in that permafrost expanding unevenly, both vertically and laterally, into unfrozen strata may have induced unequal pressures which resulted in the formation of diapir-type structures. Whilst clearly tempted to draw an analogy with pingos, he did not go so far as to make strict comparisons.

Alternative views would explain the structures as crumpling related to marginal flexuring as the basin subsided, or to compaction of saturated sediments under unequal loading by later deposits.

Doubts on a periglacial origin may be cast by Williams' (1969) suggestion that permafrost was largely absent from the

south-west during the Devensian. Certainly the structures do not seem to be 'active layer' phenomena, but there is a stronger likelihood that they are of Wolstonian or Anglian age, produced during formation of permafrost in lowlying saturated clays and silts. Apart from the possible creation of segregated lenses of ground ice, freezing of the clays at a variable rate could have led to the incorporation of unfrozen layers and lenses (taliks). The latter, freezing later, could have produced closed-system situations resulting in localized heaving and distortion of the beds.

Crucial points for future enquiry would be to establish that the structures are genuinely superficial, and that they are the result of subsequent rather than penecontemporaneous processes.

(A. STRAW)

DARTMOOR: TORS AND PERIGLACIATION

1. Dartmoor was a periglacial area during the Pleistocene cold phases. G. Manley (1951) reasoned that at the time of maximum glaciation the permanent snow-line might be expected to have cleared its highest summits by c.30m. Thus at no time was any part of the upland a source of outward-moving ice-streams. Field evidence supports this conclusion (Waters, 1964). No landforms on the Moor can be attributed to glacial erosion but many cut and built features owe their origins or their dominant characteristics to the operation of cryergic processes. These features include summit tors and clitters, valley-side buttresses and screes, rubble-drift terraces on valley floors, smooth interfluvial slopes on the granite, benched hill-sides on the aureole and the virtually ubiquitous "head". (Fig. 8).

2. At many sites two heads are identifiable: an Upper Head of large stones and joint-bounded blocks of sound granite (of which the clitters form the major part) and a lower or Main Head of much smaller weathered granite and crystal fragments set in a fine matrix of sandy or gritty loam. Their field relations suggest that they represent two cold phases, e.g., at Shilstone pit (Fig. 9) where they are separated by an erosional unconformity. The Main Head appears to represent a pre-existing regolith, re-distributed by solifluxion and/or wash. At some sites (Merripit Hill, SX/660800) it has overrun and preserved the vestiges of a pre-periglacial weathering profile; at others it is separated from basal, *in situ*, weathered material (growan) by a layer of downwashed regolith (bedded growan). It is indicative of a prolonged pre-periglacial phase with bioclimatic conditions which would favour the selective decomposition of jointed bedrock and sub-surface differentiation of the tors. Thus field evidence is compatible with the view that existing tors were exposed largely by solifluxion during the first periglacial phase and partially destroyed (as witness the Upper Head) during the second.

Possible chronology

Periglacial -	<u>Upper Head</u> - clitter formation -	DEVENSIAN
Fluvial	- slope modification	- IPSWICHIAN
Periglacial -	<u>Main Head</u> - tor exposure	- WOLSTONIAN
Fluvial	- weathering - tor formation	- HOXNIAN
	underground	

3. D.L. Linton (1952, 1955) interpreted the tors as products of a two-stage process involving a phase of deep weathering effected by ground water and guided by joint systems followed

by a phase of mechanical stripping. J.R. Palmer and R.A. Nielson (1962) doubted the former existence of deep weathering at tor sites, attributing examples of deep decomposition to the effects of pneumatolysis, and proposed an alternative hypothesis for the production of 'Palaeo-arctic' tors by frost action on exposed bedrock and solifluction during Pleistocene cold phases. More recently M.J. Eden and C.P. Green (1971) have distinguished products of pneumatolytic alteration from those of weathering and identified the latter as the 'sandy weathering type' which J.P. Baker (1967) attributed to a 'meso-humid sub-tropical climate'. They recognized the occurrence on Dartmoor of a deeply weathered zone but from seismic investigations suggested that it may have been confined to the main river valleys and to the margin of the granite. They accepted Linton's general hypothesis but noted that it required some modification.

4. Haytor Rocks - The bulk of this double tor is in very coarse-grained, biotite-rich, strongly porphyritic granite (Brammall's 'giant' or tor granite) which shows well-developed, wide-spaced vertical joints, pseudo-bedding planes and surface etching. The lower 1-2m of its westernmost face displays the contact facies of 'blue' granite - fine-grained, non-porphyritic, relatively free from biotite and divided by several sets of closely spaced vertical joints. The contrasted granites have been brought into relief by selective frost weathering. The effects of the juxtaposition of well-jointed and massive granites are seen in many tor outlines and in the clitter streams below them.

(R.S. WATERS)

THE WILLIAM PENGELLY CAVE STUDIES CENTRE AND JOINT MITNOR CAVE

The Pengelly Cave Studies Centre is situated in Higher Kiln Quarry (a disused Devonian Limestone Quarry) near Buckfastleigh. The property was purchased in 1961 by the Society for the Promotion of Nature Reserves, by whom it is leased to the Devon Trust for Nature Conservation. The latter body works in collaboration with the William Pengelly Cave Studies Trust (which also publishes the journal, Studies in Speleology) to maintain the quarry as a field centre. Interest is based on five cave fragments, opened by quarrying (all parts of the same system), and on a group of former agricultural buildings, in course of being developed as a visitors centre with a small cave museum, lecture hall and other facilities. The idea behind the Centre has been described by Sutcliffe (1965) and Maxwell (1969). Studies are as broadly based as possible with emphasis on conservation, especially in the light of increasing accidental damage to caves associated with greater leisure and easier travelling.

Two features at the Centre are of special importance in Quaternary studies: the relationship of the cave system to the terraces of the nearby River Dart; and Joint Mitnor (bone) Cave. Other important fields of work, not immediately relevant here, include studies of calcite in Reed's Cave (the Centre's stalactite cave; Wells, 1971); of the troglobitic gammarid (crustacea) Niphargus glenniei in Rift Cave; and of horseshoe bats in the same cave. Following a sharp decline in the population of greater horseshoe bats in other parts of southern Britain the Rift Cave colony is currently the subject of a conservation operation, and a grille is to be installed at the mouth of the cave in the spring of 1974, as soon as the bats have moved from their winter hibernation quarters there.

The relationship between the Higher Kiln Quarry Caves (which are continuous also with Baker's Pit Cave, opening from a neighbouring Quarry; though human connection is not possible) and the Dart terraces is of great interest. At the present day the River Dart flows near the caves (to the east) at about 120 feet O.D. There is a low terrace where Buckfast Abbey is situated; a well developed terrace on the east bank at about 180 feet; and another on the west bank at about 270 feet, above the cave system itself. Buckfastleigh Church stands on the flat of this terrace. The Dart terraces have been studied by a number of workers, including Green (1949) who regarded the church flat as part of an "Upper Ambersham" terrace, graded to a sea level about 25 feet above that of the Ambersham Terrace; the 180 feet terrace as being of "Boyn Hill" age. Whatever the validity of this nomenclature may be today, an interesting picture nevertheless emerges of a cave system still submerged beneath the river bed in Lower Pleistocene

ELEVATION OF JOINT MITNOR CAVE BUCKFASTLEIGH

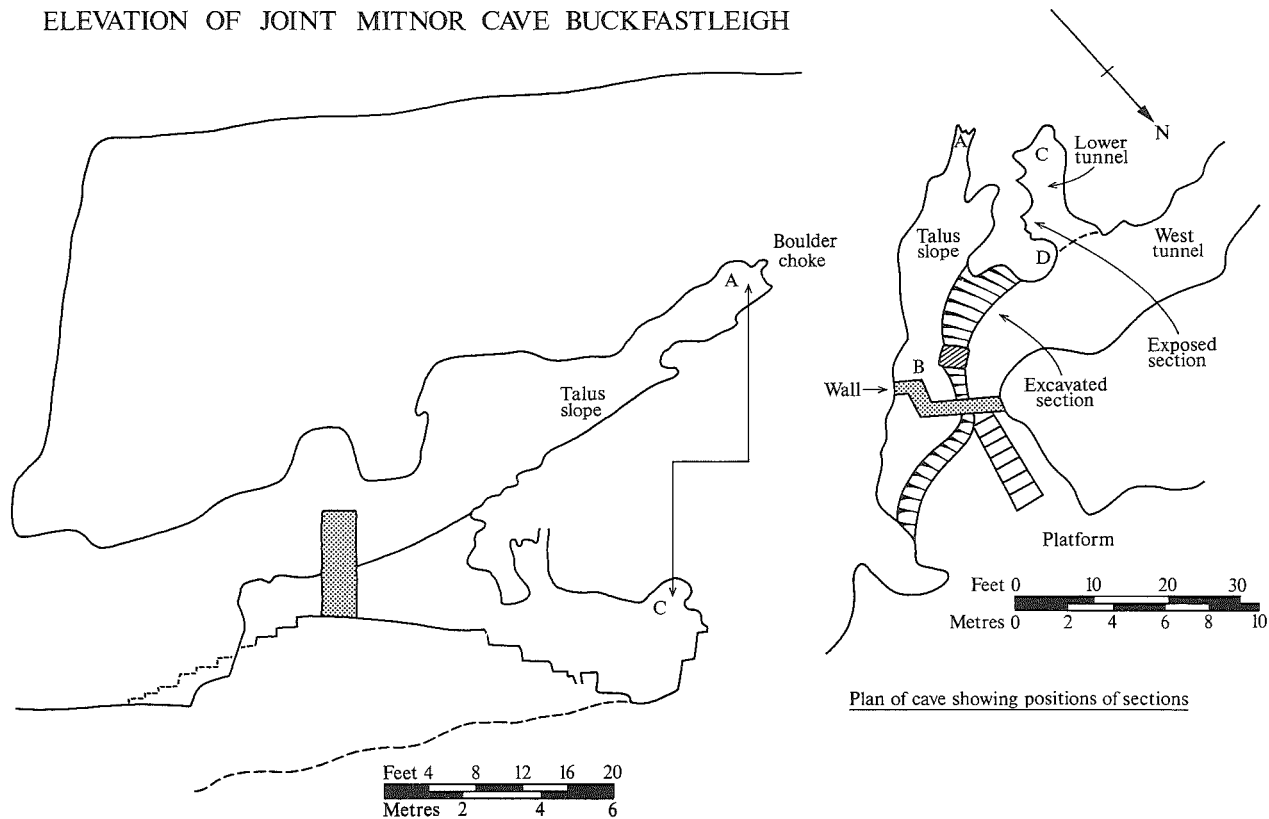


Fig. 10 - General elevation and plan of Joint Mitnor Cave.

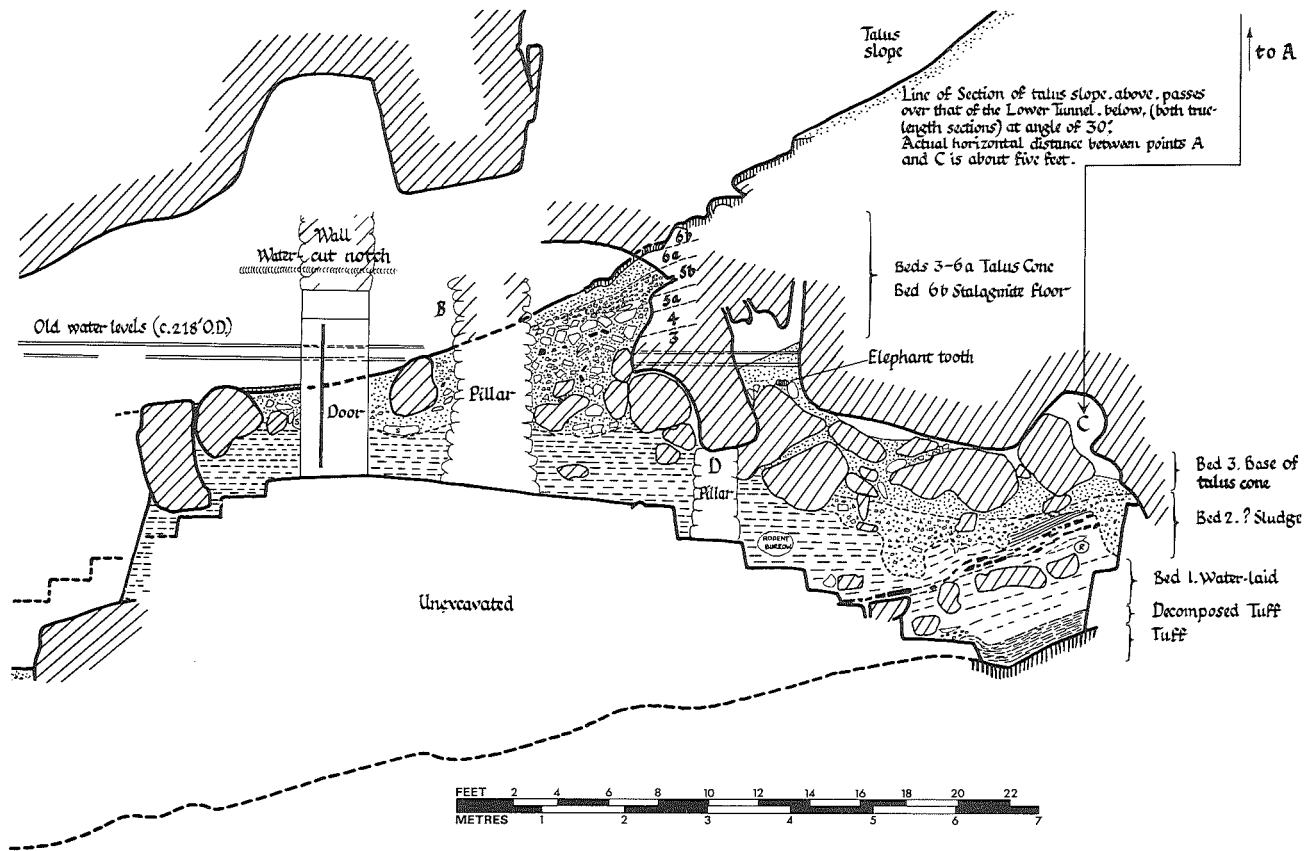


Fig. 11 - Detail of section in Joint Mitnor Cave.

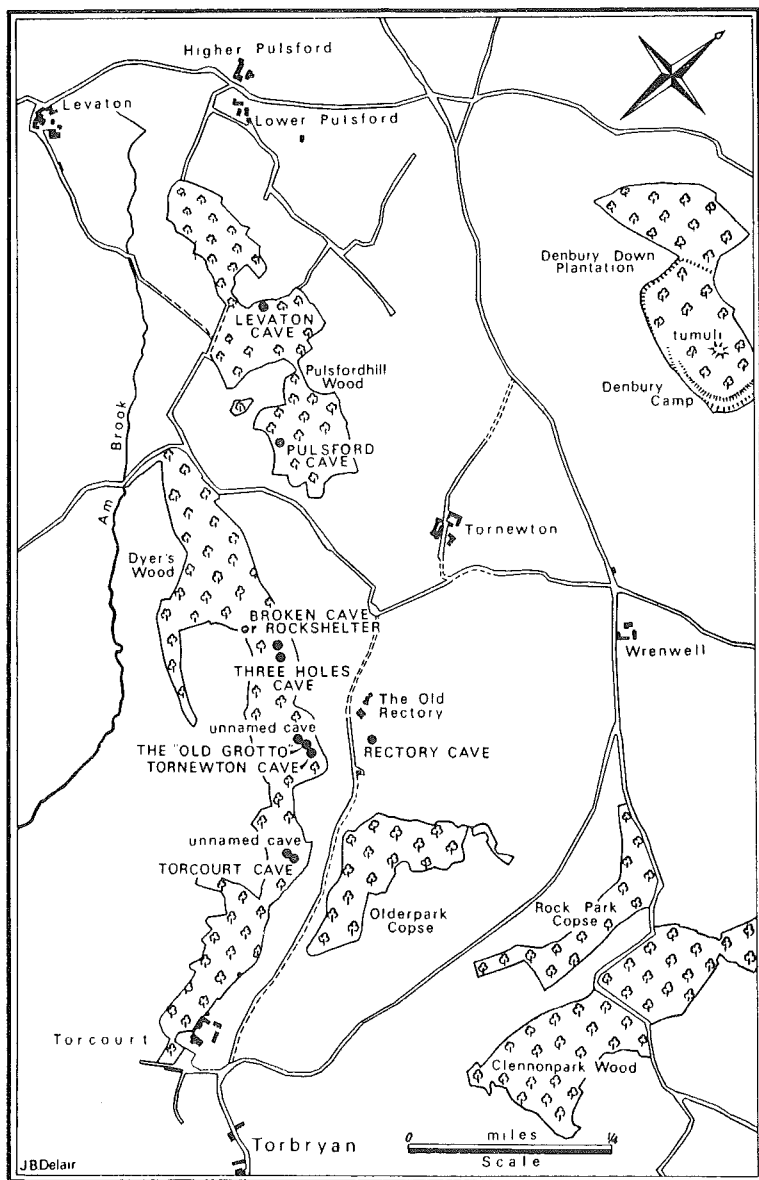


Fig. 12 - Location of the various Torbryan Caves.

PROVISIONAL (Oct. 1959.)
SECTION OF THE DEPOSITS

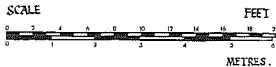


Fig. 13 - Section of deposits in Tornewton Cave.

times; gradually becoming drained of its ground water as the Dart cut down (or cut back) its bed, with consequent lowering of the water table. The caves show many characters, such as roof pendants and bedding plane anastomoses, regarded as criteria of solution below the water table (in the phreatic zone) with only minor subsequent invasion by a surface (vadose) stream. Old water levels are apparent on the cave walls at a number of places. The limestone is underlain by a basin-like and much faulted bed of green Devonian tuff, which forms the base of the cave system. This is exposed in Higher Kiln Quarry, including the floor of Joint Mitnor Cave and in nearby Bully Cleaves Quarry. Evidence that the River Dart formerly flowed above the cave system is provided by an abundance of pebbles derived from Dartmoor and its metamorphic aureole (granite, quartz-tourmaline rock, metamorphic rocks) both on the overlying flat and in many talus cones of surface deposits which have spilled subsequently into the caves below.

Two of these talus cones (one in Baker's Pit Cave, the other in Joint Mitnor Cave) have been found to contain Pleistocene mammalian remains. No excavation has been conducted in the former, which is difficult of access and where there would be major problems of earth disposal. The age of this deposit is still unknown. Extensive investigations have nevertheless been conducted in the Joint Mitnor talus deposit.

Although the present day entrance of Joint Mitnor Cave was opened by quarrying more than a century ago, it was not until 1939 that bones were first noticed there. Excavations from 1939-41 by the Torquay Natural History Society showed that the deposit contained an interglacial fauna with hippopotamus (Sutcliffe, 1960), now known to be the richest Last Interglacial mammalian assemblage from any British cave. Further excavation was conducted in 1963 at which time a door was erected at the cave mouth, electric lighting was installed and a permanent demonstration section was prepared to show the entire stratigraphic sequence, with some of the bones left in situ. A representative selection of mammalian remains and a model of the cave are also on display in the Centre's museum (Fig. 10).

Figure 11 shows a section of the deposits in Joint Mitnor Cave. Although, during the course of a visit to the cave, the upper strata are usually inspected first (since the lower deposits are best exposed in a small chamber at the back) the sequence will be described here in ascending order.

The floor of the innermost chamber of the cave is the top of the underlying Devonian tuff, the decomposed surface of which is visible at the base of the exposed section.

This is overlain by bed 1 - a water-laid deposit, umber coloured at the base, overlain by a red ochreous pan-like layer and laminated

clay and silt. A few Dartmoor-derived pebbles are present at the bottom bed 1, showing that some extraneous material was already able to enter the cave at this stage. Although no chemical tests have yet been carried out it is nevertheless tempting to regard most of this deposit as the insoluble residue from the limestone, deposited whilst the cave was still being formed beneath the water table. The Buckfastleigh limestone (though itself fairly pure) is criss-crossed with veins of umber and specular haematite (probably the extreme outer limit of the Dartmoor metasomatism) which could provide a ready source for such deposits. Bed 1 can also be seen below the bone bed in the entrance chamber and at the cave mouth, on the left of the steps outside the iron door. Three horizontal water-levels (two calcite ridges and one notch) on the right wall outside the iron door indicate former water levels in the cave at about 218-222 feet O.D.

Bed 2, visible only in the innermost chamber of the cave lies in channels in bed 1 and probably represents sludging of the top of this deposit. The water table had by now apparently fallen below this level.

Beds 3-6 are the deposits of a talus cone beneath a now blocked shaft in the cave roof. These deposits exceed 20 feet in thickness at the back of the cave and they thin out towards the cave mouth where they disappear completely outside the iron door. They are typical talus deposits, with steeply sloping stratification, and with ungraded earth and rock fragments mixed together; quite unlike any water-laid deposit.

The mammalian remains are restricted to layers 3-4 which seems to have accumulated in a relatively short time. The following mammals are represented:-

Wolf	<u>Canis lupus</u>
Fox	<u>Vulpes vulpes</u>
Wild cat	<u>Felis silvestris</u>
Cave lion	<u>Panthera spelaea</u>
Spotted hyaena	<u>Crocuta crocuta</u>
Badger	<u>Meles meles</u>
Brown bear	<u>Ursus arctos</u>
Straight-tusked elephant	<u>Palaeoloxodon antiquus</u>
Narrow nosed-rhinoceros	<u>Dicerorhinus hemitoechus</u>
Wild boar	<u>Sus scrofa</u>
Hippopotamus	<u>Hippopotamus amphibius</u>
Fallow Deer	<u>Dama dama</u>

Giant deer	<u>Megaceros giganteus</u>
Red deer	<u>Cervus elaphus</u>
Bison	<u>Bison cf. priscus</u>
Hare	<u>Lepus sp.</u>
Water vole	<u>Arvicola terrestris</u>
Field vole	<u>Microtus agrestis</u>

The above fauna is of interglacial character and appears to be entirely homogeneous with no cold species such as woolly mammoth, woolly rhinoceros and reindeer. A similar faunal assemblage occurs in the Ipswichian Upper Floodplain Terrace deposits of the River Thames and it seems likely that the two faunas are approximately contemporaneous. The high proportion of herbivores (especially bison) in Joint Mitnor Cave and the relative rarity of carnivores suggests that the animals had fallen down a shaft, beneath which their remains became mixed with the talus deposits. Of the carnivores, remains of hyaenas are most numerous, but these are nearly all of adult animals and there is no evidence of the cave having been a lair like Tornewton Cave (see below).

Layer 5a is composed mainly of medium sized blocks of limestone with no interstitial earthy material; 5b of small fragments of limestone; 6a is a compact cave earth with abundant fragments of local slate; 6b is a stalagmite floor; overlain by another deposit resembling 6a. The significance of these uppermost strata, which are unfossiliferous, is not clear. At the present day the field above the cave is mantled with a slaty deposit which may represent Last Glaciation solifluxion. The possibility that layer 5b represents frost shattering around the mouth of the shaft; and 6a derived solifluxed material; suggests that the uppermost part of the talus may be of post Ipswichian age. The shaft is now entirely choked and no sign of it is visible in the field above.

Joint Mitnor Cave is visited each year by a substantial number of students, cavers, palaeontologists, and others (even cave landlords). It is hoped that, by demonstrating the importance of stratification in cave deposits; and of the need not to excavate caves from ceiling to floor and from wall to wall, but to leave part of the deposit intact wherever possible; and by stressing the need to publish all work; there will be a decrease in the "pot hunting" type of excavation (often never published), which has been so numerous in the past. The results, in Devon at least, where there is a great local awareness of sites needing protection, are most encouraging.

(A.J. SUTCLIFFE)

The Torbryan Caves, including Tornewton Cave

A group of ten small caves and rock shelters of great palaeontological and archaeological importance is situated near the village of Torbryan, about five miles east of the Pengelly Centre, (Figure 12).

The Torbryan Caves have been the subject of a series of excavations, going back more than a century. The earliest phase of work, and probably the most remarkable, took place between about 1865 and 1990 when James Lyon Widger (a local draper's assistant) excavated in four of the caves. At this time William Pengelly, who had only shortly beforehand demonstrated Man's antiquity in the Brixham Cave, was excavating in Kent's Cavern and it is astonishing that there is no mention of either the Torbryan Caves or of Widger in any of Pengelly's published writings. This problem has recently been explained by the discovery of a series of unpublished letters in the Torquay Museum and the British Museum (Nat. Hist.). These have shown that Widger and Pengelly did meet in 1870, when Pengelly offered to buy the good will of the caves from Widger, on behalf of the Torquay Natural History Society. Widger declined to part with this and expressed his intention to prove that Man was of no greater antiquity than our forefathers had supposed. This led to a dispute and Pengelly turned his interest elsewhere. Meanwhile the far reaching potential significance of Widger's work was not fully appreciated by Pengelly or by Widger himself. While Pengelly was writing that there was no evidence of hippopotamus in Devon, Widger had found hippopotamus remains in Tornewton Cave, though their identity was unknown to him during his lifetime. His account of the stratigraphy of this cave, published posthumously in a local newspaper (Widger, 1892) clearly records the cold - interglacial - cold sequence, now recognised as of such great stratigraphic importance, yet this was never grasped by Pengelly, who only saw the cave at an early stage of its excavation. For a general account of the Torbryan caves, of Widger's work there and of his dispute with Pengelly, see Walker & Sutcliffe (1968).

Tornewton Cave was further excavated by the Torquay Natural History Society from about 1936-39 and there have been excavations by Cheesman, Rosenfeld, Sutcliffe and Zeuner in various Torbryan caves during the years since the second war.

The main object of the visit to Torbryan will be to examine Tornewton Cave. The party will enter Dyer's Wood at its northern end, at which point the now dry Torbryan valley has been decapitated by the River Ambrook. The cave openings occur in a series of limestone crags at the sides of the dry valley. The party will walk southwards passing the entrances of the BROKEN CAVE, a Neolithic occupation site partly excavated by Widger;

THREE HOLES CAVE, a Mesolithic occupation site with Pleistocene lower strata, partly excavated by Widger and further by Rosenfeld & Zeuner (Rosenfeld, 1964); an unnamed cave with a Pleistocene fauna; and the OLD GROTTTO, with the remains of a Medieval secret chapel (Zeuner, 1960), finally arriving at TORNEWTON CAVE. LEVATON CAVE and TORCOURT CAVE, two important Last Glaciation hyaena lair caves in other parts of the valley, unfortunately can not be included in the schedule.

Tornewton Cave is shaft like in form, access to the bottom of the shaft being possible through a side entrance. Since the cave has been excavated in installments for a century and since the bottom of the shaft floods after exceptional rainfall, no demonstration section such as that in Joint Mitnor Cave has been preserved, though fragments of most of the strata can still be examined on the cave wall. The long sequence of deposits (Figure 13) has been described by Sutcliffe and Zeuner (1962). The deposits are physically divided into two parts, those of the cave shaft itself and those of the talus outside the cave, separated by a barrier of bed rock with only partial continuity through two interconnecting tunnels. The two parts differ extensively in stratigraphic detail.

The deposits represent the most complete Upper Pleistocene sequence in any British cave. If we disregard the basal water laid clay, M, the four stalagmite floors and other minor deposits, four strata stand out as being of special importance. These are:

- D Widgers 'Diluvium'
- F 'Reindeer Stratum'
- I 'Hyaena Stratum'
- L 'Glutton Stratum'

The 'Glutton Stratum' contained great quantities of remains of the brown bear, Ursus arctos, and apparently accumulated while the cave was occupied as a lair by these animals. Other large mammals are wolf, Canis lupus; fox, Vulpes vulpes; cave lion, Panthera spelaea; Glutton (wolverine), Gulo gulo; horse, Equus caballus; rhinoceros; reindeer, Rangifer tarandus; bovid (cf. Bison); hare, Lepus sp., and clawless otter, Cyrtionyx antiqua (a new record for Britain). Reindeer and glutton are suggestive of cold climatic conditions.

By the time the 'Hyaena Stratum' accumulated the cave had apparently been taken over as a lair by spotted hyaenas and the presence of hippopotamus indicates that the climate had become interglacial. The large mammals from this layer are hyaena, Crocota crocuta; wolf, fox, cave lion, brown bear, narrow-nosed rhinoceros, Dicerorhinus hemitoechus; hippopotamus, H. amphipius; fallow deer, Dama dama; red deer, Cervus elaphus; bovid and hare.

The quantity of hyaena remains, which make up nearly the whole of the finds from this deposit, is astonishing. The total

number of hyaenas represented is uncertain, since excavation has been conducted over such a long period, but probably approaches 4-500 in a deposit less than 30 feet long, six feet wide and two feet thick. The remains are fragmentary, with teeth and foot bones predominating, and some are gnawed. They represent animals of all ages from juveniles with milk teeth to aged animals. Coprolites are numerous. Immense accumulations of fragmentary hyaena remains such as this have frequently been found in British bone caves. Kirkdale Cave was the first instance to be recorded. So similar were the finds in Kirkdale and Tornewton Caves that one could readily believe that Buckland had been describing those from the latter site. Although it has been suggested from some quarters that Man was concerned with the concentration of hyaena remains at Kirkdale, it has been pointed out by Boylan that the cave was far too low for this to be feasible. There seems little doubt that both Tornewton and Kirkdale Caves were indeed spotted hyaena lairs, as postulated by Dean Buckland for Kirkdale Cave, a century and a half ago.

The 'Reindeer Stratum' (the part in the talus slope outside the cave, not excavated by Widger) produced a few worked flints of Upper Palaeolithic type, a human incisor and remains of wolf, fox, hyaena, stoat, bear, horse, woolly rhinoceros, reindeer, bovid, mole and hare. Reindeer suggests that the climate had become cooler once more.

The 'Diluvium' contained a Holocene molluscan fauna.

The above sequence is interpreted as representing a series of climatic fluctuations from cold to interglacial to cold to Holocene, during which time the cave had been used successively as a bear lair, a hyaena lair and a human occupation site. The cave is of special interest in the study of Upper Pleistocene mammalian faunas of the British Isles, being the only known locality where deposits of (presumably) Wolstonian and Last Glaciation age are separated by an interglacial stratum with hippopotamus. On first inspection the mammalian faunas of the two cold horizons are indistinguishable and they could be confused in isolation. Fortunately the deposits contained abundant rodent remains. These have been studied by Kowalski (1967) who found the two faunas to be different. The lower cold stage is characterised by, among other rodents, Cricetus cricetus (hamster) (a new record for the Upper Pleistocene of Britain); cf. Allocricetus bursae (hamster); Lagurus lagurus (steppe lemming) (another new record for the British Isles); and Microtus nivalis (snow vole). All these are absent from the upper cold layer, where they are replaced by large quantities of Microtus gregalis (narrow-skulled vole). Other rodents, including Dicrostonyx torquatus (collared lemming) occur in both levels. This key for distinguishing pre- and post-Ipswichian rodent faunas is of great stratigraphic importance.



Plate I

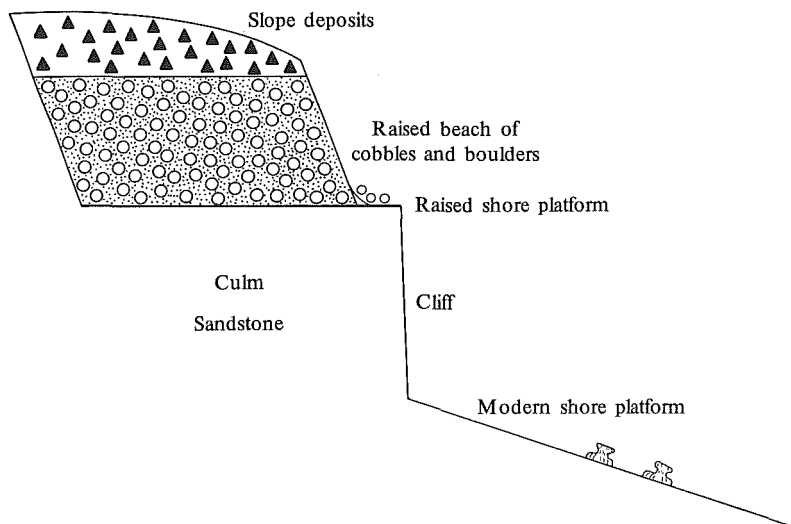


Fig. 14 - Diagrammatic cliff profile, Westward Ho!

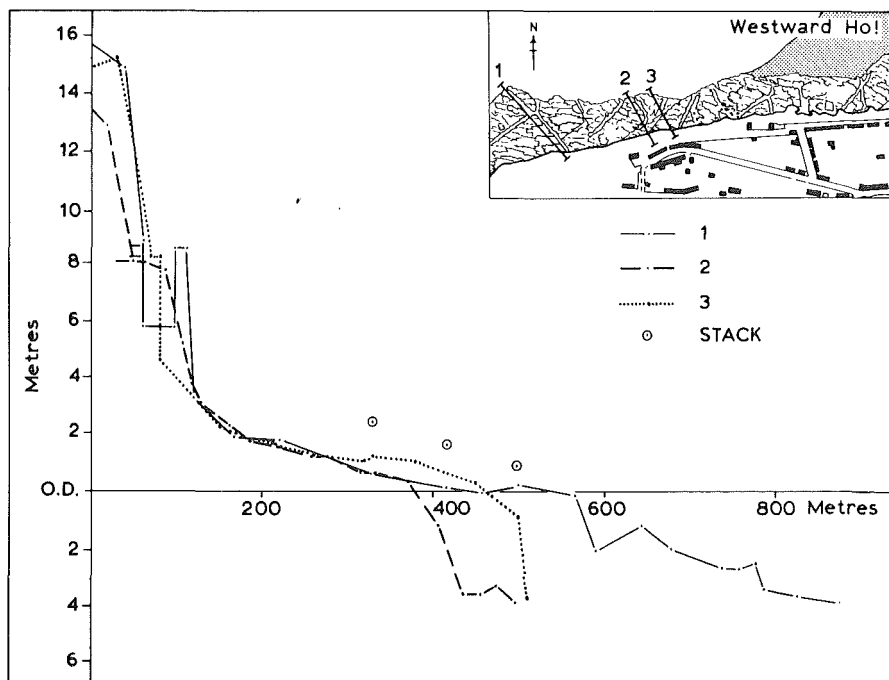


Fig. 15 - Surveyed profiles of cliff and platform, Westward Ho!

WESTWARD HO!

The Pleistocene cliff section at Westward Ho! (Fig. 14) (Plate I) on the southern flank of the Taw-Torridge estuary, shows a simple tri-partite division : raised shore platform, raised beach and slope deposits.

- a) The raised shore platform, at a height of 8-9 metres O.D. (Fig. 14) can be traced for some 600 metres from near Rock Nose (SS 419 290) to east of the Holiday Camp (SS 424 291). By comparison the shore platform at Saunton on the opposite side of the bay passes under raised beach and dune deposits at a height of 5 to $5\frac{1}{2}$ metres. Stephens (1966) gives a height of 45 feet (13.7 metres) for the rock platform at Middleborough in Croyde Bay. Rogers (1946) suggested that the height of the Westward Ho! feature falls progressively from west to east over a range of 23 feet (7 metres) in 600 yards. He quoted J.F.N. Green's idea that this reputed fall can be accounted for by the fact that the present cliff line runs obliquely across the shore platform, i.e. that in the west the overlying deposits have been removed by erosion to expose the notch while in the east a large part of the platform is still covered and the recorded height is much further from its high tide limit. The raised shore platform is quite distinct and separate from that of the present day which reaches a height of between 2 and 3 metres O.D. where it passes beneath the present storm beach. Kidson (1971) has suggested that there are indications of other shore platforms a) at $-1\frac{1}{2}$ metres and b) at about +5 metres (Fig. 15). This latter is only represented by "stacks" above the present platform. More than one phase of shore platform formation is clearly indicated.
- b) The raised beach consists almost exclusively of cobbles of culm sandstone in a sandy matrix. It varies between 0.5 metre and 4.5 metres in thickness. It is as devoid of erratic material as is the modern pebble ridge which is partially supplied with cobbles and boulders by the erosion of the raised beach. Prestwich (1892) showed that it can be traced from the cliffs at Cornborough Common (SS 412 281), where it is separated from the overlying head by three feet of sand, to Appledore and thence, by implication, to Fremington. Stephens (1973) ascribes the raised beach to the Ipswichian. Since it is entirely barren such a date is essentially tentative. Nevertheless, on grounds of probability alone, it seems logical to accept this date until further evidence disproves it. However, it seems to the present writer that the Westward Ho! beach is of the same age as the Saunton raised beach which Stephens ascribes to the Hoxnian.

- c) The head overlying the raised beach is of undifferentiated angular slaty material which has clearly been derived from the hill slopes behind it. It varies in thickness from 2 to 3 metres.

(C. KIDSON)

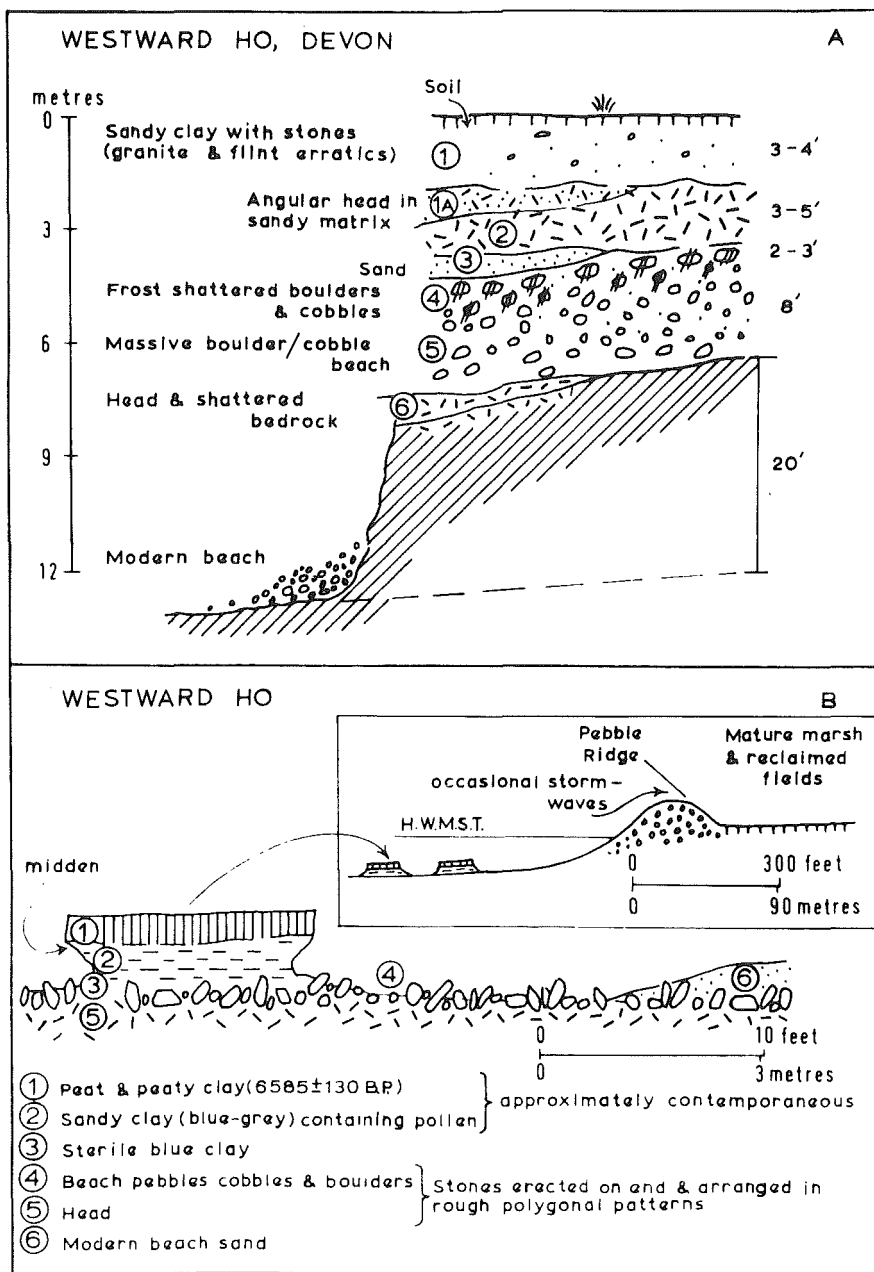


Fig. 16 - Sections at Westward Ho!

WESTWARD HO!

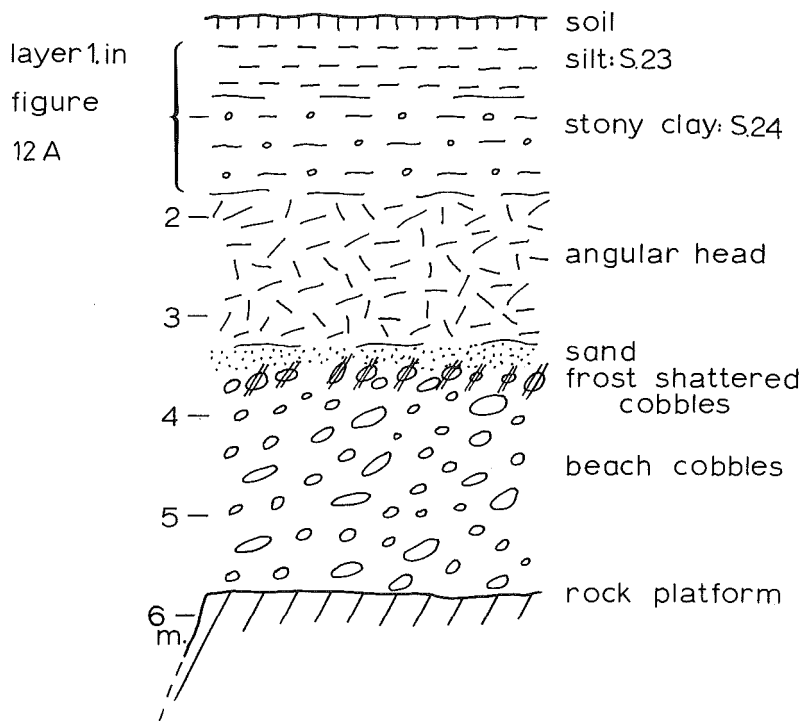


Fig. 17 - Section at Westward Ho!

Table I

Sample Ref.	SIZE			% Air/Dry Moisture	pH	Loss on Ig.	Ex. Ions			
	sand	silt	clay				Ca	Mg	K	Na
ST2 Croyde Lime Kiln	16.84	40.36	42.8	3.33	7.15	4.12	3700	88	260	205
ST6 Croyde Lime Kiln	23.60	41.20	35.20	1.91	8.00	3.46	1725	98	230	480
ST9 Croyde B. Site	18.02	34.98	47.00	3.24	7.45	4.33	3750	44	150	120
ST13 Croyde B. Site	17.64	29.16	53.20	3.34	7.60	1.46	1175	7	105	85
ST5 Fremington W. till	26.30	32.70	41.00	2.01	6.60	3.67	925	210	180	125
ST8 Fremington W. till	18.20	31.80	51.00	2.50	7.10	4.02	1650	195	210	65
ST7 Fremington W. till	26.84	33.96	39.20	2.01	7.40	3.61	1075	133	170	165
ST3 Fremington UnW. till	17.70	27.50	54.80	2.70	7.50	4.99	4500	319	315	85
ST18 Fremington UnW. till	6.18	24.62	69.20	4.82	8.50	6.37	2200	600	150	140
ST22 Fremington Quay W. stony clay	10.00	39.80	50.20	4.28	7.60	2.02	850	90	39	250
ST27 Croyde Bay-stream section W. stony clay	24.20	36.40	39.40	11.86	7.40	6.71	450	235	77	850
ST23 Westward Ho! Sample A	9.72	39.08	51.20	2.98	7.70	3.90	450	310	60	185
ST24 Westward Ho! Sample B	8.44	43.16	48.40	3.71	8.00	3.49	650	485	80	185

WESTWARD HO'

The elevated rock platform in Fig. 16 A rises to at least 6 m (20 ft) above the present tidal platform and modern beach, and the old notch is at about 12.2-13.7 m (40-45ft) O.D. Layer (1) is considered to be an Upper Head deposit which has moved by solifluction to its present position, including some pebbles derived from a till, presumably an equivalent of the Fremington till, which outcrops only a few miles away in the Taw estuary. Layers (2) and (3) represent a Lower Head, and the frost shattering on the top of the raised beach represents freeze-thaw conditions during the same cold period. In places, along the cliff-top layer (1) is replaced by blocky, angular head (layer 1A), similar to that seen at Middleborough in Croyde Bay.

Analyses have been made of two samples (ST23 and ST24) of material overlying head and beach gravels in sections below the old quarry, at about 300 m. from the large hotel on the western edge of the town. The stratigraphy is shown in Figure 17, and analyses in Table I.

It is interesting to note that no fresh, angular head is present at the top of the section, where what may be either a wind blown or colluvial silt overlies a stony clay containing erratics. If this latter material is till, as the writer believes, then is it in situ, and does it represent a facies of the Fremington till?

The arrangement of the deposits suggest that a period of beach formation, at a higher level than present, was followed by climatic conditions, sufficiently severe to disturb and crack the beach cobbles, produce head, and distribute till with erratics. A further cold period, and a long period of weathering, accounts for the weathering of the material in layer (1) and a coarse upper head. In general, there is good agreement with the stratigraphy recorded from other sections around Barnstaple Bay, especially near Croyde.

The 'submerged forest' at Westward Ho' has been known for over 300 years (E. H. Rogers, 1946). Churchill and Wymer (1965) have reinvestigated the site and provide a summary of previous work at Westward Ho'. They describe in some detail a kitchen midden (also referred to in Rogers, 1946) occurring under a layer of dry fen peat (deposit 1) from which a date of 6585 ± 130 B.P. (Early Atlantic age) was obtained (Fig. 16 B, is based in part on their drawing). The midden, overlying peat, and associated upper blue clay (2, with pollen) were regarded as being contemporaneous and Mesolithic flints were recovered from the midden. The deposits can still be seen in patches between the pebble ridge and low-water mark. Churchill and Wymer (1965) recorded that the 'sterile blue

clay (3) contained no foraminifera, diatoms, mollusca, pollen or seeds', but was merely penetrated by roots from the peat above. They demonstrated that mean sea-level at about 6500 years B.P. was approximately 4-6 m (13.7-20 ft) below that at present, which is consistent with conditions at Margam (South Wales) and in Somerset; their results implied an absence of crustal warping in the Bristol Channel since that time.

In 1966 and 1973 the scouring of the beach by winter storms permitted fresh observation to be made of deposits (4) and (5). The postglacial peats and clays, and sterile clay overlaid a definite horizon of beach cobbles (4). The majority of the beach cobbles were erected on end, some being embedded in sterile blue clay (3) but most in the head (5). There was a rough polygonal arrangement of the cobbles and stones in the head, making a kind of patterned ground (Fig. 16 B). The lower intertidal rock platform forms the base for these deposits, and is thus in part at least a relic feature, older than the head resting directly on it. The difference in height of the beach deposit in sections A and B is significant, but the contrast in the stratigraphy makes correlation difficult. It seems likely that these are beaches of a different age. Head layer (2) in the cliff section (Fig. 16 A) is correlated tentatively with head layer (5) in Fig. 16 B resting on the foreshore rock platform. Nowhere can it be shown that the beach cobbles (4) on the foreshore are overlain by a head deposit, only by sterile blue clay, and datable postglacial deposits.

It seems likely that the cryoturbation of the head (5) and beach cobbles (4) took place during the Devensian cold period (cf. frost disturbance of deposits at Saltmills, Co. Wexford; Mitchell, 1962) and thus the beach gravels may be of Ipswichian age. The highly weathered head (5), and probably head (2) in the cliff section could then be regarded as Wolstonian in age.

Postglacial shingle beaches have never been observed to be disturbed by frost action in this way, for many of the cobbles and boulders are erected, and embedded in the head (5). This 'Ipswichian' beach (4) has been responsible for the trimming of an older rock platform, eroding and stripping away part of a head (5) deposit resting upon it, and also cutting back a new rock cliff in places. There is no evidence to suggest that the height of beach formation and cutting of a platform across rock and head differed significantly from that of the present day. It seems likely that the Flandrian transgression simply reworked beach gravels already in existence on a pre-existing platform of rock and head. Temporary lagoons allowed the fossiliferous clay (2) and peat (1) to form, before a particular shingle bar was rolled landward across it, at some time after 6500 years B.P. One of these postglacial shingle bars now forms the famous 'Pebble Ridge' of Westward Ho! (about 3 km (2 miles) long and 6-9 m (20-30 ft) high above its base) its crest rising

some 4.6 m (15 ft) above high-water mark (Spring tides). It has been estimated that the south-western end of the ridge occupied a position 180 m (600 ft) seawards of its present position in 1863. In position and height (crest at about 7.6-9 m: 25-30 ft O.D.) it probably resembles the form of the Eemian beach ridges, for it rests upon head (5) in at least one place, and rock near the southern end of the ridge.

(N. STEPHENS)

THE FREMINGTON AREAThe Fremington boulder clay

The Fremington boulder clay (Maw, 1864; Mitchell, 1960; Stephens, 1966b) extends along the depression from Fremington to Lake and a small outlier occurs at Clampit, situated on a lower rock ridge which is orientated east to west, from Hele to Penhill (Fig.18). A narrow tidal creek known as Fremington Pill occupies part of the western end of the depression between the rock ridges, and a wave-cut rock platform is seen around the western end of Hele-Penhill ridge. It is particularly well exposed in the railway cutting near Fremington Station, and from a height of 10 m (33 ft) O.D. it sinks northward and disappears below the modern beach before the old Lime Kiln is reached. Beach deposits rest upon the rock platform on either side of the tidal creek, and in the railway cutting. The beach shingle forms hummocky ground near Combrew Farm (where the surface is at about 16 m (50 ft) O.D.); it is overlain by weathered till in places near Fremington Quay Station (Dewey, 1913) and by fresh, unweathered boulder clay in the clay pits. Analyses of the weathered and unweathered facies of the Fremington till are provided in Table I, in comparison with till deposits from Croyde Bay and Westward Ho!

When unweathered the Fremington boulder clays (layers 4 and 6, Fig.19A), and the included mass of stoneless clays (layer 5) are highly calcareous, contain shell fragments, pieces of lignite, erratics and striated stones, and from analyses appear indistinguishable from the Irish Sea till, known as 'Eastern General' or 'Ballycroneen till' in Ireland (Stephens, 1966b). A composite section from the east and south faces of Brannam's Pit is reproduced in Fig.19A.

Mottled stony clay containing erratics (=weathered till) and solifluction 'earth' (layer 2) overlie the boulder clay. Deep frost cracks or pipes, filled with a sandy-clay paste which gives a non-calcareous reaction, extend some 1.5m (5 ft) down into the stony clay, but no fossil ice-wedges have been detected; many of the angular rock fragments are inclined at vertical or high angle positions which may be interpreted as resulting from severe frost heaving and reorientation. A distinct red-coloured layer of gritty-sand about 0.6m (2 ft) thick separates the upper stony clay (layer 2) from 1.2m (4 ft) of red weathered (decalcified) till (layer 3) in places. Thus the total depth of the weathered and disturbed material overlying the fresh till is from 2.4 to 3.6m (8 to 12 ft), a depth comparable with that obtained from many Irish sections in the older Irish Sea till. The inference is that such weathering and disturbance represents a full interglacial followed by another glacial period (=Devensian). Away from

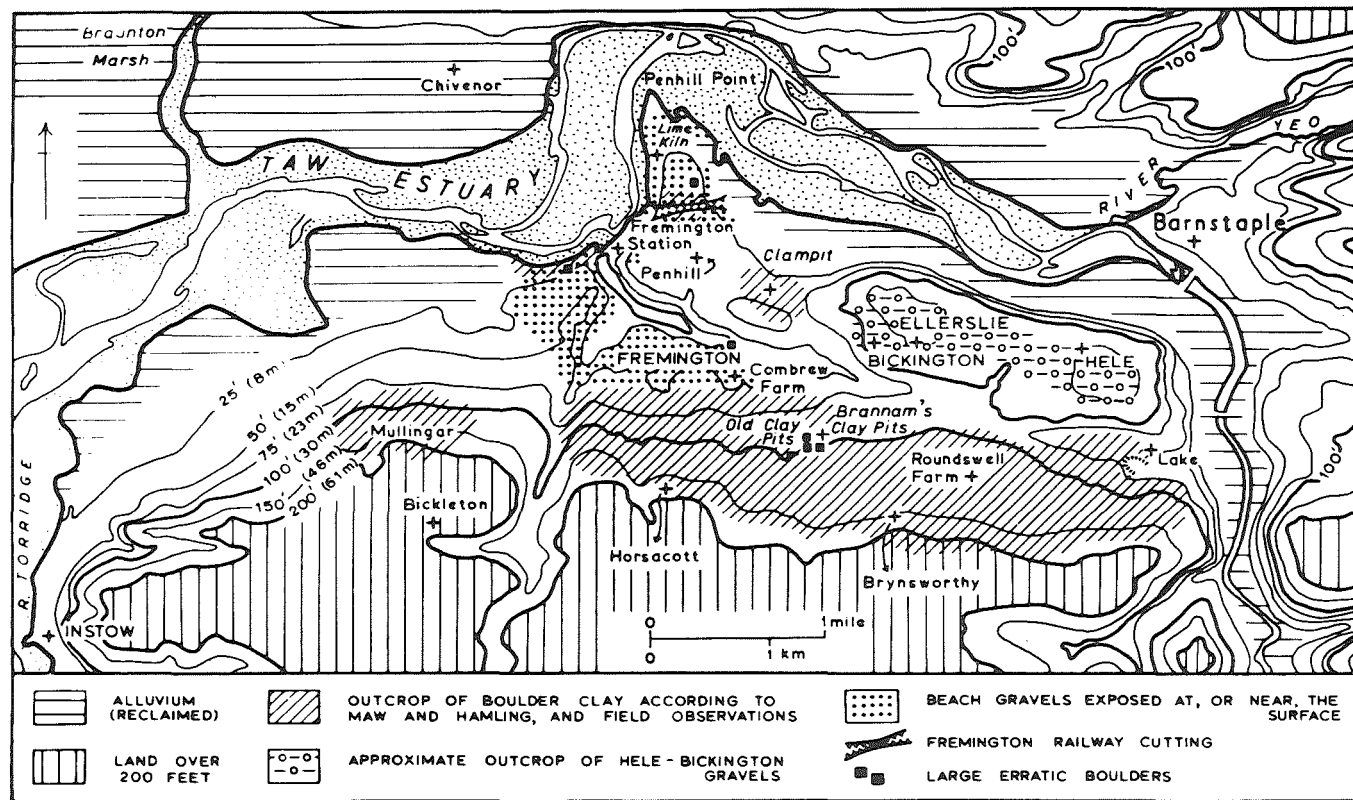


Fig. 18 - Relief and drifts around Fremington.

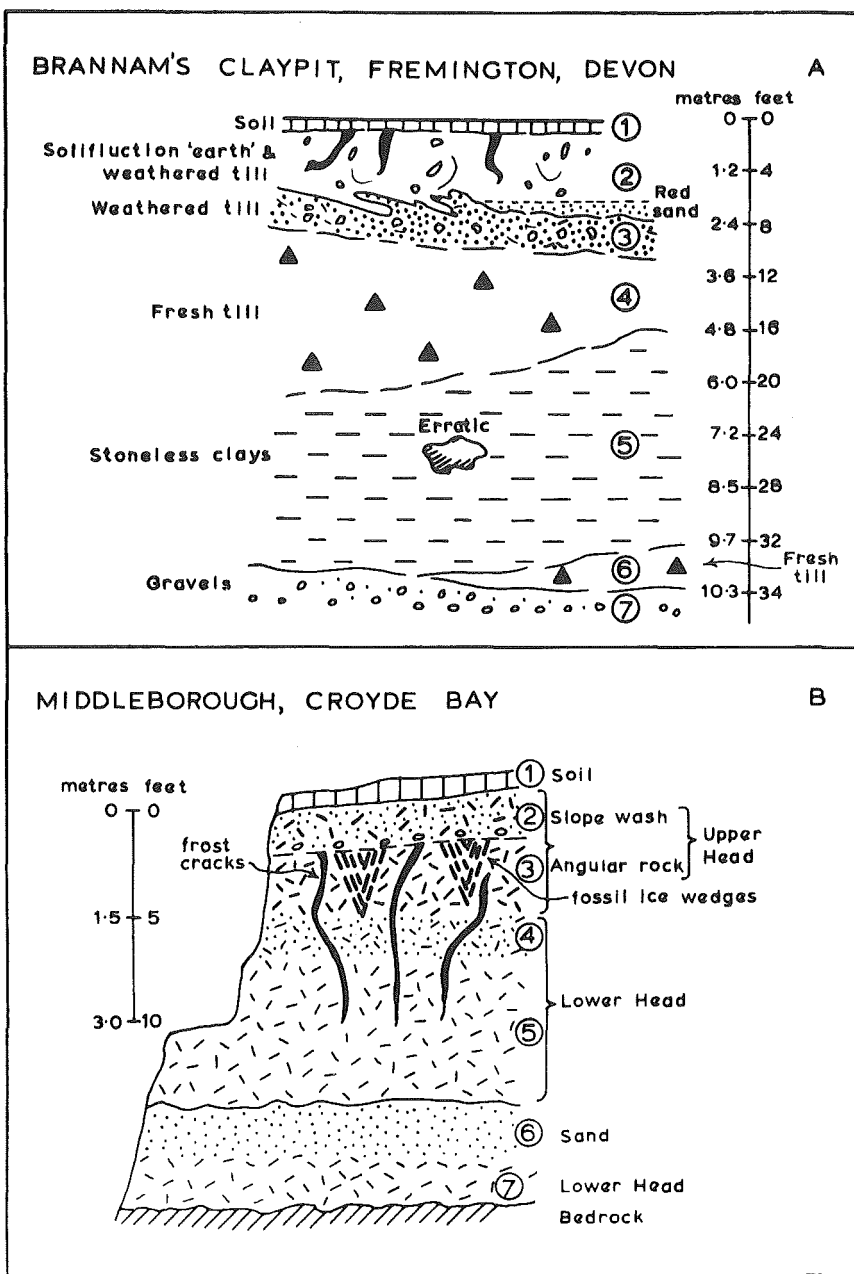


Fig. 19 - A - Composite section in E. and S. faces. B - Cliff section
(sample analyses, layers 2,3,5,6 and frost-crack, see Table II)

FREMINGTON QUAY

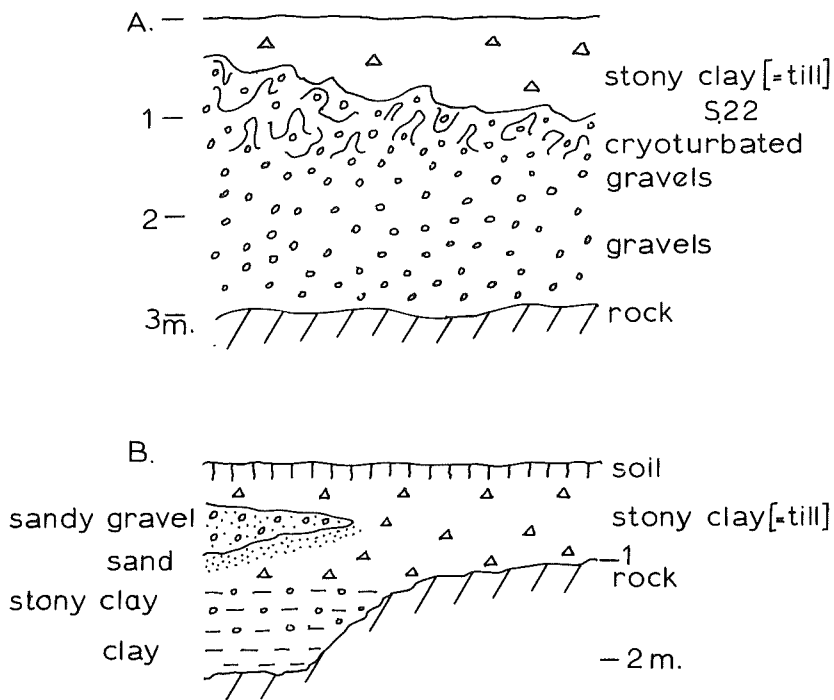


Fig. 20 - Sections at Fremington Quay.

the vicinity of the clay pits the local head or solifluction 'earth' contains no erratics or striated stones, which are abundant in layers 2 and 3 in Brannam's Claypit. Till has also been recorded along the Fremington Pill (stream), and near the new bridge carrying the main road across the Pill some two metres of red-brown, weathered stony clay was exposed in the new road cut in 1966. The stony clay contained abundant striated stones and a few erratic pebbles, and rested upon black shale rock.

Fremington Quay

The stratigraphy of the sections exposed to the west of the railway bridge over the Pill stream varies considerably. Two sections are reproduced in Figure 20 A and B. The various exposures show stony clay (=till) in contact with either gravels, which appear sometimes to be cryoturbated, or bedrock. The clay has yielded occasional striated and erratic stones, and has been described by Dewey, 1913.

Penhill, near Fremington Quay Station

Sections are rather poorly exposed in the railway cutting east of the old station, where the stratigraphy shows:-

Brown sandy clay	up to about 1m.
well-rounded pebbles with sand, and a fine matrix (silt plus clay);	about 2m.
pebbles mostly disturbed by frost (?) or passage of ice (?)	
well-rounded pebbles and cobbles, with sand	about 2-3m.
rock platform, well-planed at height of 33ft. O.D.	

The pebbles and cobbles appear to be part of the enormous mass of material forming Penhill Point; throughout, and especially at the Old Lime Kiln section, about halfway along the Point, a fine matrix is seen, apparently derived from the brown clay overlying the pebbles and cobbles in the railway cutting.

The gravels capping the Hele-Ellerslie ridge (Fig.18) are highly weathered, contain abundant flint, but with local rock types predominating, and have been disturbed by frost cryoturbation. They may represent outwash deposits from the Fremington till ice, or be, in part, the remains of ancient river alluvium.

(N. STEPHENS)

QUATERNARY DEPOSITS AROUND FREMINGTONPenhill raised beach

North of the railway line at Penhill a perfectly preserved fossil spit is seen which is related to a sea level higher than today's. Its summit reaches a height of 16.7 m.A.O.D. The whole structure rests on a broad rock platform at heights as low as minus 1.8 metres near the distal end of the spit. Bands of coarse shingle interdigitated with finer sands and gravels are seen in the coastal sections and in the railway cutting. The orientation of the shingle is typical of that produced during the deposition of a spit and disturbance is limited to the areas immediately beneath the overlying slope deposits. This overturning is attributed to periglacial processes.

There is no evidence of glacial deposits in association with the spit, nor is there evidence of any but minor disturbance of the shingle.

It is difficult to believe that such primary structures preserved in the unstable and delicate medium of shingle could have survived its overriding by Irish Sea ice. It would seem impossible that ice which elsewhere laid down up to 24 m of boulder clay could have left intact, and in such perfect detail, the shingle spit of Penhill. The overturning of the shingle is inadequate testimony to the powerful machinery of an advancing ice sheet.

Site of old clay pits at Clampitt (SS527328)

Borehole 4 in Figure 2/ shows a section through the worked out claypits at Clampitt. This reveals backfill over a thin veneer of Fremington Clay (till) with a lens of gravel trapped beneath the clay. Only the clay and gravel are in situ, the clay being left by the workers to seal the floor of the old pits. The gravel is Maw's basal gravel. It is notably different from the shingle of the raised beach of Penhill, being angular and poorly sorted.

Similar boreholes, together with geophysical work, show the presence of small patches of till on the interfluvial areas south of the raised beach. Few of these have Maw's basal gravel beneath them. In particular there is no basal gravel beneath the area of till which is closest to the raised beach at grid reference SS519 330.

Resistivity and seismic work confirmed by boreholes shows a separate distribution of till and raised beach. The tills are confined to the east-west valley south of Bickington with a few small outliers occupying the interfluvial areas of the Penhill

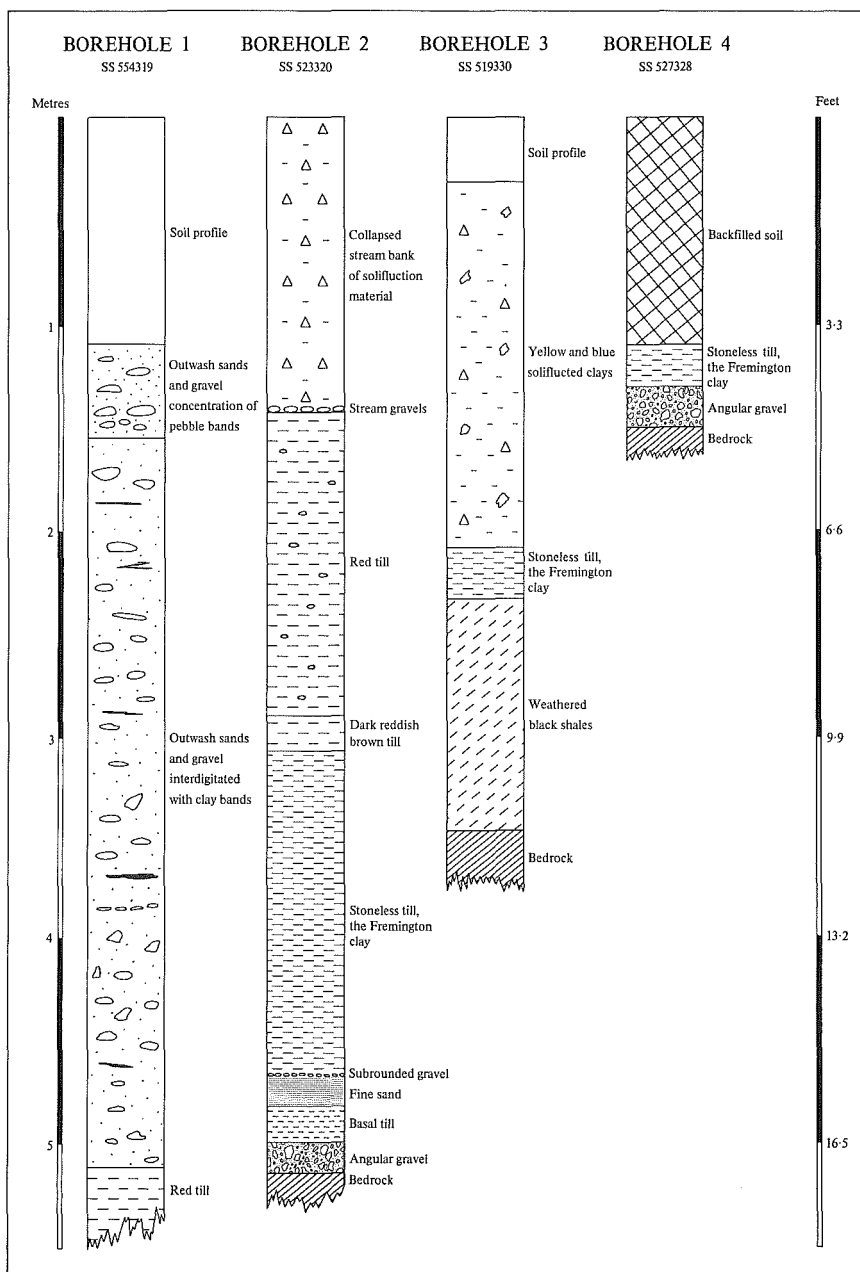
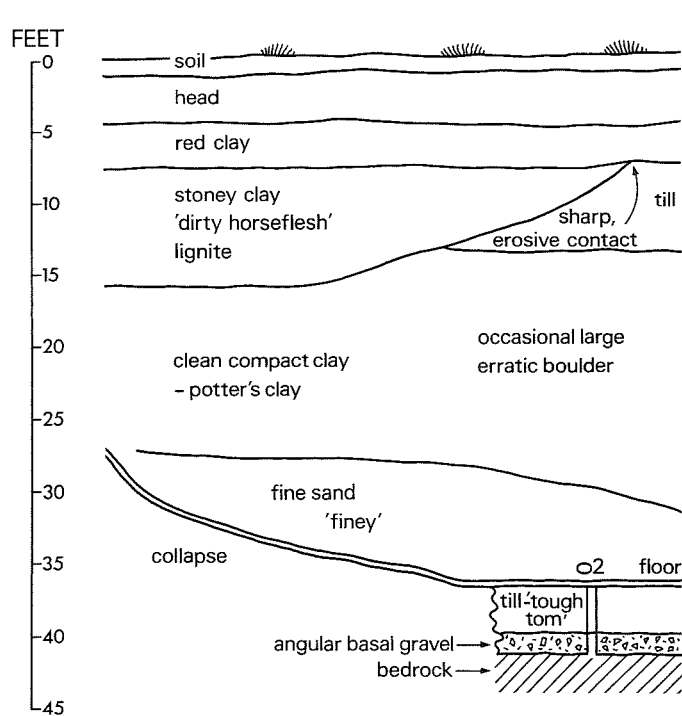


Fig. 21 - Borehole records in Quaternary sediments around Fremington.



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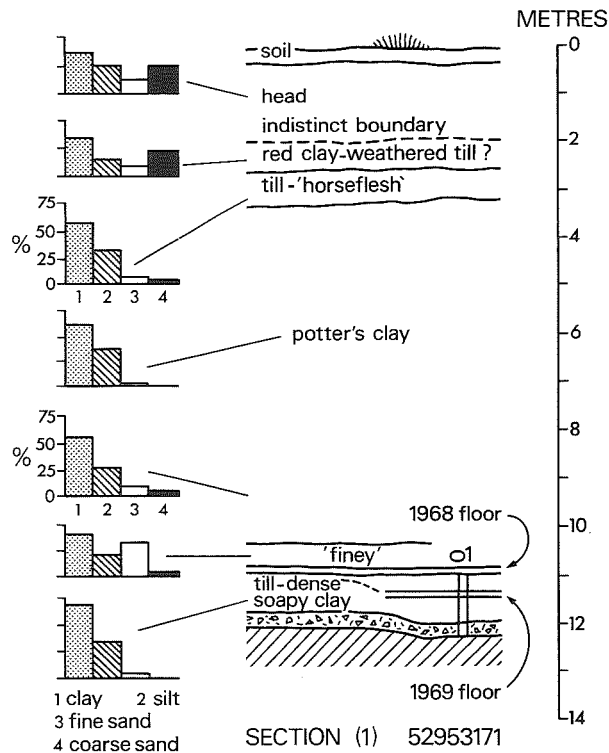


Fig. 22 - Sections in the S. face of Brannam's Claypit, Fremington.

to Bickington Ridge. The raised beach gravels flank the coastal base of the ridge and are largely confined to the area north of the railway line.

Brannams clay pits (SS 529317)

Figure 22 shows the sequences of deposits revealed in Brannams Clay Pits between 1967 and 1970.

In the south face some 1.2 m to 1.5 m of a yellow solifluction earth overlies the clay series. The upper layers of the solifluction earth are disturbed by frost wedges. In contrast to other head deposits in Barnstable Bay this solifluction earth has a relatively high clay content resulting from the underlying clay series.

Beneath the solifluction earth is a deposit referred to by Stephens as a weathered till. However, it is considered here to be a separate deposit, not a weathering product of the underlying fresh till. Two lines of evidence are present in the clay to support this view, and further evidence from other sites tends to agree with it. Within the clay pit, the boundary between the "weathered till" and the underlying fresh till, is clear and readily stripped. It is horizontal, and is the boundary above which the overburden is removed by Brannams. A weathering horizon would not produce such a boundary. This separate deposit, termed the red clay, overlies the fresh till in the western section of the south face, but overlies a different deposit in the south-east face. There it overlies a stony silt, which has replaced the till, and therefore the red clay cannot be a weathering product of the fresh till. It is possible that beneath the red clay, there has developed a weathering horizon, upon the other deposits, and prior to the deposition of the red clay. However, this weathering horizon is thought to represent only a short period of time between advances of the ice front, rather than the long period postulated by Stephens. Similarly, Stephens considers that the frost structures are evidence of a second period of permafrost, after the deposition of the solifluction earth. Again, these features are here thought to have been produced in a relatively short time period, and are not evidence of a second separate cold period.

The fresh till beneath the red clay is one of twin till sheets, which are separated by a stoneless potter's clay. The till above the potter's clay is a dark reddish brown (Munsell code 5 YRN 2/2), and contains a number of sub-angular and sub-rounded pebbles, cobbles, and occasional boulders. These include dolerite, granite, gneiss, flint, local Devonian and Carboniferous grits, shales, sandstones and limestones. The till is compact, greasy, tough, and inelastic, and would appear to be a lodgement till. Beneath it, the potter's clay extends for a depth of up to 6.1 m. In its upper part it contains less than 1% material coarser than 0.02 mm, and 60% is finer than 0.002 mm.

The potter's clay coarsens towards its base. At 2.5 m down the profile, 1% is coarser than 0.02 mm, but near the base 6% exceeds 0.02 mm. Infrequently, large erratic boulders have been found within the potter's clay (Arber 1964). Of those that have been kept at the claypit, one is a dolerite, and another a granodiorite. Both are of unknown provenance, and weigh between one and five tons. These and other boulders, however, are markedly similar to those seen below the raised beach deposits on Saunton Downend. The potter's clay demonstrates a pseudo-lamination, which can best be seen when a fresh piece is broken in the hand. These laminae are suggestive of a waterlaid origin. The potter's clay overlies a fine sand, and although there is a distinct change from a clay with some 6-10% fine sand to a fine sand with 33% in the range of 0.2 to 0.02 mm, this transition is heralded by a gradual coarsening of the stoneless clays throughout their 6 m, a coarsening which is accelerated in the lower 2 m. Despite its depositional association with the stoneless clays, the fine sand is not laminated. This fine sand lies conformably upon a till. This lower till is extremely tough and greasy, and has a high density. It has a lower stone count than the till above the potter's clay. Beneath this till lies the basal gravel.

In previous years when the water table was low large samples of this gravel have been collected both from boreholes and test pits. It is some 15 cm thick, and is trapped beneath the till and above bed-rock. The gravel is openwork and water bearing, the water being under considerable pressure. Because of this the present owners of the pit will not allow a section to be opened in the early part of the year. The largest recovered fragment from the basal gravel measured 45 x 15 x 10 mm, and is exceptional, although one other particle measured 17 x 15 x 11 mm. Both of these are markedly angular Culm gravels and were found partially incorporated within the till. The gravel has a median grain size of 3.4 mm. It is poorly sorted, (sorting coefficient 2.1). No erratics have been recovered from the basal gravel. It is different in size distribution and sorting coefficient and is markedly more angular than the Penhill raised beach.

In the south east face of Brannams Clay Pit the till immediately beneath the red clay had been completely eroded and replaced by a stony silt. This material contains lignite and local and erratic stones. There is a steeply dipping boundary between the in situ and the stony silt. Following a similar pattern the fine sand seen in the south face below the potter's clay broadens to a depth of 2 m. The concurrence of the thickening of the fine sand with the presence of the stony silt would argue for the reoccupation of a channel during the oscillation of the ice front. Resistivity mapping supports the view that these deposits cut across the main clay body occupying a broad channel orientated north/south. This may be reflected in the col at Grid Reference 531 304.

Notable, in the light of this examination of the deposits, is the absence of shells and shell fragments, although Stephens recovered shell fragments from the till above the potter's clay. However, this till does include a considerable derived microfauna, which is given below. The sample was collected by Professor A. Wood and examined by Dr. J. Haynes.

Fremington Foraminifera

<i>Ammonia beccarii</i> var.	<i>Cibicides lobatulus</i>
<i>Angulogerina fluens</i>	<i>Cibicides refalgens</i>
<i>Bolivina spathulata</i>	<i>Elphidium crispum</i>
<i>Cibicides fletcheri</i>	<i>Elphidium selseyense</i>
<i>Nonion labradoricum</i>	<i>Globigerina</i> sp.
<i>Recturigerina</i> sp.	

Dr. Haynes commented on the fauna that these are all typical Irish Sea types, that a high percentage are damaged, and that the specimens are generally opaque. *Nonion labradoricum* is an arctic and boreal form, and is common in Late Pleistocene sediments in Norway.

It appears that the Fremington clay series was deposited by Irish Sea ice. This evidence clearly excludes ideas of a locally developed ice mass and also a fresh water origin for the clay. The basal gravel, twin tills, red clay and potter's clay are regarded as representing one glaciation and together are termed the Fremington Clay Series.

The mechanism of their deposition is imperfectly understood, but the whole series together with the outwash sands and gravels is regarded as representing oscillations in the ice front of a mass of Irish Sea ice impinging on the North Devon coast.

Hele gravels - Hele Manor Farm (SS 554319)

The Hele outwash gravels, which form the uppermost part of Fremington Clay Series can be seen in the fields around the farm. No sections are available for examination, but boreholes have been driven through the deposits to show the coarse, poorly-sorted fluvio-glacial sands and gravels interdigitated with the Fremington Clay (see borehole 1, Figure 21).

In the Barnstaple area these sequences are interpreted as showing a fluvioglacial sequence of basal fluvioglacial gravels, tills and outwash gravels. The raised beaches are separate and are thought to be younger than the fluvioglacial deposits

because of:

- (a) The morphological distribution of the raised beach surrounding the tills and occupying low ground.
- (b) The perfect detail of the spit which has not been overridden by ice.
- (c) The presence of giant erratics beneath the beaches at Saunton which are similar in lithology and provenance to those seen in the till at Brannam's Clay Pit.

(T.R. WOOD)

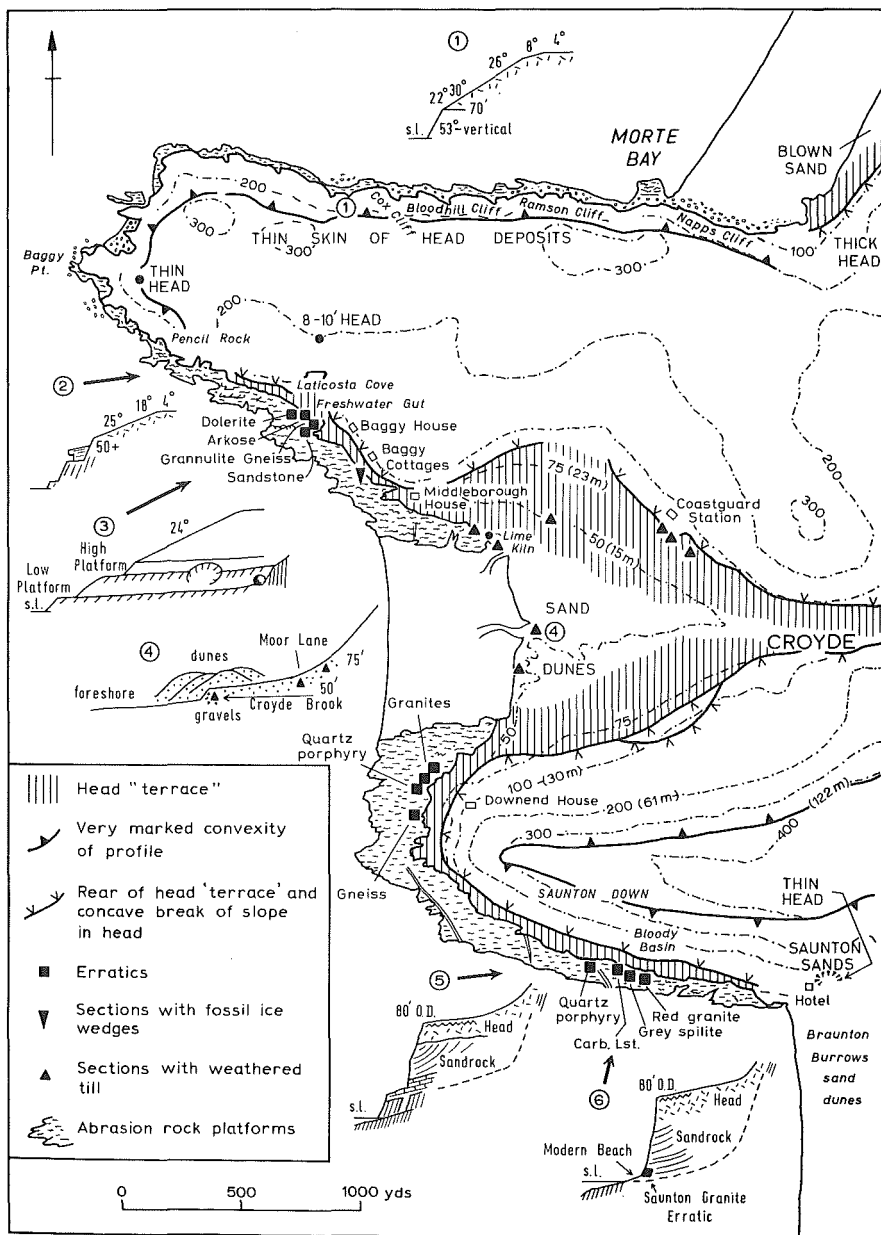


Fig. 23 - Pleistocene deposits and coastal morphology near Croyde and Saunton.

MARINE CUT ROCK PLATFORMS

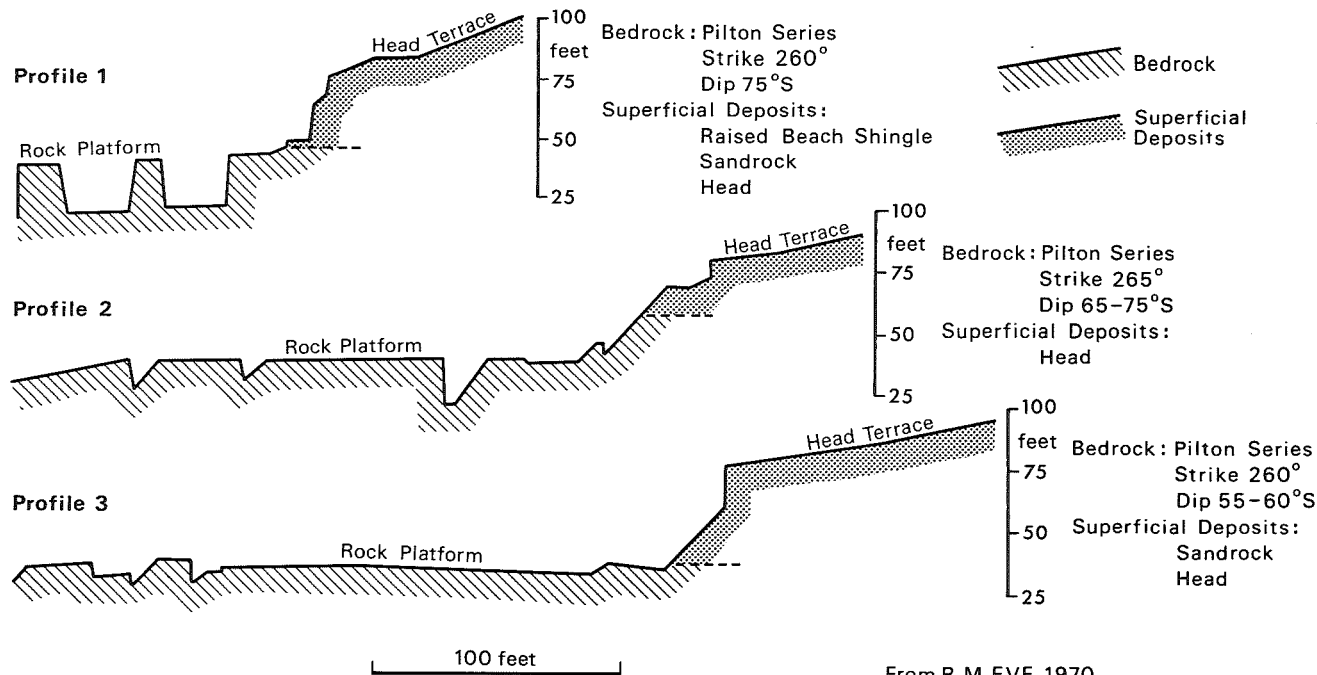
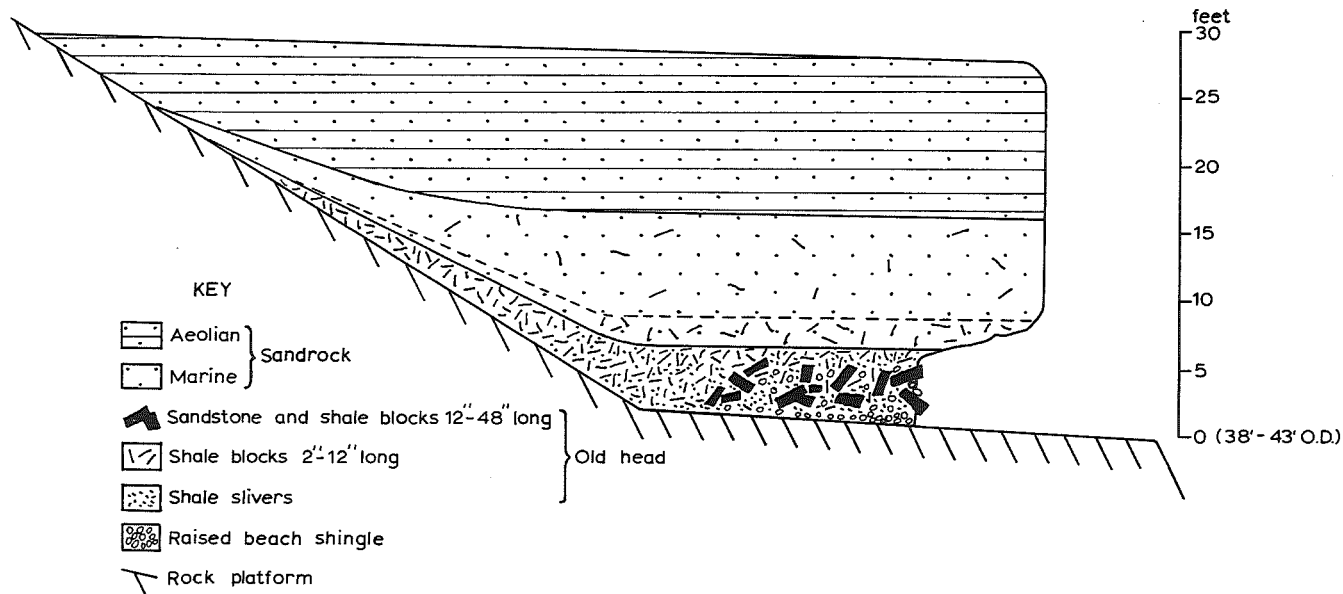


Fig. 24 - Marine-cut platforms between Saunton and Baggy Point.

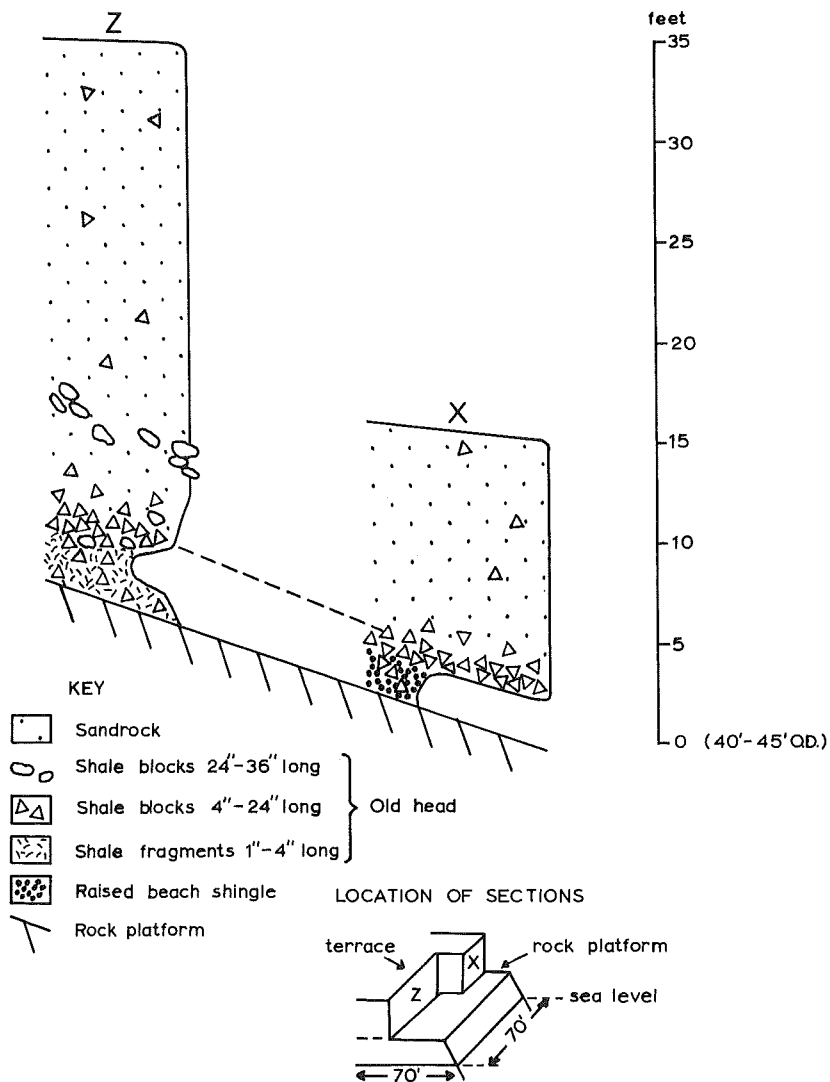
SECTION OF THE RAISED BEACH OLD HEAD AND SANDROCK AT PENCIL ROCK



From R.M. EVE 1970

Fig. 25 - Section of raised beach, old head and sandrock at Pencil Rock.

SECTION OF THE RAISED BEACH OLD HEAD AND SANDROCK TO THE EAST OF PENCIL ROCK



From R. M. EVE 1970

Fig. 26 - Section of raised beach, old head and sandrock to E. of Pencil Rock.

SECTION OF THE HEAD AND TILL TERRACE IN CROYDE BAY

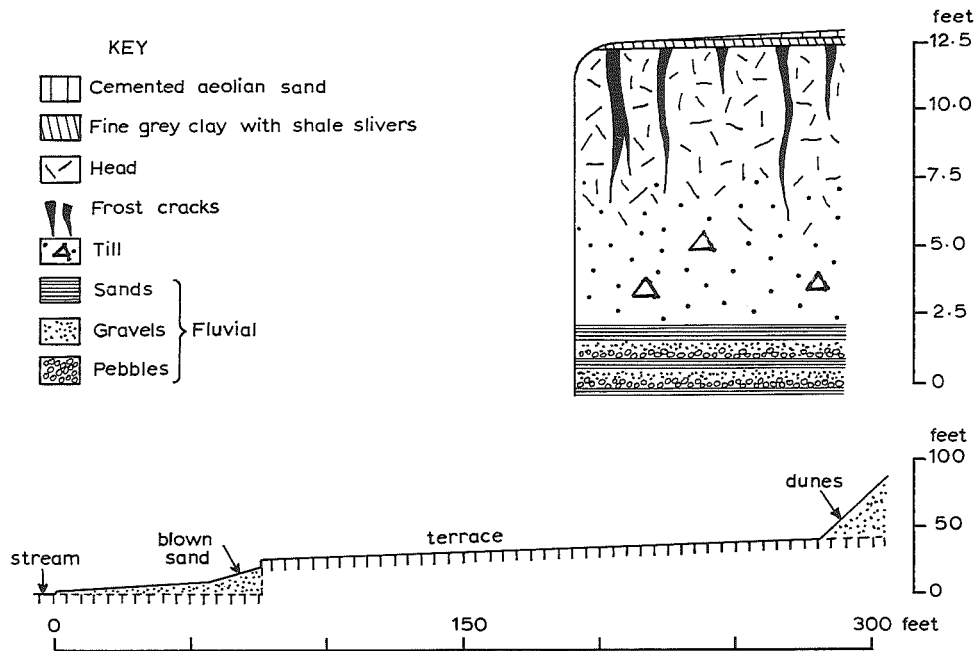


Fig. 27 - Section of head and till terrace in Croyde Bay.

From R.M.EVE 1970

NORTH DEVONBarnstaple Bay: rock platforms

The sequence of Pleistocene deposits which overlies a series of low wave-cut rock platforms in the coastal sections round Barnstaple Bay have been described by Sedgwick and Murchison (1840), Maw (1864), Hughes (1887), Dewey (1913), and more recently by Mitchell (1960) and Stephens (1966b).

Between Saunton and Baggy Point (Figs. 23, 24) there are traces of three distinct platforms - height ranges 0-6 m (0-20 ft) O.D.; 5.5-7.6 m (18-25 ft) O.D. and 10.7-15 m (35-50 ft) O.D. - although one is seldom able to see all three platforms in profile, one above the other. The lowest platform passes below modern high-water mark and hence below modern beach level. But at Bloody Basin and Middleborough its great age and exhumed nature are demonstrated by the Pleistocene beach and head deposits cemented upon it, which are now being eroded by the sea. The two higher platforms are best seen between Middleborough and Pencil Rock, and at Freshwater Gut a 50,800 kg (50 ton) 'giant' erratic block of granulite gneiss 1.38 m^3 (10 x 7 x 7 cubic ft) is situated near the upper limit of the 5.5-7.6 m (18-25 ft) platform, where it notches the higher platform (Taylor, 1956).

The enigma posed by these rock platforms is that they are all relic features by virtue of the suite of Pleistocene deposits which rest upon them. While some late-Pleistocene and Holocene modification of the lower platforms has taken place it is certain that much wave energy has been directed to the stripping of the superficial deposits and exhumation of old rock surfaces.

The erratics

Near Croyde and Saunton numerous erratic boulders rest on wavecut rock platforms (Fig. 23) (Taylor, 1956). At Freshwater Gut main (lower) head seals the large erratic, and at Saunton a large pink gneissose granite boulder is buried by sandrock, which is the upper part of the raised beach sequence, and also sealed below main head. These erratics compare in size with the Porthleven erratic (Flett and Hill, 1912; Stephens and Synge, 1966), and there seems to be no doubt whatever that they were delivered on to pre-existing rock platforms, and were later sealed by a variety of deposits.

The problem whether these large erratics were moved into position by a regional ice-sheet (Kidson, 1970, 1971; Mitchell, 1960), or by floating icebergs in the early Pleistocene, has not been solved satisfactorily, except that the widespread

distribution of erratics on the Bristol Channel, southern Ireland and English Channel coasts, and on the French coast (Tricart, 1956) would appear to support the latter hypothesis (Mitchell, 1965; Stephens, 1966b). In Devon and Cornwall, and in Ireland, the very large erratics appear to be confined to a narrow zone along the coast, below 9 m (30 ft) O.D., within the reach of storm waves at the present time, but their true age relationship to the raised beach is not yet known.

Flint is a common constituent of many modern beaches along the Bristol Channel and English Channel coasts, and it is present also in some of the raised beach deposits, in the Fremington boulder clay, and some head and outwash gravel deposits. At first sight it might appear to be a diagnostic 'erratic', only brought to the area by ice-carriage. But the modern beaches have probably received flint as the Flandrian transgression rolled material landwards during the post-glacial rise of sea-level. Submarine outcrops of flint-bearing Cretaceous rocks are known in the English Channel, but this explanation is less certain for the north coast of Cornwall and Devon (Whittard and Bradshaw, 1965), where southward moving ice-sheets (Fig. 3) might have carried flint. There is, however, another explanation for the presence of some of the flint. At Orleigh Court, a few miles southwest of Bideford, at about 106-122 m (350-400 ft) O.D. there is some 7.6 m (25 ft) of flint nodules, chert pebbles and sand (I. Rogers and Simpson, 1937). The deposit resembles other Pliocene outliers in Cornwall, and is not unlike the deposits capping the Haldon Hills near Exeter; it is certainly not a glacial deposit but a remanif of a once larger outcrop which may have contributed material to many different deposits.

The raised beach deposits

At the Bloody Basin near Saunton (Fig. 23) a section shows the beach shingle, 2 m (7 ft) in places, and overlying sandrock (cemented shelly sands=aeolianite) resting upon a rock platform which is covered at times of spring tides. The sandrock may be up to 9 m (30 ft) thick and is always overlain by the main head. The upper or younger head can be seen in roadside cuts (near Saunton Sands Hotel, Fig. 23) where fresh, angular, shattered rock rests upon bedrock. This very coarse blocky layer of upper head, which lacks the high content of sandy matrix of the lower, main head, rarely reaches the top of the present cliff, in marked contrast to the main head which forms much of the cliff profile.

Near Saunton the horizontal bedding of the sandrock is often striking for the first 1.8-3 m (6-10 ft) upwards from the base, thence changing to gently sloping beds of sand with

fine fragments of slate head dispersed through the sand in places (cf. sections at Fethard, Co. Wexford, in Mitchell 1962, Plate 4; and see Stephens and Syge, 1966). The shell content of the upper sand rock (Hughes, 1887) and comparison with the bedding in modern dunes suggests a windblown deposit or series of fossil dunes (Greenwood, 1972).

At Pencil Rock the rock platform is at 13.7 m (45 ft) O.D. The raised beach shingle extends to 18.3 m (60 ft) O.D., and the overlying sandrock to well over 30.5 m (100 ft) O.D. Fragments of sandrock were recovered from the head on the cliff-path (Figs. 23, 25, 26). The shingle beach is 1-1.5 m (4-5 ft) thick and composed of well-rounded pebbles and cobbles, 0.17 m (6-8 inches) long, with occasional larger boulders and angular blocks. The matrix is made of coarse sand, shale slivers, small pebbles, shells and shell fragments - all of temperate species. The sandrock consists of cemented sand, shell fragments, and pebbles, with pieces of shale scattered through it in a haphazard manner: it has a well-bedded appearance, and in places has broken up into large cube-shaped blocks. Just as at some sections in Cornwall (e.g. Prah Sands, Porthleven and Pendower), and in southern Ireland (Farrington, 1966), the raised beach contained many angular blocks, which may be described tentatively as an old head deposit. This ancient head may have been contemporaneous with the ice-advance responsible for the distribution of the large erratics and therefore considerably older than the transgressive raised beach. On the other hand we may also regard the raised beach as a regressive feature, formed as sea-level began to fall during the onset of the cold conditions which accounted for the main head on the coastal slope; although it is recognised that ordinary cliff falls could account for the angular debris included in the beach, which might have been quickly buried by rapid beach accumulation. The subsequent exposure of a sandy strand allowed wind-transported material to accumulate to a great height, while head was forming. This would account for the layers and lenses of head found in the sandrock at all levels. Eventually the accumulation of head became dominant and a great 'terrace' formed seawards of the old cliffline, completely covering the sandrock, beach gravels, 'giant' erratics and a series of rock platforms.

A nearby section a little to the east of Pencil Rock reveals sandrock resting upon a lower head of shale blocks and rock fragments, and passing within 10 metres or so to rest directly upon bedrock (Baggy and Marwood Beds). The diversity of the sections is considerable between Pencil Rock and Freshwater Gut, for yet another section shows sandrock overlying head and several feet of shingle, the latter cemented in a matrix of sand, sandrock and fine slate slivers.

The main head

The main head is a solifluction deposit of great thickness, the bulk of which is regarded as having been formed under periglacial climatic conditions during the Wolstonian cold period. This is suggested because in south-east Ireland there is no such enormous deposit of head which can be associated with the advance of the last glaciation ice (= Midland General in Ireland) to the southern Ireland end-moraine (Synge, 1963) (Fig. 3). Outside this end-moraine the head deposits, and disturbance of the older tills rarely exceeds 2 m (6 ft). While the age of the southern Ireland end-moraine depends in some measure upon the interpretation of the stratigraphy of the Shortalstown site, and the distribution of pingos (Colhoun and Mitchell, 1971; Mitchell, 1971), this moraine marks the outermost limits of fresh, relatively unweathered drift and a distinctive topography. The main head on the other hand is associated with the purple, shelly, calcareous Irish Sea (Eastern General or Ballycroneen) till in southeast Ireland (Farrington, 1944), deposited by Irish Sea ice moving across the eastern and southern coastlands.

At Garryvoe, Co. Waterford, the calcareous Irish Sea till rests on main head, which in turn overlies raised beach shingle containing erratics. All the deposits rest on a rock platform, providing a close analogy with north Devon. Where the Irish Sea (Ballycroneen) till has been subjected to weathering it is decalcified to depths of 2.4-4.5 m (8-14 ft), in complete contrast to the tills north of the southern Ireland end-moraine. Furthermore, at the Kilbeg and Newtown Gortian Interglacial (= Hoxnian or Holstein) sites (Watts, 1959), the till resting upon the peats is derived from the north (Munster General Glaciation) and was almost certainly responsible for excluding the Irish Sea (Ballycroneen) ice from these sites (Mitchell, 1960, 1962). The circumstantial evidence is strong, but not conclusive. If this contemporaneity is accepted, allied to the highly contrasting depth of weathering of the 'older' and 'younger' tills, and if the difference of degree of head formation is considered, then a Wolstonian age for the main head seems not unreasonable.

In south-west England, as in southern Ireland, the main head consists of blocks of all sizes of local slate, sandstone and quartz, set in a sandy matrix but without erratic pebbles, except occasionally as a surface find. Where it has not been disturbed by later frost action the rock fragments have a preferred orientation downslope, often lying at low angles to the horizontal ($0-10^0$) and projecting out of the face of the cliff (Kirby, 1967). The material has moved downslope as a kind of sludge and spread out as a great apron or solifluction terrace at the foot of the coastal slope (e.g. Saunton Down,

Baggy Point). It must be emphasised that there is no evidence to suggest that the terrace-like surfaces of the solifluction deposits owe their form to wave action, for no marine deposits have been found to cap the main head in south-west England, South Wales or southern Ireland (M.A. Arber, 1960; Stephens, 1961b, 1966b) (Fig. 27).

The main head is the thickest of the solifluction deposits, and at certain points in Devon and Cornwall (e.g. Croyde Bay, Godrevy) it can be seen to be highly weathered (due partly perhaps to the accumulation of previously weathered material?), and disturbed by cryoturbation, frost cracks, wedges and convolutions which extend down 1.5-1.8 m (5 or 6 ft) below the surface. This is interpreted as meaning that the head had ceased movement when renewed periglacial activity churned the surface of the deposit. This could have taken place during the Saale cold period, or resulted from renewed freeze-thaw action during the Weichsel cold period (cf. Bryant, 1966).

Three profiles have been levelled by R.M. Eve between Middleborough House and Freshwater Gut across the superficial deposits and rock platforms, these are shown in Fig. 24, profiles 1, 2, 3. These profiles illustrate the varying height of the rock platforms and the degree of dissection that has taken place. Near Middleborough House a deep inlet exposes an interesting section:-

Head of angular slate and shale fragments	1.5 m
Sandrock (cemented sand)	3 to 4 m
Head of highly weathered shale fragments in a silty matrix, which also contains pieces of cemented sand and shell fragments	2 m
Coarse cemented sand with shells fragments)	3 m
Well-rounded shingle and sand)	
Rock platform at about 40-45 ft. O.D.	

Between the hotel at Middleborough and Freshwater Gut (Fig. 23) the surface of the head deposits flattens out to a shelf of almost negligible slope ($< 3^\circ$) at the cliff edge. An upper head or slope wash (deposit 2, Fig. 19 B) overlies 0.6-1.0 m (2-3 ft) of disturbed head, and the slate fragments are erected on end instead of lying flat with their long axes dipping gently seawards. Frost action is invoked to explain this cryoturbation of the head, where fossil ice wedges occur (Fig. 19 B). The wedges appear to be confined to a 0.9 m (3 ft) layer of angular slate fragments (mostly 2 inches long) overlying a more sandy horizon (0.3-0.6 m: 1-2 ft), below which is more head, consisting of a mass of fine slate rubble set in a sandy matrix, the whole being well-weathered.

Two possible interpretations of the full section at Middleborough House have been suggested (Stephens, 1966b; Waters, 1966). Layers 3, 4, 5, 6 and 7 have been attributed to the Devensian cold period, representing the waxing cold phase of the Last Glaciation as the ice advanced; layer 3 (= ice wedges) the coldest and driest part of the cold period, and layer 2 a return to less cold solifluction conditions during the waning of the glaciation. The interpretation of such sections in multiple layers of head is crucial in south-west England and southern Ireland, although perhaps too much should not be based upon one section. At Middleborough layer 3 consists of relatively fresh rock fragments, and contains less clay-mineral material than the layers 4, 5, 6 and 7, which are more weathered (cf. the two head deposits at Godrevy). While therefore, it is tempting to interpret the whole set of deposits as belonging to the last glacial period, this is still unsatisfactory. Layer 3 closely resembles the shattered rock in the quarry near Saunton, and along the road to Croyde Bay, where rock strata have been distorted down the coastal slope. Here the head is clearly 'young', but nowhere is there any sign of the lower head material, the latter is found only in the great 'terraces' of head. Consequently, it is believed that there are two separate head deposits present. The horizon containing the fossil ice wedges indicates that the material in which they occur had already ceased to move significantly when the wedges were formed, whereas only continuous mass movement could account for the great thickness and form of the lower (main) head. Another distinct phase of severe cold climatic conditions is therefore suggested to account for the presence of the wedges (Williams, 1965) and for the finer head (layer 2) which moved downslope to seal them off. The upper heads (coarse layer + wedges + stony layer) may therefore represent the total depth of the 'active layer' over permafrost during the Last Glaciation (Devensian), and the sandier head below may be older (Wolstonian?) (Williams, 1965).

Croyde Bay

New sections have been revealed in building sites during recent years, mainly near the road leading to Middleborough. The most recent of these sections showed about 1.5 m of hard, tough red-brown stony clay, containing many striated stones and a few erratics. The stony clay was covered by an apparently discontinuous, thin layer (less than 0.2 m) of sand - probably blown sand. No angular head was seen in contact with the stony clay.

It is interesting to compare the analyses of the stony clay, with similar material found on the coast at the Lime Kiln and Brook sections - see Tables I/II. At the Lime Kiln site the stratigraphy shows:-

Table II CROYDE

Sample Ref.	SIZE			% Air/Dry Moisture	pH	Loss on Ig.	Ex. Ions			
	sand	silt	clay				Ca	Mg	K	Na
ST20 Upper stony layer	14.24	43.36	42.40	5.94	7.40	1.93	245	275	165	650
ST17 Coarse head with fossil ice-wedges	51.56	22.24	26.20	0.92	6.10	5.74	95	170	120	345
ST19 Lower Head	21.22	54.38	24.40	0.80	6.50	4.33	105	350	250	1600
ST21 infilling of frost crack	7.83	54.87	37.40	1.59	6.40	3.77	100	220	240	600
ST16 silty sand at base of Lower Head	21.34	46.46	32.20	2.48	6.40	2.34	85	225	220	1100

Sand layer - probably blown sand, but no dunes here.	1 m+
Brown, sandy-coloured stony clay; highly weathered, and disturbed by cryoturbation.	3 m
Stony clay becomes increasingly charged with well-rounded pebbles and cobbles, in a sandy matrix, towards the base (pebbles plus cobbles = marine shingle?): erratic stones recorded include flint, granite.	

At Croyde Brook, where the dunes system is breached by a small stream the stratigraphy shows:-

(Along the dune foot south of Croyde Brook a terrace is exposed (Fig.27) below blown sand, which seems to be the seaward edge of deposits underlying the whole dune system).

Grey clay with slivers of shale	a few cms
Brown sandy head (?) with blocks of sandstone and shale	1.5 m
Brown sandy clay (till?), with an increasing amount of weathered and rounded pebbles of different size; erratic stones recorded include chert, mica-schist, fine-grained, dark igneous rock.	1.5 m
Alternating layers of sands and gravels, some well-rounded.	0.7 m

The head and till appears to have suffered cryoturbation, and deep frost cracks have penetrated nearly two metres into the deposit; these cracks are filled with grey clay, with iron staining, and are comparable with similar features seen at the Middleborough fossil ice-wedge section, and at the Fremington claypit. Below Saunton Downend other sections show up to 1.8 m of weathered stony clay overlain by about 1 m of head.

Discussion

It is suggested that till is present in Croyde Bay, and thus a number of related problems must be considered:-

1. Is the till in situ?
2. What is the stratigraphical relationship of the till to the other members of the local Pleistocene succession - beach gravels, head deposits, sandrock etc?
3. What is the age of the head deposits?

Each of these problems is extremely difficult to solve, mainly because of the absence of deep, extensive sections in critical areas. At present it is uncertain whether or not the till is in situ, although in view of its deeply weathered character

and probable age it is unlikely to be in its original position - but this is not yet certain. At Croyde Brook a case could be made to suggest that head and till are mixed together, although in Figure 27 they are shown separate.

The stratigraphical relationship of the till to the other members of the succession is also difficult to ascertain:-

1. No angular head has been seen resting upon the till or mixed till plus head.
2. The till is nowhere seen to rest upon head deposits at Croyde (in contrast to the situation at Westward Ho'). But it is possible that the Croyde till has caught up and incorporated masses of older head, and possibly also beach shingle.
3. No beach gravels are seen to rest upon the till or till/head mixture at heights well within the range of the height of the raised beach seen elsewhere around the bay. If, as might be expected, a substantial amount of head formed as the climate deteriorated and ice advances took place, then subsequently till was deposited in patches, and was incapable of removing all the old head (cp. Garryvoe sections). Thus head and till may remain in places to cover older beach gravels. If, on the other hand, Croyde till is older than the so-called Main Head, and lies stratigraphically below it, then it is curious that no substantial quantity of erratic and striated material has been recovered from the head.

Croyde Bay till extends to over 100 ft O.D., and is full of erratics and striated stones, and yet nowhere, so far, have similar stones been found in the head deposits. There is therefore a great contrast between the beach gravels, rich in erratic material, and the overlying head which is not. It is submitted that it seems unlikely that the Last Interglacial sea could have eroded all the till and all the older head deposits, without leaving abundant erratic material at higher levels, to be moved and incorporated in the Last Cold Period head deposits.

In the absence of absolute dates for the various deposits little more can be proved from the available sections - but there seems to be a number of important stratigraphical problems still awaiting solution - enough to make this writer pause before accepting any one finite interpretation of the Pleistocene succession between Saunton and Croyde.

(N. STEPHENS)

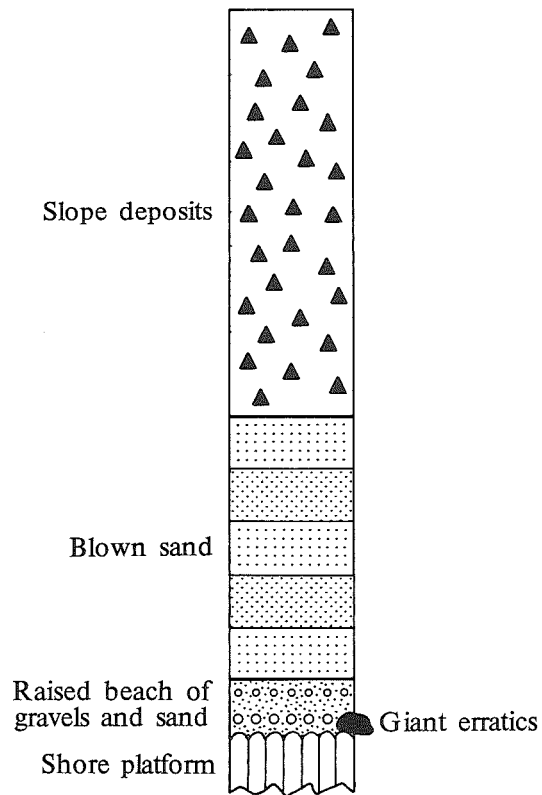


Fig. 28 - Stratigraphy of deposits at Saunton Down End (SS 438379).

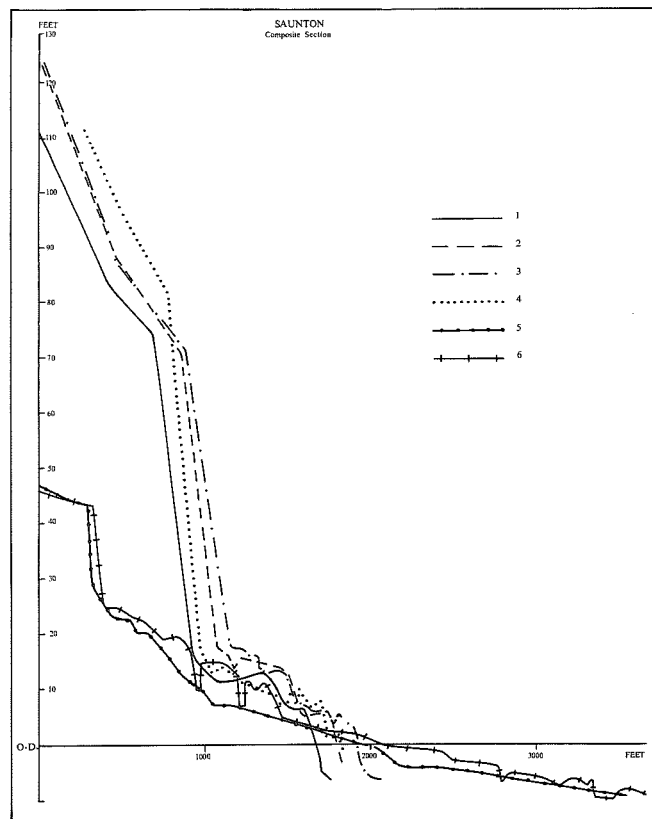


Fig. 29 - Surveyed profiles of cliff and shore platform, Saunton Down End.



Plate II

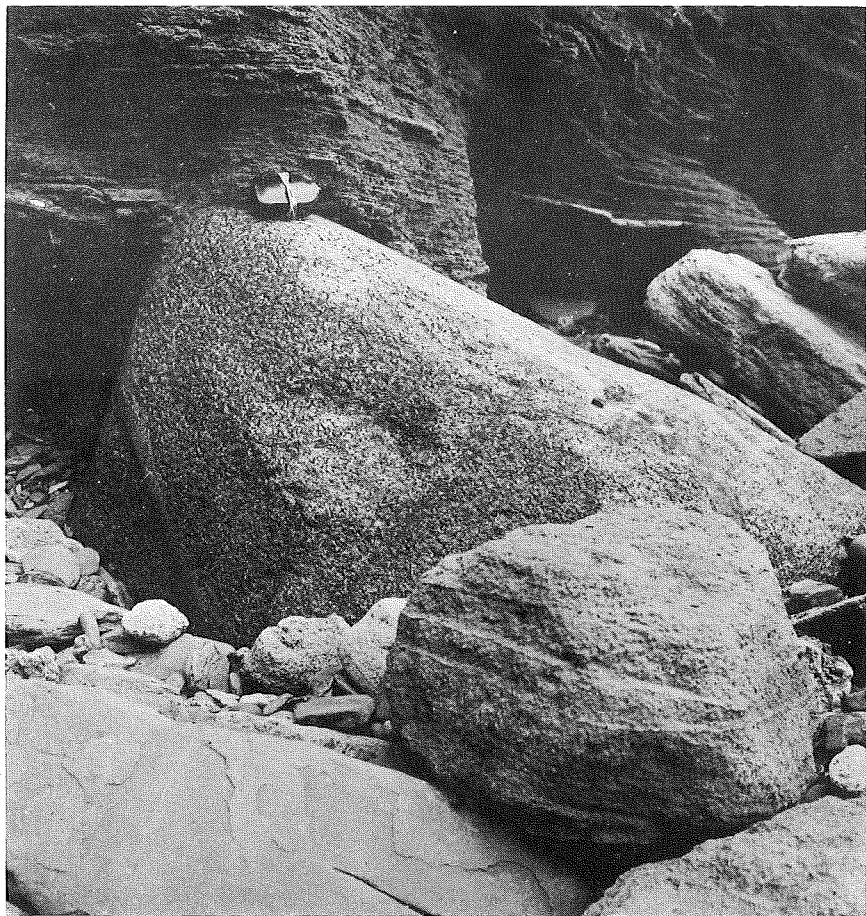


Plate III

SAUNTON DOWN

Prestwich (1892), in summarising the work of earlier geologists including Pengelly, described the raised beach of Barnstaple Bay as extending, with interruptions, from Croyde Bay by Baggy Point to Morthoe. In his view there were three components of the deposits resting on the shore platform cut across steeply dipping Devonian slates. From top to bottom these are:

- a) the "usual local angular bubble" composed of small and large fragments of slaty Devonian rocks in a brown earth without apparent bedding and varying from 10 to 50 feet in thickness. He described it as "apparently contemporaneous" with the head overlying the Fremington Clay.
- b) blown sands extending to from 5 to 30 feet in thickness, horizontally bedded but with frequent oblique laminations. The sands are partly or wholly concreted. They include large numbers of land shells with an occasional weathered valve of Mytilus and Cardium. He interpreted them as old dunes contemporaneous with the Fremington Clay which he regarded not as a true boulder clay but as a lake deposit.
- c) a beach which consists of "hard grey and micaceous sandstones, chalk flints, and pebbles of white quartz and reddish quartzite in a matrix of sand, with a large proportion of comminuted shells," which is often concreted. He listed 26 marine mollusca found in the beach including Cardium papillosum "not now known to range further north than Falmouth". In addition to the smaller erratics in the beach gravels, he noted the presence of the large erratic blocks such as the red granite of Baggy Point and a fine grained white granite and one of "hornblendic granite" in "other parts of the cliffs".

The section at Saunton Down End (SS 438 379) (Fig. 28) between Barnstaple Bay and Croyde Bay illustrates the essential simplicity of the stratigraphy as described by Prestwich. The raised beach beneath the aeolian deposits (Plate II) includes much erratic material including the Saunton "pink granite" boulder (Plate III) which according to Dewey (1910) originated in north west Scotland. The fact that it is trapped between the base of the beach and the shore platform indicates that the beach was developed on a coast which had been previously glaciated. The blown sand which is some 9 metres (30 feet) thick exhibits the same structures as do the dunes of the adjacent Braunton Burrows. Indeed, a section through the present beach and dunes

would show an essentially similar arrangement. The old dunes are overlain by some 21 metres (70 feet) of head which shows little differentiation. The sequence of events represented in the section is therefore, a glacial phase, followed by an interglacial in turn succeeded by a cold phase. The very gently dipping shore platform (Fig. 29) which passes under the raised beach at a height of 4.5 to 5 metres (14-16 feet) O.D. clearly antedates them all and is related to earlier (interglacial) high sea levels. Unlike the high shore platform at Westward Ho! it is being trimmed by the present sea and is almost covered at H.W.O.S.T.

There is little agreement on chronology. Cl4 dates on Balanus balanoides (?) from the shore platform give an infinite age while one on shells from the raised beach, which included about half the species listed by Prestwich, (I-2981 : 33,200 \pm 2800 - 1800 B.P.) is clearly unrealistic. Zeuner (1959) took the view that no beach in South-West England shows signs of having been overridden by ice and that they must all, therefore, stem from the last interglacial. Stephens (1973) ascribes the Saunton beach to the Hoxnian. Kidson (1971) regarded it as Ipswichian and suggested that the giant erratics were deposited by the ice which laid down the Fremington Clay. Interpretation of the deposits above the beach clearly vary in response to the preferred date of the beach. Stephens (1966) divided the head into two, separated by a weathering/sand layer and thus saw evidence of a long and complex history following the emplacement of the beach. Kidson regarded all the head as Wolstonian.

There seems little reason to assign different ages to the Saunton and Westward Ho! beaches. They exhibit precisely the same differences as their present day counterparts and the likelihood is that these represent responses to differing sources of material and differing wave environments rather than differing ages. Perhaps the most intriguing differences is that between the height of both the beaches and the underlying shore platforms.

(C. KIDSON)

HARTLAND QUAY AND DAMEHOLE POINT

Of all the possible ice-marginal or subglacial channels which have been described briefly (Stephens, 1966), those near Hartland Quay and Damehole Point are perhaps the most convincing examples (Fig. 4). At both sites channels have been incised in such a way as to isolate a small hill on the seaward side of the channel, and throughout their length the channels 'hang' above the sea. The channels are characterised by flat floors, frequently overlain by 1.8-2.4 m (6-8 ft) of coarse, blocky head.

The 'in and out' channels at Hartland Quay and Damehole Point are not marine-cut features, but probably form part of the seaward ends of a system of coastal valleys, which have been linked together and widened appreciably by water flowing along the edge, or below the margin, of an ice mass impinging against the coast. It is conceivable therefore that the channels were formed when ice was depositing till at Fremington, Trebetherick Point and on the Scilly Isles; subsequently they received a thin layer of head during the last glacial period.

(N. STEPHENS)

THE CHARD AREA AND THE AXE VALLEY SECTIONS

Introduction

Our route will take us to Chard via Honiton, and thence south-eastwards through the Chard gap to Chard Junction. Here a series of gravel pits have been opened in a large terrace, the surface of which stands at about 61 m. (200ft O.D.). Messrs. J.R. Pratt & Sons Ltd. operate the largest working pit and have kindly given permission for us to inspect the large sections exposed.

GREAT CARE MUST BE EXERCISED IN THIS PIT BECAUSE OF THE
POSSIBILITY OF SUDDEN FALLS OF MATERIAL FROM SIDE WALLS
AND BECAUSE OF OPERATING MACHINERY.

Similar sections in working pits occur near Kilmington, but it is unlikely that we shall have time to visit them.

Geology.

A simplified geological map (Fig.30) has been constructed from Sheets 311, 312, 326 and 340 of the Geological Survey of Great Britain, and this, together with the appropriate Ordnance Survey 1" to 1 mile map (Sheet 176), will illustrate the physiography of the area near Chard, part of the Lower, and part of the Upper Axe Valley. The stratigraphical succession is set out below, together with some descriptive notes:-

Alluvium

- This is mostly confined to existing river floodplains.

Valley gravel

- This forms extensive outcrops on low ground to the north of the Chard Gap, is present within the gap in small patches, and forms an important morphological feature, as a terrace, in the Lower Axe Valley. In places a fine-grained 'brickearth' outcrops on the surface of the terrace.

Head

- Head consists of a variety of materials according to the particular geological outcrop from which it is derived, and it is indicated as distinct from the Clay with flints.

Clay with flints and chert-

This is largely composed of argillaceous material believed to be derived from pre-existing Tertiary strata, and mixed with flints and chert from Cretaceous rocks. The material

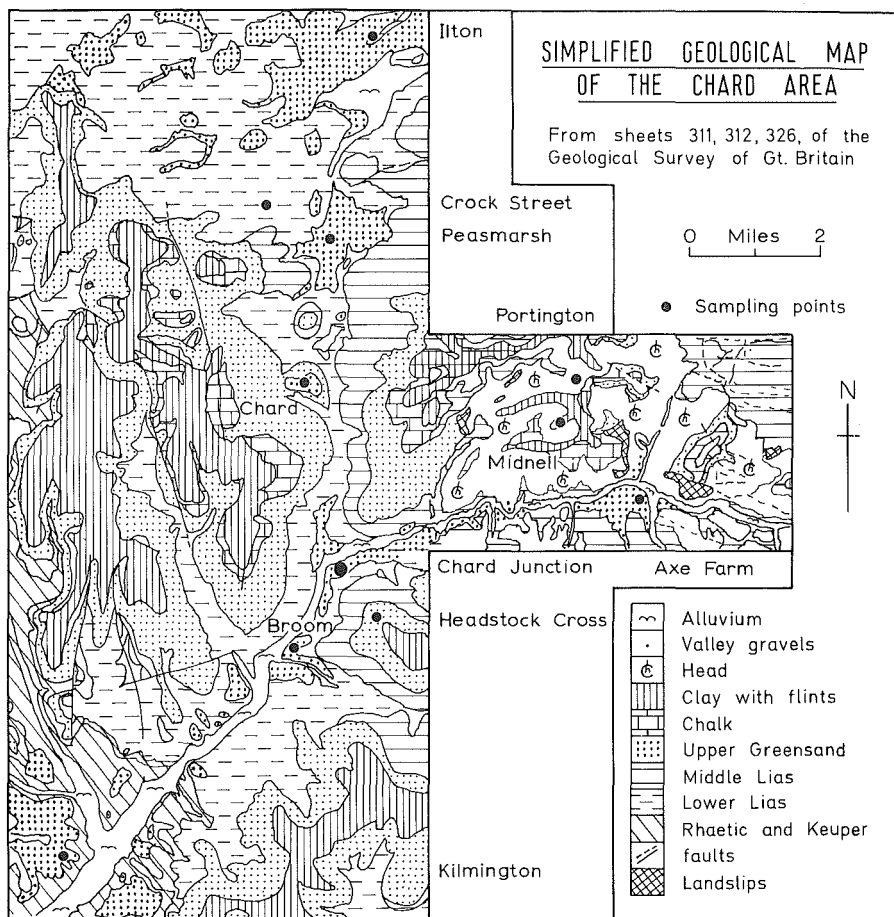


Fig. 30 - Geological map of Chard area.

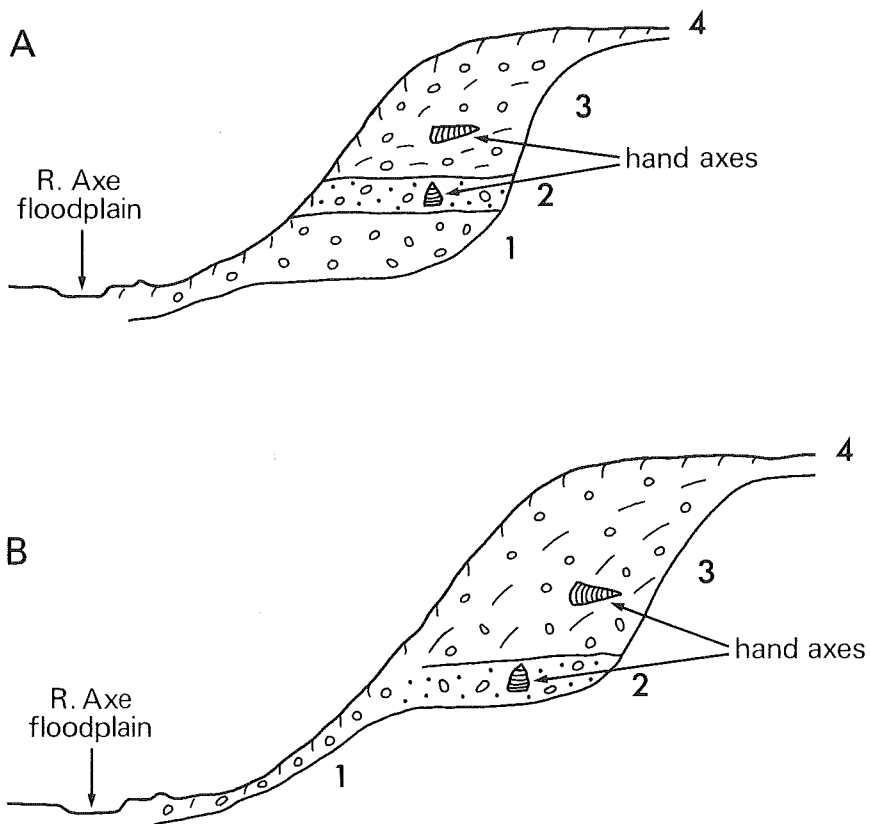


Fig. 31 - Two possible interpretations of the stratigraphic succession at Broom.

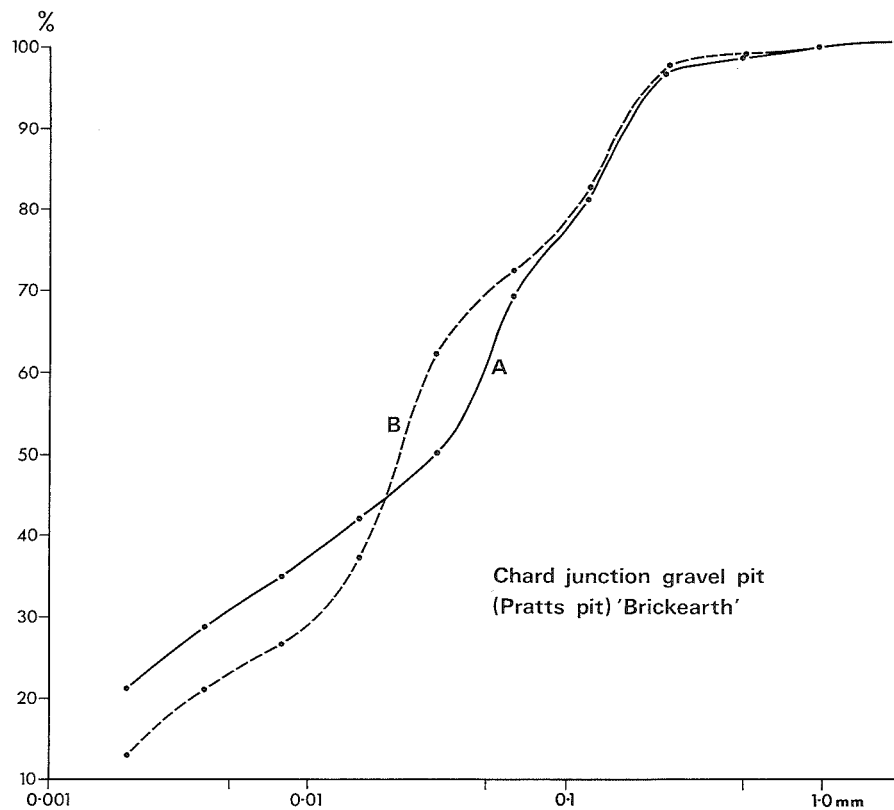


Fig. 32 - Chard Junction gravel pit (Pratt's Pit) - 'brickearth' analyses.

forms a capping of irregular thickness on the plateau-like interfluves east and west of Chard and the Lower Axe Valley.

Interfluve gravels
(see below)

- The gravels are found in patches on interfluves on either side of the Axe valley north of Axminster. The material varies from sub-angular to well-rounded pebbles in a sandy matrix, with flint, quartz, tourmalinised rocks, greywacke, and a miscellaneous assortment of Palaeozoic rock types.

Cretaceous Upper Chalk

- consists of hard chalk rock.

Middle Chalk

- consists of white chalk with scattered flints and hard nodular chalk.

Lower Chalk

- consists of white chalk rock with a few siliceous nodules and grains of quartz and glauconite. The chalk basement bed may have abundant phosphates, mostly as fossils, and phosphate-encrusted pebbles of the underlying grit.

Upper Green-sand

- consists of sands and sandstone (sometimes silty, cross-laminated and massive), with chert beds: calcareous grit with many small quartz pebbles and shell fragments may also be present.

The top of the Greensand may be glauconitised and rotten, and with green staining penetrating downwards into the calcareous grit. A phosphatic crust may be present locally.

Jurassic Milford Sands

- these consist of sands with bands of calcareous sandstone and occasional bands of shelly limestone.

Upper Lias Clay

- consists of limestones and clays or marls, with 'ironshot' limestone at the base.

Middle Lias

- consists of sands with ironstone nodules, sandy marls and limestones.

Lower Lias

- consists of an upper series of clays with occasional bands and nodules of

limestone, and a lower series of limestones, clays and shales.

Rhaetic Beds

- consist of marls, clays, marlstones, oolitic marl and gypsum; a flinty bed of limestone may be present.

Trias and Permian

Upper (Keuper) Marls

- consist of red, cuboidal and fissile marls, which may be mottled, and containing occasional sandstone horizons.

Upper Sandstone

- consists of rather soft, fine-grained red sand and sandrock, with beds of calcareous and conglomeritic sandstone; towards the base there may be intercalated beds or seams of red clay. Quartz grains and some felspathic material, with mica abundant may also occur in places.

N.B. Interfluvial gravels

Ussher (1906) and Waters (1960) have provided descriptions of these gravels, which are widely separated on interfluvial surfaces between 200 m and 315 m. They have been interpreted as river gravels (Reid, 1898), although Waters (1960) has claimed the presence of "unmistakable beach cobbles of flint" (page 92). Waters further suggests that with the patches of gravel resting upon interfluvial surfaces separated by deep valleys, the wave-trimmed surface upon which the gravels rest has been subject to gentle flexuring by the Mid-Tertiary earth movements. Thus a west to east sloping marine trimmed surface of Early Tertiary age has been substantially dissected and replaced by a Late-Tertiary subaerial surface, upon which the main elements of the predominantly southward-flowing streams arose.

An important problem concerning these well-rounded interfluvial gravels is the contribution they have made to the erratic content of the valley gravels forming the important terrace in the Lower Axe valley. From the limited amount of sampling so far completed it seems at least somewhat doubtful if downslope movement (by solifluction, landslip, and fluvial action) would account for the percentages of "foreign" material in the valley gravels.

Pleistocene Events in the Axe Valley near Chard

The possibility that a pro-glacial lake might have been created in the Severn Valley by ice blocking the Bristol Channel was first suggested by Maw (1864), when he also described the

Fremington till. Mitchell (1960) and Stephens (1970) have also commented upon this possibility, and suggested that such a lake might have discharged southwards across the main watershed to the English Channel. According to the 1:63360 O.S. maps the lowest breach in the watershed occurs at Chard in South Somerset. Here a dry valley intakes at 275-300 ft. O.D. and falls southward into the lower Axe Valley. A remarkable terrace passes down the Axe Valley from Chard Junction, and comment has been made by A.E. Salter (1899) as follows:-

"The valley of the Axe above Chard Junction is comparatively free of drift containing even local material. From this point, however, and at levels of about 150 ft. O.D. much drift gravel is found. At Broom ballast pit it is very extensive and over 30 ft thick and is made up of the debris of the High and Lower level Plateau Drifts, such as chert, flint, quartz, and schorl-rock pebbles. It is regularly stratified in places, and has sandy or clayey partings here and there and is covered by patches of brick earth deposit. Roughly shaped chert implements are abundant, mostly in the bottom layers. At Chard Junction Station is an old section of a similar gravel. Near Axminster a deposit occurs containing worked flints. Twelve feet of this gravel is being worked but there is more below. On the opposite side of the Axe valley at Kilminster it again occurs, and is well seen in a roadside section 16 ft. deep having patches of sand in places. Rudely chipped cherts occur here, and large blocks of chert up to 10 x 8 ins., schorl-rock etc. Another section occurs at a point near Colyton Station at 100 ft. O.D."

At Broom numerous Palaeolithic implements of early Acheulian type have been found (made of dark Upper Greensand chert), some being sharp-edged and some water worn, with an ovate type predominating (Evans, 1897; D'Urban, 1878). The various authorities seem to agree on a Early-Middle Acheulian age for the implements, which allows them to be regarded as ranging in age from the Hoxnian interglacial to the Wolstonian glacial period. Thus archaeological dating of the Axe Valley gravels seem to place the important terrace as no earlier than the Hoxnian and no later than the Wolstonian cold period. The Early Acheulian hand axes (not generally recovered from Eemian interglacial deposits) may have been picked up as the terrace gravels were deposited during the Wolstonian cold period as waters poured through the Chard Gap, perhaps from "Lake Maw". Cryoturbation of these gravels and the deposition of "brickearth" in patches on the terrace surface may be attributed to the latter part of the Wolstonian, or the Devensian cold periods.

Chard Junction

The general stratigraphy at Pratt's Pit is as follows:-

Surface at approximately 61 m (200 ft.)

Surface soil 0.2 m

Discontinuous layers of 'loam' or 'brickearth' 0.5 m

Coarse, poorly sorted gravels and sands, with many
erected stones and some convolutions up to 2 m

Coarse poorly sorted gravels and sands, with
sandy-silt lenses 10 m

A further 10 m of gravels have been proved below the base of
the present pit.

Various quantities of "foreign" or "erratic" pebbles are distributed throughout the gravel layers; generally these form the well-rounded component in the gravels. The percentages of various rock types present in the gravels for several sites are given in Table III.

Axe Valley: Broom Pit

Unfortunately this section is completely obscured by slipping of the old faces in the pit and by vegetation, but Reid-Moir described the section as follows:-

- | | |
|---|---------------------------|
| 4. surface soil | 188 ft. O.D. |
| 3. Tumbled coarse gravels with partings of
sandy clay and clayey matrix (derived
implements) | 25 ft. thick 163 |
| 2. Stratified gravel with clayey and
sandy seams, some black bands
(fresh, unrolled implements) | 8 ft. thick 155 |
| 1. Stratified Sand and gravel - all
lying above Lower Lias shales
forming the floor of the valley
below river alluvium | 17 ft. thick 138 ft. O.D. |

The exact stratigraphical setting is not known and two possible interpretations are shown in the sketches (Fig. 3I). In diagram 3I/A the lowest member of the series is a gravel (1) without implements. In diagram 3I/B the lower gravels (1) were, according to Calkin & Green (1949), a 'buff deposit', and thus that the true terrace base is at about 155 ft. O.D. It also follows from this interpretation that the implement-bearing gravels form the lowest member of the succession. The upper gravels (3) were regarded as a higher 'bluff deposit' resulting from solifluction.

It is not clear why solifluction was invoked to account for the deposition of the upper gravels (3). Comparisons with

Table III Percentages of rock types represented in the gravel deposits

	Chert	Flint	Greensand	Milky quartz	Vein quartz	Palaeozoic
<u>Chard</u> (in gap at 300 ft.)	42	24	10	19	-	5
<u>Crock St.</u> (300 ft.)	53	41	1	4	-	1
<u>Broom</u>	28	48	12	4	-	7
<u>Chard Junction</u>						
2 ft.	24	52	6	6	-	12
10 ft.	21	51	17	5	-	6
15 ft.	22	45	-	23	-	10
base	27	49	10	6	-	7
<u>Wayford gravels</u>	40	44	3	7	2	7 (+ Limestone 3)
<u>Headstock Cross</u>						
400 ft. above Chard Junc.	84	-	16	-	-	-
<u>Peasmarsh</u>						
200 ft. N. of Chard gap	33	52	17	-	-	-
	30	50	15	-	-	5
<u>Brockhole Lane</u>						
400 ft.	13	69	-	6	3	9

Table IV

	Coarse-Med. sand	Fine-v. fine sand	Silt	Clay
<u>Chard Junction</u>				
1	3.8	27.2	40.2	28.8
2	2.7	25.2	51.1	21.0
Sample numbers				
10	15.14	33.26	29.40	22.20
14	3.70	28.62	42.68	25.00
15	10.62	28.40	36.98	24.00

other sections in the terrace-forming gravels at Chard Junction and Kilmington, for example, suggests that the whole gravel sequence consists of poorly sorted, 'dirty' gravels and sands, crudely bedded, and severely cryoturbated at the surface. In places a capping of aeolian derived brickearth, or a colluvium of fine silt material may be present, but is apparently discontinuous. Two graphs are reproduced in Figure 32 (A and B) of size analysis of this silt material, and it is also interesting to compare the percentage analyses by weight of samples collected at Chard Junction shown in Table IV.

The implements contained in the gravels

The industry includes triangular hand axes and twisted ovates, and is probably comparable to the Acheulian at Swanscombe, and the Middle or Later Hoxnian, and perhaps part of the Wolstonian (Wymer, 1968). There seems little doubt that they are pre-Ipswichian, and are included in what is apparently a massive gravel deposit which forms a distinctive terrace system south of the Chard gap.

(N. STEPHENS)

THE BURTLE BEDS OF SOMERSET

The Burtle Beds, as described by Bulleid and Jackson (1937), are confined to the valleys of the Rivers Brue and Parrett (Fig.33). They referred to them as the Burtle Sand Beds and ascribed a marine origin to them, largely on the basis of the included marine mollusca. These marine faunas, in which Prestwich (1892) had noted the lack of cold northern forms, suggest an interglacial age but do not give a more precise indication. Bulleid and Jackson recorded the presence of 3 valves of the freshwater Corbicula fluminalis and of antlers of Cervus brown : the brown deer. From these they inferred that the deposits are not younger than the terrace gravels at Crayford in the Thames Valley, where flint implements give a Mousterian age. They were, however, also able to compare them with the gravels at Clacton. The former suggest an Ipswichian, the latter a Hoxnian age.

Kidson (1971) supported the marine origin and ignoring C14 dates on shells ranging from 29000 to 36200 BP (Kidson 1970), suggested that, on morphological grounds alone, an Ipswichian age was the more likely. Kellaway (1971) described the Burtle Beds as glacial on the basis of their included 'erratics'. "These include Devonian or Old Red Sandstone, Carboniferous, Bunter and Jurassic rocks, Cretaceous chert and flint. These are associated with pellets of soft red and green Triassic mudstone, some mixed with marine shells and remoulded in ice, others, lumps which may have been rounded while in a frozen condition." In addition he cited a "mega-erratic", the "Devil's Upping Stock" thought to have existed in the Westonzoyland area. According to Kellaway both Wolstonian and Anglian ice moved into the Somerset levels along a track from the Bristol Channel.

Kidson and Haynes (1972) showed that the Burtle gravels are indistinguishable on petrological grounds from those which are found at various locations in the Parrett estuary. They maintained support for the conclusions of Bulleid and Jackson on the marine origin of the Burtle sands and gravels and suggested a sand bank rather than a beach environment. Clays beneath the Burtle sands and gravels (Fig.34) yielded a microfauna (Fig.35) which indicated that they too were laid down in estuarine conditions during the Quaternary. These "Burtle clays" are quite distinct from the underlying Liassic and Triassic clays both on faunistic grounds and on physical characteristics, being much less tough and less compacted.

It is possible that the disagreement on the nature and origin of the Burtle Beds stems from an untenable "correlation" with the Kenn gravels suggested by Welch (1955) and with the "marine Pleistocene" of the Vales of Gordano proposed by

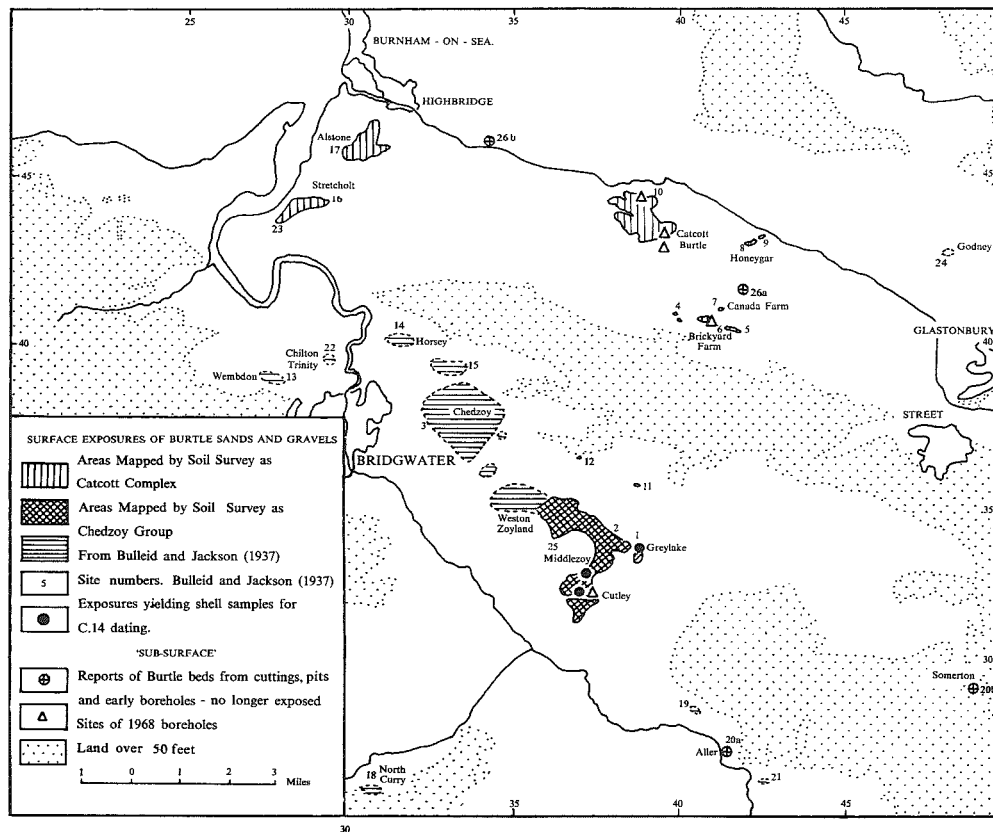


Fig. 33 - Surface exposures of Burtle sands and gravels.

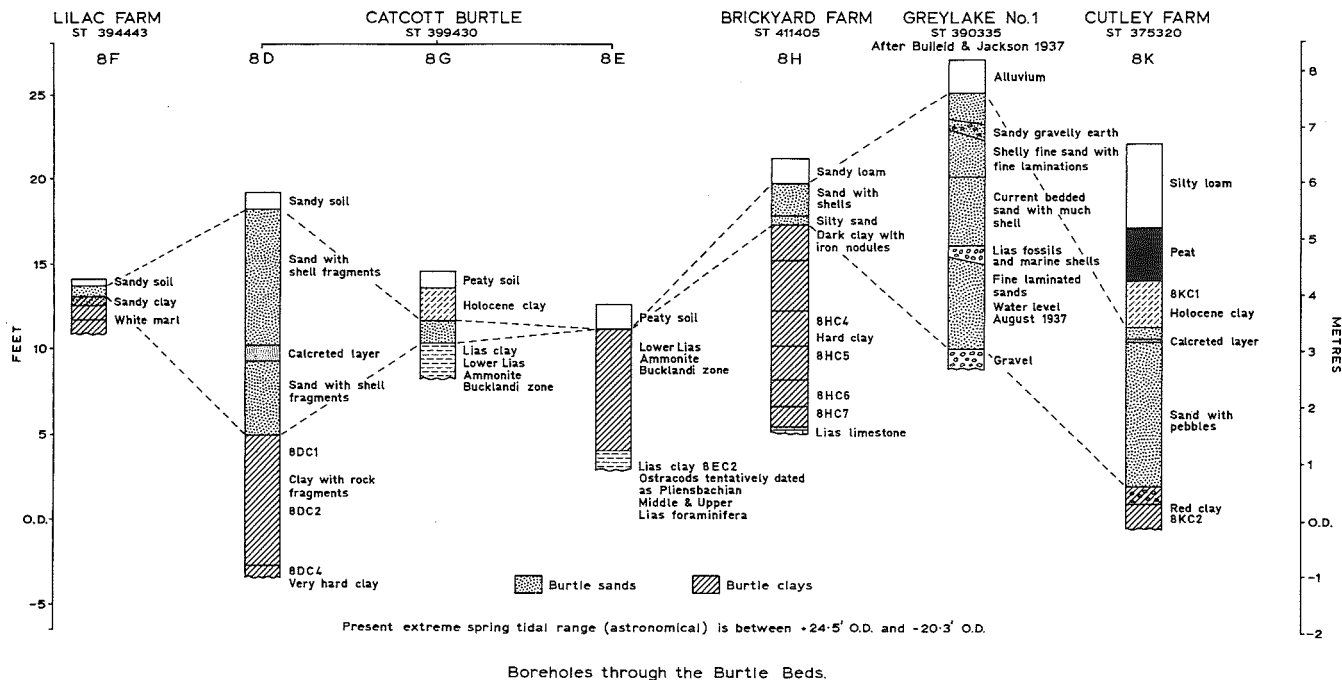


Fig. 34 - Boreholes through the Burtle Beds.

FAUNA			SAMPLES	
QUATERNARY (?EEMIAN) MICROFAUNA	FORAMINIFERA			
LIAS MICROFAUNA (DERIVED)	FORAMINIFERA			
AMMONIA BATAVUS			BDC4	
A. BATAVUS VAR.			BDC2	
A. LIMNETES			BDC1	
A. TEPIDA			BEC2	
A. SPECIES			BHC7	
ASTERIGERINATA MAMILLA			BHC6	
BOLIVINA PSEUDOPPLICATA			BHC5	
BULIMINA ELONGATA			BHC4	
B. GIBBA			BKC2	
B. MARGINATA			BKC1	
CIBICIDES FLETCHERI				
C. LOBATULUS				
C. REFULGENS				
C. SPECIES				
ELPHIDIUM c.f. ADVENUM				
E. CLAVATUM				
E. CRISPUM				
E. SELSEYENSE				
E. WADDENSIS				
E. WILLIAMSONI				
E. SPECIES				
GLOBULINA GIBBA				
LENTICULINA SUBORBICULARIS				
NONION POMPILOIDES				
PATELLINA CORRUGATA				
PLANORBULINA DISTOMA				
PROTELPIDIUM ANGLICUM				
QUINQUELOCULINA LATA				
ROSALINA ANOMALA				
R. PRÆGERI				
R. WILLIAMSONI				
TRIFARINA ANGULOSA				
CYPRIDEIS TOROSA				
CYTHEROPTERON NODOSUM				
HEMICYTHERE ANGULATA				
HIRSCHMANNIA VIRIDIS				
LEPTOCYTHERE PELLUCIDA				
LOXOCOCONCHA ELLIPTICA				
AMMODISCUS SPECIES				
ASTACOLUS S.				
DENTALINA S.				
FRONICULARIA S.				
LENTICULINA S.				
LINGULINA S.				
MARGINULINA S.				
NODOSARIA S.				
PLANULARIA S.				
VAGINULINA S.				
BAIRDIA MOLESTA				
HUNGARELLA SPECIES				
PROCYTHERIDEA S.				
LOPHODENTINA S.				
LOXOCOCONCHA ELLIPTICA				
Symbols showing numbers in 50 gms stand. weight.			• = 1 = 2-5 O = 6-20	• = 21-50 ■ = 50+ ✓ = present

Microfauna in selected samples from Burtle clays.
(Ostracod determinations Dr.R.C. Whatley.)

Fig. 35 - Microfauna in selected samples from the Burtle Beds.

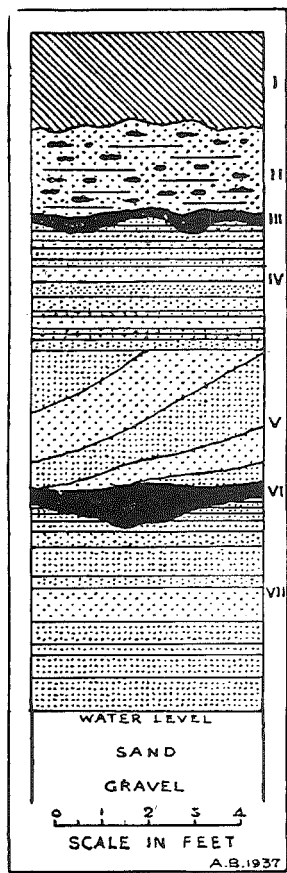
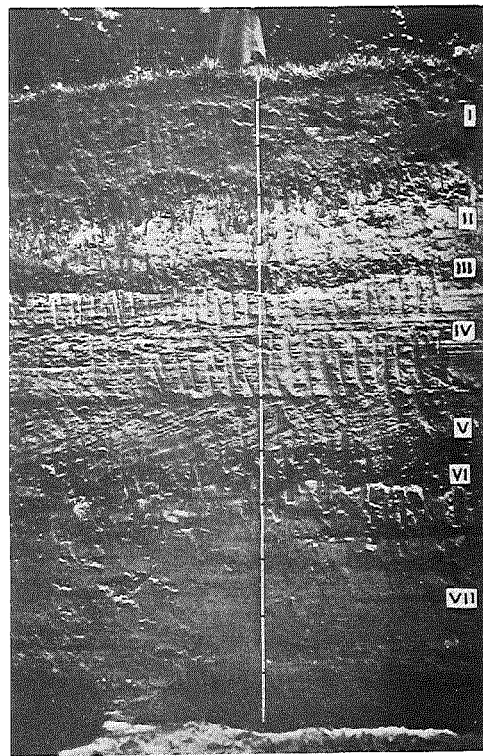


Fig. 36 - Burtle Beds (Bulleid and Jackson, 1937)



SECTION OF GREYLAKE QUARRY No. 1, LOOKING EAST
Tape gives scale in feet

FROM A PHOTOGRAPH BY DR. A. BULLEID, F.S.A.

Fig. 37 - Burtle Beds (Bulleid and Jackson, 1937)

BURTLE BEDS

Figures 36/37 Details (Bulleid and Jackson, 1937)

- i. Alluvium, reddish, averaging 2 ft. in depth.
- ii. Light-coloured coarse sand containing concretionary nodules and thin slabs of cemented sand, 18 in. to 3 ft. in depth, bedding indistinct; few marine shells.
- iii. Thin layer of brownish, sandy, gravelly earth, thickness varies, at places only a few inches in depth.
- iv. Belt of fine sand, 2 ft. 6 in. to 3 ft. in depth, bedding uniformly level, traceable entire width of quarry, thin laminations remarkably evident, separated by lines of harder sand, the intervening soft sand weathering out on quarry face; upper surface waved with shallow depressions which cut through the superficial laminations; lower surface straight and even; marine shells numerous.
- v. Layer of fine shelly sand 3 ft. to 3 ft. 6 in. in depth, current bedding strongly developed, colour of sand varies in different sections, upper surface even, lower waved rests on gravel, comminuted shell in large quantity.
- vi. Gravel 3 in. to 15 in. in depth, contains marine shells, bones of extinct mammalia, occasionally an extinct fresh-water shell.
- vii. Fine laminated sand 4 ft. to 5 ft. in thickness, bedding level similar to 4. The water level on 1.8.37 was 15 ft. 6 in. below the surface near the centre of the quarry.

ApSimon and Donovan (1956). Neither "correlation" has ever been more than a suggested possibility. It is important to remember that the Burtle Beds as mapped by Bulleid and Jackson are confined to the valleys of the Somerset levels, i.e. south of the Mendips.

Figures 36 and 37 show the section in the Burtle sands and gravels recorded by Bulleid and Jackson at Greylake No. 1 sand quarry (ST 390335). This has been almost completely infilled with farm waste. It is, however, hoped to demonstrate the similar section in Greylake No. 2 sandpit (ST 385336). This is currently used by Bridgwater R.D.C. as a rubbish tip but tentative arrangements have been made with the Council surveyor for an exposure to be available. Arrangements have also been made for a hole to be dug by JCB on the site of the boreholes at Hill Farm, Catcott Burtle (ST 399430) (Kidson and Haynes 1972) to allow the underlying clays to be examined.

(C. KIDSON)

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