Quaternary of South-West England

S. Campbell
Countryside Council for Wales, Bangor

C.O. Hunt
Huddersfield University

J.D. Scourse
School of Ocean Sciences, Bangor

D.H. Keen
Coventry University

and

N. Stephens
Emsworth, Hampshire.

GCR Editors: **C.P. Green and B.J. Williams**

JOINT NATURE CONSERVATION COMMITTEE

CHAPMAN & HALL

Chapter 7

The Quaternary history of north Devon and west Somerset

INTRODUCTION
N. Stephens

The Quaternary deposits and associated landforms of north Devon and west Somerset have been investigated for over 150 years. Some of the most significant early contributions were made by Sedgwick and Murchison (1840), who studied the raised beach and associated deposits between Saunton and Baggy Point (Croyde Bay), and De la Beche (1839) who established the term 'head' for a variety of slope deposits developed under non-temperate freeze-thaw conditions. Maw (1864) identified and mapped the controversial Fremington Clay for which he proposed a glacial origin. Dewey (1910, 1913) considered the possible source of various erratic and striated pebbles and boulders and investigated the stratigraphical relationships of the local raised beach deposits and the Fremington Clay.

Since this early work, numerous examinations of Quaternary deposits in north Devon have been carried out (e.g. Mitchell, 1960, 1972; Stephens, 1961a, 1961b, 1966a, 1966b, 1970a, 1973, 1974, 1977; Churchill and Wymer, 1965; Wood, 1970, 1974; Kidson, 1971, 1977; Edmonds, 1972; Kidson and Wood, 1974; Gilbertson and Mottershead, 1975). Attention has also been given to a variety of landforms including hogback cliff profiles (E. Arber, 1911; Steers, 1946; M. Arber, 1949, 1974), dry valleys, including the Valley of Rocks (Simpson, 1953; Stephens, 1966a; Pearce, 1972; Mottershead, 1977c; Dalzell and Durrance, 1980), and the buried rock channel of the Taw-Torridge Estuary (McFarlane, 1955). Erratic-rich gravels on Lundy Island have been investigated (Mitchell, 1968) as well as the curious flint-bearing gravel at Orleigh Court near Bideford (Rogers and Simpson, 1937).

Numerous attempts have been made to date and correlate deposits in the region, but as yet there is little agreement on many aspects of its Quaternary history. However, it is generally agreed that the bulk of South-West England was not overrun by Pleistocene ice sheets. Fragmentary evidence for the encroachment of an ice sheet along the north coast, from the Isles of Scilly to north Devon, is, however, widely recorded, taking the form of giant erratics stranded on shore platforms (e.g. Saunton), postulated glacigenic gravels (Isles of Scilly, Trebetherick and Lundy Island) and possible outcrops of till (Fremington) (Stephens, 1973; *in* Mitchell *et al.*, 1973b). This has led to the proposition that the most extensive of the Pleistocene ice sheets reached its southernmost limit at or near the north Devon and Cornish coasts (Figure 2.3). Traditionally, this glacial event has been regarded as 'Wolstonian' in age (Mitchell, 1960, 1972; Stephens, 1966a, 1966b, 1970a; Mitchell and Orme, 1967; Kidson, 1977). However, recent intense scrutiny of the status of 'Wolstonian' deposits in Britain (e.g. Sumbler, 1983a, 1983b; Rose, 1987, 1988, 1989, 1991) has necessitated a radical revision of the concept of the Wolstonian. Best estimates now ascribe glaciation of the northern Isles of Scilly to the Late Devensian (Scourse, 1985a, 1987, 1991), refute evidence of glacial activity at Trebetherick (Kidson, 1977; Scourse, 1996c), and assign the Fremington Clay or Till of north Devon, albeit tentatively, to a glaciolacustrine event of Anglian age (Croot *et al.*, in prep.; Campbell *et al.*, in prep.). Evidence of an earlier glacial event comes from the Bristol district where marginal marine deposits, dated by amino-acid geochronology to Oxygen Isotope Stage 15 (Cromer Complex), are underlain by glacigenic sediments (Gilbertson and Hawkins, 1978a; Andrews *et al.*, 1984; Bowen, 1994b). An attribution of the glacial beds to Stage 16, a major ice-volume episode, is possible, and may also be appropriate for some of the large stranded erratics such as the Giant's Rock at Porthleven (Bowen, 1994b).

Large erratic boulders weighing up to *c.* 50 tons are found around the shores of Barnstaple Bay and Croyde Bay. Some authorities have linked them with similar erratic material recovered from the Fremington Clay (Kidson, 1977), but in reality the relationship is far from clear. Moreover, large erratic boulders are also found on the south coast of Cornwall (the Giant's Rock at Porthleven; Flett and Hill, 1912), along the English Channel coast as far east as Sussex and even in Brittany (Tricart, 1956).

The presence of glacier ice in the Bristol Channel has also been used to account for numerous dry valleys, channels and cols found in north Devon especially near Lynmouth and Hartland Point. Stephens (1966b, 1974) raised the possibility that these were cut by pre-Devensian, probably Wolstonian, meltwater. Others have interpreted them as remnants of dismembered fluvial valley systems formed by protracted coastal erosion and cliff retreat (Steers, 1946; Dalzell and Durrance, 1980).

Throughout the Peninsula there is widespread evidence of former periglacial activity. The development of large coastal 'terraces' of head deposits testifies to the mobility of slope deposits, including weathered residues and frost-shattered rock. These sediments bury ancient cliff notches, some of the marine-planated rock platforms and raised beach deposits, fossil sand dunes (the sandrock of the Croyde–Saunton coast; Stephens, 1966b, 1970a; Kidson, 1977) and some of the large erratic boulders. On the higher slopes the head deposits are generally thinner, and, where sections exist, display a more coarse-textured and blocky nature than at the foot of the coastal slopes, but there is considerable sedimentological variation.

Above about 175 to 200 m no genuine erratic material has been recorded from the mantle of head deposits, although detailed mapping is far from complete. Investigations of erratic limits and erratic-free areas have proved difficult, largely because of human activity (e.g. Madgett and Inglis, 1987). For example, quantities of Carboniferous Limestone from South Wales were off-loaded at local quays and beaches and then transported inland for spreading on cultivated fields. Such activity undoubtedly accounts for the presence of numerous small 'foreign' pebbles such as quartz and flint and some Palaeozoic rocks found in ploughed fields for several kilometres inland from the coast. The modern sandy shingle beaches are rich in quartz and flint pebbles together with erratic material, but the former inland extent of any ice from the Bristol Channel and Irish Sea is unknown.

Thus not only the extent of former glaciation, which most authorities have argued must be pre-Devensian, but the age of the Fremington Clay (till?) and its relationship to the arrival of the large erratic boulders, and the fitting of these events into a timetable which also encompasses deposition of the raised beaches and the various head deposits are far from clear. This is reflected by widely disparate views and correlation tables which have been published of the Pleistocene history of the area (e.g. Edmonds, 1972; Stephens, 1973; Kidson, 1977; Bowen *et al*., 1985, 1986; Campbell *et al*., in prep.).

The Holocene is represented inland principally by sand and silt deposits which make up the present floodplains of the Taw–Torridge rivers and their tributaries. Holocene gravel and boulder debris is associated with the steeply falling north coast rivers such as the East and West Lyn, which are deeply incised in the coastal plateau. On slopes, variable amounts of hillwash and colluvium can be observed and, on Exmoor, pollen-bearing peats provide evidence of Holocene climatic and environmental changes (Merryfield and Moore, 1974; Moore *et al*., 1984). Coastal peat, organic clays and trees from the submerged forest testify to the progressive drowning of the coast by the Holocene sea.

The coastal deposits and the sequence of events at Westward Ho! have been described in detail by Rogers (1908), Churchill (1965), Churchill and Wymer (1965) and Balaam *et al*. (1987). Sea level is considered to have been 4–6 m below present some 6–7 ka BP, thus allowing peats and peaty muds to accumulate and trees to grow on what is now the modern foreshore. Radiocarbon dating of the peat places it at 6585 ± 130 BP and a Mesolithic kitchen midden was recorded from the same set of deposits. Holocene sea-level rise is also well documented from other parts of the Bristol Channel and the Somerset Levels (Kidson and Heyworth, 1973, 1976; Heyworth and Kidson, 1982; Chapter 2). At Stolford, a submerged peat with tree stumps and fallen trees is seen in much the same position as the Westward Ho! deposits (between MLWOT and MHWOT) and radiocarbon dates indicate a very similar timescale of events, culminating in the sea returning to approximately its present level.

Thus in north Devon and the Somerset Levels, and probably also for much, if not all, of the South-West, the Holocene transgression appears to have been a continuous process, implying crustal stability over a wide area (Kidson and Heyworth, 1973; Kidson, 1977). In Barnstaple Bay the last few thousand years have seen construction of the enormous shingle and cobble ridge which extends northwards from Westward Ho!; the south-western end of this structure is estimated to have moved inland at least 60–70 m in the last 150 years (Stuart and Hookway, 1954). Massive sand dune systems have also formed at Northam Burrows, Braunton Burrows, in Croyde Bay and Woolacombe Bay; these dunes mask parts of the foot of the coastal slope in each of these localities (Kidson *et al*., 1989; Chisholm, 1996).

The evidence

Rock platforms

In north Devon, Quaternary deposits constitute a wedge of sediments up to 18–20 m thick and mask the mainly convex coastal slopes. These deposits overlie a series of marine-planated rock platforms which lie between *c*. − 1.5 m to + 15 m OD. Cliffs cut in the Pleistocene sediments vary in height from *c*. 2 to 20 m and it is clear that the extensive rock platforms now visible were once buried and have been exhumed by recent Holocene marine erosion. Although there has been some trimming of the old platforms, the evidence indicates that the greater part of the exposed platforms are ancient features.

At Saunton the platform at 5 m OD is most prominent. However, Kidson (1971) has shown other platforms also occur, extending from a few metres below OD and the modern beach to + 8 m OD. In Croyde Bay a series of platforms can be observed between Middleborough House and Pencil Rock, the 8–10 m OD platform being the dominant feature. A higher platform at 12–16 m OD is seen near Freshwater Gut and Middleborough House, rising to 14–15 m OD at Pencil Rock. Although marine processes undoubtedly account for the erosion of the platforms, it is not clear whether this took place entirely under interglacial climatic conditions; some parts of the platforms may have been cut by the sea under periglacial conditions (Dawson, 1990).

At Westward Ho! several platforms are superbly exposed. The present tidal platform extends for some 200 m at low tide with a height range of 2–3 m OD; a lower rock surface at about − 1.05 m OD disappears northwards below the modern beach. The 2–3 m platform terminates in a near-vertical rock cliff above which the 8–9 m OD platform is seen. Isolated remnants of a platform at 5 m OD rise locally above the 2–3 m surface (Stephens, 1970a; Kidson, 1971, 1977; Figure 7.9). The generally ragged appearance of the wide 2–3 m platform gives way to more smoothed surfaces at the cliff-foot where wave action has constructed an impressive storm beach of sandstone pebbles and cobbles. These appear to have been derived from raised beach material lying on the 8–9 m platform. The seaward edge of the 8–9 m platform lies 3–4 m above the highest storm beach ridge and about 6 m above the back of the 2–3 m surface. The notch of the 8–9 m platform is estimated to be at about 13–14 m OD although it is completely hidden by a suite of superficial deposits.

Buried rock channels

McFarlane (1955) demonstrated a buried rock channel at the confluence of the Taw-Torridge rivers, lying at a depth of about − 24 m OD and buried by *c.* 30 m of sediment in the estuary. He considered that both rivers formerly graded to a level of − 24 m OD north of Appledore. Similar flat-bottomed buried channels elsewhere in South-West England may have formed when sea level was lower by up to 45 m, and the shoreline some 15 km off the present coast.

The age of the channels has not been determined, but they are likely to have been formed during a variety of Pleistocene cold stages when sea levels were low. Similar buried channels have been described elsewhere in South-West England by Codrington (1898), and comparable features have been traced and recorded in South Wales and the Severn Estuary (Anderson, 1968). The sediment content of the channels varies from till, sand and gravel to a variety of Holocene deposits, and much of the sedimentary infill has been reworked.

Erratics and glacigenic materials

Large erratic boulders on the coasts of north Devon and Cornwall, on the English Channel coast as far east as Sussex and in Brittany, together with significant quantities of pebble-sized erratics and some other glacially derived sediments have long provided interesting problems for Quaternary researchers (Williams, 1837; Pengelly, 1867, 1873a; Hall, 1879b; Dewey, 1910; Taylor, 1956; M. Arber, 1964; Stephens, 1966b; Kidson, 1971; Edmonds, 1972; Madgett and Inglis, 1987; Hallégouët and van Vliet-Lanoë, 1989; Sims, 1996). Virtually all the large coastal erratics are found within a narrow range of height (0–10 m OD) and resting upon one of the several marine-planated rock platforms (Stephens, 1970a, 1974; Kidson, 1971, 1977). A few have allegedly been recorded at higher altitudes, as for example an epidiorite block on Baggy Point at + 80 m OD (Madgett and Madgett, 1974), but some erratic material may owe its position to anthropogenic activity. Madgett and Inglis (1987) have made a comprehensive survey of erratics, of all sizes, found between Baggy Point and Saunton, and Sims (1996) reviews the possible mechanisms for their emplacement.

The wide distribution of the large erratics has been accounted for by the movement of land-based ice masses (Mitchell, 1960; Kidson, 1971; Kellaway *et al.*, 1975) or floating icebergs and floes (Synge and Stephens, 1960; Stephens, 1970a, 1974; Bowen, 1994b). However, deposition of the large erratics has also been linked directly to the emplacement of the Fremington Clay (Kidson and Wood, 1974; Kidson, 1977) where the erratic suite is similar to that on the open coast at Croyde and Saunton. The rejection of the proposition (Kellaway *et al.*, 1975) that land-based ice could have advanced sufficiently far eastwards into the English Channel to deposit large erratics from south Cornwall to Sussex and in Brittany (Gibbard,

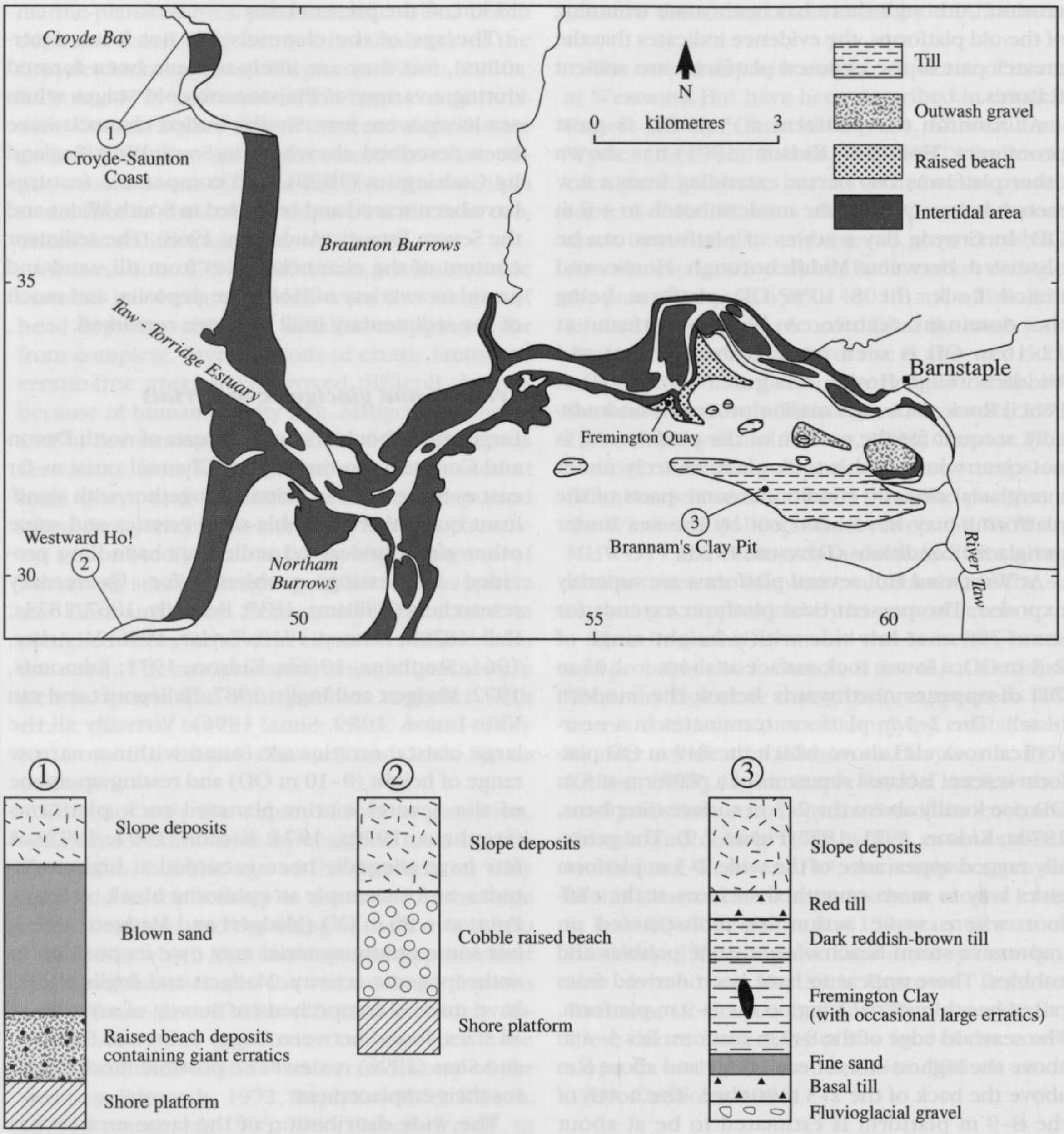

Figure 7.1 The distribution and proposed stratigraphical relationships of Quaternary deposits around the Taw-Torridge Estuary. (After Kidson and Heyworth, 1977.)

1988), suggests that, at least for these coasts, floating ice was probably involved. In north Devon and north Cornwall the problem is more difficult because there is good evidence for incursions of Irish Sea ice into the Bristol Channel during some stage or stages of the Early and Middle Pleistocene to deposit till and related sediments as far east as Somerset (Hawkins and Kellaway, 1971; Hawkins, 1977; Andrews *et al.*, 1984). Thus two mechanisms of deposition may be involved in the South-West Peninsula, although it is also possible that the wide geographical distribution of the large erratic boulders was accomplished during a single glacial event of pre-Devensian age.

Erratic emplacement by floating ice requires a delicate balance between sea level and climate to allow the stranding of ice-rafted material. If isostatic adjustments were also involved then a complex relationship between land and sea level must be envisaged for which, at present, there is little or no evidence during the Early and Middle Pleistocene. Oscillations of the position of the North Atlantic Polar Front have been postulated by Ruddiman and McIntyre (1981) during the Devensian. If similar movements occurred during earlier Pleistocene glacial events then climatic conditions may well have allowed substantial ice-floes to stream southwards to latitudes of the Bristol and English channels while sea level remained sufficiently high to allow the floes to be stranded on the lower of the rock platforms.

The Fremington Clay and related deposits

An important suite of Pleistocene deposits is known from a small area between Fremington and Barnstaple. The description and analysis of these deposits began in the mid-nineteenth century but their interpretation and dating remains difficult and contentious (Maw, 1864; Dewey, 1910; Taylor, 1956; Mitchell, 1960; M. Arber, 1964; Stephens, 1966b, 1970a, 1974; Wood, 1970, 1974; Edmonds, 1972; Kidson and Wood, 1974; Kidson, 1977). The Fremington Clay in fact comprises a complex and variable sequence of clays, silts, sands and stony clays overlying gravels (Stephens, 1966b, 1970a; Croot, 1987; Croot *et al.*, 1996). Up to 30 m of clay have been recorded and erratics, including some large examples, and striated stones are abundant in certain horizons (but see Brannam's Clay Pit). The sub-clay gravels exposed in the base of the clay pits, at Fremington Quay, Fremington Railway Cutting and at Lake Quarry provide further problems of interpretation and correlation (Figure 7.1).

Sections at Fremington Quay, the Railway Cutting, Penhill Point and Lake Quarry show gravels which have been considered to represent a raised beach (usually equated with that exposed in the Croyde–Saunton coastal section) resting on bedrock and overlain by erratic-bearing stony clays (Figure 7.1). Stratigraphical variation over several hundred metres of section, however, has made interpretation difficult and dating controversial (Dewey, 1913; Stephens, 1966b, 1970a, 1974; Wood, 1970, 1974; Kidson and Wood, 1974; Kidson, 1977; Croot *et al.*, in prep.; see Fremington Quay).

Several metres of sand and gravel cap the Bickington-Hele ridge which rises to 55 m OD and stands above the main body of the Fremington Clay (at 30 m OD). These deposits, which contain erratic stones, may represent ice-marginal or sub-ice sediments associated with the Fremington Clay, which until recently has been regarded as, at least in part, a till. Edmonds (1972) re-mapped this area and reaffirmed the presence of till, a view accepted by most authors but recently questioned by Croot (1987) and Croot *et al.* (1996) who have proposed a glaciolacustrine origin for the bulk of the Fremington Clay (see Brannam's Clay Pit). Edmonds also mapped river terraces in the lower Taw Valley and between Barnstaple and Swimbridge. These terraces were related to a series of events involving both deposition of the Fremington Clay and the raised beach of the outer coast, and were considered to have accumulated during the Wolstonian and Ipswichian stages.

Foundation trenches for a housing development in Croyde Village revealed a red-brown clay containing erratics and striated stones. This too may be related to the Fremington Clay and other stony clays exposed in low cliffs below modern sand dunes in Croyde Bay (Madgett and Inglis, 1987). Although a glacial origin has traditionally been proposed for the Fremington and Croyde clays, there is still considerable doubt concerning the precise origin and age of these deposits and estimates of both vary widely. Most authorities have invoked a land-based ice sheet of Wolstonian (Saalian) age to account for the deposits, but this now seems highly unlikely (see Chapter 2; Anglian and Saalian events). Some workers have suggested the possibility of a Devensian age for the Fremington Clay; Eyles and McCabe (1989) postulated that the deposits could have accumulated as a glaciomarine mud drape from a disintegrating, floating, Devensian Irish Sea ice sheet. Such a possibility was also given credence by Bowen *et al.* (1989) and Campbell and Bowen (1989), and also by Synge (1977, 1979, 1981, 1985) who has argued consistently for extensive floating Devensian ice off the south-east Irish and south-west Wales coasts. Although such dating of the Fremington Clay fits neatly with Scourse's (1985a, 1986) proposal that land-based Devensian ice reached the Isles of Scilly, it runs counter to the view of Kidson (1977) and others that there is no evidence of a glacial event post-dating the raised beaches at Croyde, Saunton and Westward Ho! The most recent attempts to date the Fremington Clay using OSL techniques (Croot *et al.*, 1996; Gilbert, in prep.) have provided ambiguous results. An age greater than *c.* 400 ka BP, however, is indicated suggesting that the deposits are at least of Anglian age. Evidence from the Bristol district suggests that glacigenic sediments there may be as old as Oxygen Isotope Stage

16 (Gilbertson and Hawkins, 1978a; Andrews *et al.*, 1984; Bowen, 1994b). If a correlation can be proved between these deposits and the Fremington Clay, then the Stage 16 ice limit in South-West England (Figure 2.3) proposed by Bowen and Sykes (1988) may appear increasingly realistic.

Lundy Island

Further evidence for the former presence of glacier ice in north Devon occurs on Lundy Island (Mitchell, 1968). The island is composed mainly of Tertiary granite except for a small area in the extreme south-east where Upper Devonian slates (Upcott Slates) crop out. There are also numerous dykes of basic and acid rocks. Pebbles of sandstone, flint, chert and greywacke up to 10 cm diameter are widely scattered over a considerable area at the northern end of the plateau between *c.* 84 and 107 m OD, and occasional erratics are also found in head which mantles coastal slopes in the east. Ice-moulded bedrock, demonstrating possible evidence for a WNW to ESE direction of ice movement, is recorded on the west side of the island north of St James's Stone. In the north of the island, small, deep dry valleys slope eastwards and trench the coastal slope: these have been interpreted as glacial meltwater channels (Mitchell, 1968). Although the precise age of the Pleistocene sediments and landforms is unknown, the evidence appears to confirm the presence of an ice sheet in this vicinity to a minimum height of 115 m OD: both Anglian and Wolstonian glacial events have been suggested (Mitchell, 1960, 1968, 1972).

The Doniford gravels

The Doniford gravels crop out for approximately 2 km along the Somerset coast near Watchet. According to Gilbertson and Mottershead (1975), they appear to have no direct connection with the glacial deposits and raised beaches of north Devon nor the glacial deposits reported from the Somerset Levels at Kenn (Gilbertson and Hawkins, 1978a) and in the Bristol area (Hawkins and Kellaway, 1971).

The Doniford gravels have a maximum thickness of about 5 m and consist mainly of slates, sandstones, grits and chert derived from the Devonian rocks of the Bredon Hills, with subordinate blocks of local Liassic shale. Both the gravels and the underlying shale bedrock are severely disturbed by periglacial structures which extend upwards into the lowest member of a series of pebble-bearing loams; no far-travelled erratics have been detected in either set of sediments.

The gravels contain remains of ***Mammuthus primigenius*** (Blumenbach) (woolly mammoth) and well-rolled Palaeolithic implements (hand-axes and flakes) of Acheulian typology (Wedlake, 1950; Wedlake and Wedlake, 1963) which might appear to raise the possibility of a pre-Devensian age. However, since the uppermost loam, which caps the gravel sequence, contains Mesolithic artefacts and because there is no marked discontinuity between the lower loams and the gravels, Gilbertson and Mottershead (1975) have assigned the bulk of the Doniford sequence to the Devensian, arguing that the gravels accumulated as a mixture of periglacial fluvial and slope deposits.

Raised beach, sand and head deposits

Slope deposits of varying composition and thickness mantle most of the landscape of north Devon. They range from weathered clasts supported in a sandy-silt matrix to coarse, loosely packed angular rock fragments. At the foot of some coastal slopes the deposits form 'terraces' of considerable extent and thickness. The term 'head' has been universally adopted to describe the bulk of these deposits since it was first used by De la Beche (1839).

It is accepted that non-temperate freeze-thaw processes were responsible for the break up of the regolith and underlying bedrock and, together with some water-action, enormous quantities of material were moved downslope. The terraces of head are particularly well developed around Croyde Bay, at Saunton, Lee Bay and Westward Ho!, and in each case the head overlies extensive raised beach deposits (Figure 7.1). In Croyde Bay and at Saunton, cemented dune sands rest directly on raised beach sediments and these in turn are covered by head, which in places interdigitates with dune sand. At the base of the sections, and overlain by either raised beach deposits, cemented dune sand or head, are found some of the large erratic boulders; in every known case these are in contact with the bedrock of the shore platforms.

The head deposits are clearly younger than the raised beach sediments and the large erratic boulders. The cemented sands (sandrock) rest directly on the raised beach sediments, which are pebbly towards their base at Saunton but pass upwards into current-bedded (marine) sand. The latter then gives way, often imperceptibly, to cemented dune sand (Greenwood, 1972; Gilbert, 1996) which accumulated, at least in part, when periglacial processes began to produce the extensive head deposits, thus accounting for the interdigitation of the two very different sediments.

Attempts to recognize divisions within the head deposits (Stephens, 1966a, 1966b, 1970a) have been based on the presence of a coarse, angular and blocky layer up to 2 m thick – the Upper Head – which forms the upper surface of the head terrace. The terrace was considered to comprise a Lower Head, a relatively consolidated deposit with well-weathered clasts set in a matrix of sand- and silt-sized material, while the Upper Head consists mainly of angular rock fragments, little weathered and without a substantial matrix. Occasional ice-wedge casts and other infilled (with silty clay) cracks disturb the bedding of the Upper Head. However, such a division of the head deposits is not universally accepted and Kidson (1971, 1977) regards the head as a single, if very variable, sedimentary unit. Thus, Kidson would regard the head as the product of a major periglacial phase during the Devensian cold period while Stephens suggested that at least two separate periglacial phases are represented. Aeolian sand, which underlies and interdigitates with the head along the Croyde–Saunton coast (e.g. Greenwood, 1972; Gilbert, 1996), has been dated recently by Optically Stimulated Luminescence (OSL) techniques (Gilbert, 1996). The preliminary results show that the aeolian sediments were deposited during Oxygen Isotope Stage 4, around 70 ka BP, and that the considerable thicknesses of overlying head must be Devensian. Precise subdivision and dating of the head are still, however, tenuous. There is no evidence that the surface of the coastal terrace here, or at other localities, was fashioned by marine activity.

The raised beach deposits would therefore appear to represent an interglacial sea-level event, or events, before at least one, and possibly more than one, major periglacial phase. Exposures of raised beach deposits vary in height and it is only in Croyde Bay, at Pencil Rock on Baggy Point and at Middleborough House at about 10 to 14 m OD that notches in bedrock can be observed. Raised beach deposits are seen at lower levels towards Saunton but here the rock notch is obscured.

Attempts to resolve the age of the raised beach deposits between Croyde and Saunton have been made using amino-acid analyses of fossil marine shells (Andrews *et al.*, 1979; Davies, 1983; Bowen *et al.*, 1985). The results show that most of the raised beach deposits can probably be correlated with high relative sea levels during Oxygen Isotope Stage 7. However, the presence of some shells with amino-acid ratios typical of Stage 5e (Ipswichian) and Stage 9 provides major problems of stratigraphic interpretation: Bowen *et al.* (1985) have tentatively suggested that locally Stage 5e deposits may be banked against an older (Stage 7) raised beach deposit (see Croyde–Saunton Coast). Gilbert (1996) assigns the bulk of raised marine sediments at this locality to Stage 5e.

The raised cobble beach deposits at Westward Ho! have been ascribed both to the Ipswichian (e.g. Kidson, 1977) and to the Hoxnian (e.g. Stephens, 1970a, 1973). However, the deposit lacks shells and cannot therefore be dated by amino-acid techniques. Comparison based upon position, stratigraphy and height range in fact suggests that the raised beach deposit at Westward Ho! is possibly equivalent to the Croyde–Saunton raised beaches, although such evidence alone is insufficient to justify correlation. The raised beach deposit at Lee Bay (see the Valley of Rocks), sealed below massive head deposits, may also be related. Unfortunately, there is no section known in north Devon where two undoubted raised beach deposits of different ages occur in clear superposition. Only in South Wales, at Portland Bill and in the Isles of Scilly (Mitchell and Orme, 1967) have two superposed beaches of different age been identified, although in the latter locality Scourse (1986) interprets the higher (younger) deposit as having been derived by solifluction from the older (Chapter 8).

The evidence presented by Bowen *et al.* (1985, 1989) and Bowen and Sykes (1988) has been summarized admirably by Jones and Keen (1993). It appears that for the present, a number of permutations for the ages of the various outcrops of raised beach deposits in southern Britain are possible. If the Saunton and Croyde raised beach sediments are not Ipswichian (the Pennard Stage of Bowen *et al.* (1985)) but belong to some pre-Ipswichian event (the Unnamed Stage and/or the Minchin Hole Stage of Bowen *et al.* (1985)), then many questions still arise concerning the age of the overlying head deposits, the Fremington Clay and the raised beach sediments reported from Fremington Quay, Fremington Railway Cutting and at Penhill Point.

Attention must also be given to the substantial patches of well-rounded pebbles and cobbles exposed at low tide on the foreshore at Westward Ho! These deposits are exposed sporadically beneath a suite of Holocene sediments. The pebbles and cobbles vary in size, many exceeding 30 cm in length. Most are embedded in a head deposit and stand on-end, and some appear to have suffered post-depositional fracturing, perhaps by freeze-thaw processes. Rough polygonal patterns are displayed by the upstanding cobbles, suggesting an exposure of relic patterned ground in material almost identical to that of the modern storm beach ridge and the 8–10 m OD raised beach deposit (see Westward Ho!).

The lower intertidal rock platforms (− 1.5 m and/or 2–3 m OD levels of Kidson, 1971) must surely pass below these deposits. Dating and correlation, however, remain very difficult although it has been suggested tentatively that these foreshore deposits constitute a periglacially disturbed beach of different age from the 8–10 m OD raised beach deposit (Stephens, 1974). Such an explanation is rejected by Kidson (1974) as an unnecessary division of the same raised beach. However, it can be argued that these periglacially disturbed beach deposits were closely associated with the cutting of the 2–3 m OD rock platform and removal of some of the head deposits originally covering its surface. Although the sea is at present trimming this low platform it seems clear that it is a relic feature cut below the higher raised beach platform at 8–10 m OD. There remains, therefore, the possibility that two different phases of rock platform cutting and beach deposition are preserved at Westward Ho!

The relationship of the raised beach deposits to the Fremington Clay and related sand and gravel deposits also remains highly contentious. The raised beach sediments exposed at Fremington Quay, the Railway Cutting and at Penhill (resting on bedrock at 10 m OD) are considered by most authors to post-date the Fremington Clay and to represent an Ipswichian beach deposit (Kidson, 1971; Edmonds, 1972; Kidson and Wood, 1974; Wood, 1974; Kidson, 1977). However, alternative explanations of the stratigraphy at these sites have been proposed (see Fremington Quay) and the age and origin of a sub-Fremington Clay gravel remains crucial to establishing the relative age of the raised beach (Stephens, 1966b, 1974). Dewey (1913) considered that at Fremington Quay raised beach gravels were overlain by weathered stony clay containing erratics and striated pebbles, while Stephens (1966b) recorded contorted beach gravels overlain by till in the nearby Railway Cutting; whether or not these stony, erratic-bearing clays overlying the raised beach rest *in situ* or not requires further investigation.

It is thus of critical importance that the age of the raised beach deposits on the outer coast at Croyde and Saunton be determined, that there should be a fresh examination of the Westward Ho! beach deposits (both in cliff and foreshore exposures), and that a major effort be made to establish the precise stratigraphical relationships of various deposits in the Fremington area and their relationship to the sedimentary sequence on the outer coast. At present it is not possible to assign any of the beach deposits, the sandrock, the very large erratic boulders, the Fremington Clay and related sands and gravels at Bickington and Hele to a precise Quaternary timescale with any confidence.

Holocene deposits at Westward Ho!

The finest coastal exposures of Holocene deposits in north Devon crop out on the foreshore at Westward Ho! The sediments consist of peat and organic-rich clays with tree stumps and blue-grey clays. The sequence contains mammal remains and Mesolithic artefacts (I. Rogers, 1908; E.H. Rogers, 1946). Detailed excavation of the intertidal site was carried out by Churchill (1965), and Churchill and Wymer (1965) provided a radiocarbon date of 6585 ± 130 BP (Q–672) for a fen peat overlying a Mesolithic kitchen midden. A comprehensive reassessment of the site's palaeoenvironmental and archaeological history is provided by Balaam *et al.* (1987).

The site is one of many localities in southern Britain where former land surfaces (the 'submerged forests') can be shown to have been transgressed by the rising Holocene sea. At the time of the formation of the peat at Westward Ho!, sea level is considered to have been 4–6 m below that at present, which is consistent with the evidence from the Somerset coast at Stolford and South Wales (Kidson, 1977). The Holocene deposits rest upon a sterile blue-grey clay which in turn overlies the well-rounded pebbles and cobbles of periglacially disturbed beach deposits and head (Stephens, 1966b, 1970a).

Dry valley systems in north Devon

Dry valleys, dry cols and related features are widely recorded in north Devon. These include the Valley of Rocks near Lynmouth, the Hartland and Damehole Point channels south of Hartland Point, and some dry valleys and 'through' valleys near Bideford and Newton Tracey.

Controversy surrounds the origin of the Valley of Rocks, the associated dry col at Lee Abbey and a series of flattened spurs at Duty Point, Crock Point and Woody Bay, extending in all some 5 km westwards along the high cliffed coast from the joint mouth of the East and West Lyn rivers. The Valley of Rocks is incised over 100 m below the northern edge of the Exmoor plateau and hangs 120 m above the sea. It is a dry valley trending east-west, cut in the sandstones and slates of the Devonian Lynton Beds. It appears to occupy an anomalous position in relation to the mainly north-flowing drainage off the Exmoor plateau, except for segments of the East Lyn river.

Stephens (1966a, 1966b) suggested that if large ice masses had once occupied the Bristol Channel, there was a distinct possibility that conditions would have favoured the development of ice-marginal meltwater channels between the ice and the northern edge of Exmoor and even, locally, subglacial channels. However, other mechanisms involving coastal retreat and river capture have been suggested (E. Arber, 1911; Steers, 1946; Mottershead, 1964, 1967, 1977c; Pearce, 1972, 1982; Dalzell and Durrance, 1980). Pearce (1972, 1982) outlined a series of possible drainage diversions involving the East and West Lyn rivers, and the Lee stream, which he argued resulted from the retreat of the cliffed coastline.

Mottershead (1977c) invoked coastal erosion to account for the diversion of the East and West Lyn rivers to their present outlet at Lynmouth and the consequent abandonment of the Valley of Rocks. Such an hypothesis does not, however, take into account the enormous thickness of superficial (mainly head) deposits obscuring the rock floor of the Valley of Rocks and the Lee Abbey col. Similarly, the projection of river profiles from the East Lyn River to fit the Valley of Rocks and the Lee Abbey col also ignores the fact that thick superficial deposits overlie the rock floor (Simpson, 1953; Stephens, 1966b).

Dalzell and Durrance (1980) confirmed the existence of considerable thicknesses of superficial material, including thick head deposits, in the Valley of Rocks and the Lee Abbey col. Rockhead was shown to fall steeply westward to Wringcliff Bay and, in the Lee Abbey col, stands well above any westward projection of its profile under the Valley of Rocks. In a carefully argued account they envisaged that the East and West Lyn rivers and the Lee stream formerly joined at Wringcliff Bay and then flowed westwards along the coast to Duty Point and Crock Point, where the flattened spurs represented remnants of the old valley floor. This extended river system was then dismembered by coastal erosion and substantial cliff retreat during the Ipswichian.

The well-argued case that marine erosion and considerable cliff retreat is the most likely agent responsible for the capture and diversion of the East and West Lyn drainage is attractive and reasonable. Indeed, examination of the East Lyn Valley indicates that if very rapid cliff retreat took place about 4 km east of Foreland Point, near Glenthorne and County Gate, to reach an elbow of the river at Southern Wood and Malmsmead, where the Badworthy Water joins the East Lyn, then another gently sloping dry valley might be created between Southern Wood and Leeford. The dry valley would be about 2 km long. The lower gorge section of the East Lyn Valley between Leeford and Barton Wood, where it is joined by the Farley Water, would also form part of the abandoned system but would not be completely dry because of the input from several small streams. The implication of such an hypothesis is that cliff retreat of about 1.5 km would be necessary through ground rising to over 300 m OD. If a similar explanation is accepted for the evolution of the Valley of Rocks then the rate of cliff retreat must have been exceptionally fast to have been completed during the Ipswichian, or even during the entire Pleistocene Period.

The presence today of long, subaerially and periglacially modified slopes above a limited development of vertical cliffs, to form the hogback cliffs (E. Arber, 1911; Steers, 1946; Stephens, 1990) suggests that marine erosion along the north Devon coast has in fact been relatively slow. Consequently, the efficiency of wave attack to bring about river capture of the kind proposed must be questioned, unless special geological conditions were present. These might include the presence of particularly weak strata immediately offshore and systems of fault lines along the northern edge of the Exmoor plateau. While little is known about the rate of marine erosion on hard rocks in southern Britain, there seems insufficient evidence from north Devon to indicate that cliff recession is taking place at a rapid rate. Furthermore, the existence of a raised beach deposit (Ipswichian or older?) deeply buried by head deposits in Lee Bay indicates that at least some of the existing crenulations in the coastline have been in existence for some considerable time.

Consequently, the possible role of meltwater associated with an ice mass pressing against the north Devon coast during a pre-Devensian glacial event cannot be completely dismissed. Although there is no unanimity of agreement as to which glacial event (Oxygen Isotope Stage 16, Anglian or later?) may have been involved, there can be no doubt as to the former existence of ice masses in the Bristol Channel between the Isles of Scilly, Somerset and the Bristol area (Jones and Keen (1993) provide a summary of the evidence.). Erratic pebbles have been recovered from all the modern and raised beaches in north Devon and there is some evidence provided by erratic material that ice extended to about 150–175 m OD on the western plateau behind Ilfracombe and Berrynarbour. Meltwater erosion may have occurred with or without the development of ice-dammed lakes and the channels could have operated with steep gradients and very variable directions of flow, both parallel to the coast and transverse towards the Bristol Channel, perhaps contributing to the breaching of the seaward rim of Hollerday Hill at Wringcliff Bay. The matter clearly requires further investigation.

A series of dry channels has also been identified at Hartland Quay, Damehole Point and Speke's Mill Mouth in north Devon (Steers, 1946; Stephens, 1966b, 1974). The wide flat-floored valleys 'hang' above the sea near Hartland Point and Damehole Point and effectively isolate the prominent St Catherine's Tor; they continue as flattened spurs at Hartland Quay and Speke's Mill Mouth, which are similar features to those at Duty Point and Crock Point. Accumulations of coarse blocky head up to 3 m thick emphasize the flat floors and their accordance of level at about 25–30 m OD. Some parts of the channels contain small streams which plunge by waterfalls to the sea, as for example on the north side of St Catherine's Tor.

Steers (1946) regarded these features as part of a system of small valleys which were dismembered by cliff retreat, drawing on the evidence of the prominent vertical cliff profiles seen along the coast from Hartland Point southwards. The explanation could be accepted without question if it were not for two factors. The first is the considerable disparity between the size of the channels and the very small streams now flowing in some parts of them, the discharges of which appear to do little more than cut modest 'gutters' in the head which occasionally reach rockhead. The second is the recorded presence of glacial erratics on Lundy Island (up to 107 m OD) some 30 km to the north-west, and of the general acceptance that ice reached this coast during the Early or Middle Pleistocene. Thus, it is suggested that meltwater associated with an ice-front may well have played a part in the formation of these channels.

There are also low-level dry valleys near Bideford, which have been described by Edmonds (1972) as possible drainage channels resulting from the incursion of Wolstonian ice into Barnstaple Bay and as far inland as Barnstaple and Fremington. Edmonds provided a possible sequence of events involving drainage diversions resulting from the blocking of the outlets of the Taw and Torridge rivers and their tributaries by ice occupying the estuary, the deposition of the Fremington Clay (till and lake clay) and a series of terraces as multiple ice advances and retreat took place (Figure 7.4). Among the valleys that may have been used, and enlarged, by meltwater, is the dry valley extending from the Torridge at Bideford to the coast at Cornborough, 1.2 km south of Westward Ho! The valley floor rises from about 10 m OD in Bideford to about 30 m OD at its western end in the Cornborough col and was formerly used by the railway line to Westward Ho!

Another 'through' valley which he identified extends from the east side of the Torridge at Bideford eastwards to the Taw Valley. The linked valleys are flat-floored and both contain tiny streams: the highest point of a possible glacial drainage channel is 55 m OD at Newton Tracey (Edmonds, 1972). Edmonds also envisaged another such channel extending from the Torridge Valley at Landcross, via the River Yeo valley to Yeo Vale and then north-west towards Ford and the coast.

The Orleigh Court flint-bearing gravels

A deposit of flinty gravels and sands covers some 0.75 km^2 on a low plateau above the valleys of the River Yeo and River Duntz at Orleigh Court, 4 km west-south-west of Bideford. The gravels rest on Carboniferous sandstones and were recorded by Vancouver (1808), De la Beche (1839) and Rogers and Simpson (1937). The deposit is estimated to be about 8 m thick and consists of:

3. Upper gravels: flint-rich (flints up to 39 cm) with indurated ferruginous grit, much clay and silt
2. Lower gravels: relatively few flints, mostly small, with 'clean' sand
1. Yellow clay of unknown thickness

The most abundant flints are seen in ploughed fields over a rather smaller area of about 0.3 km^2 and there has clearly been downslope movement of the gravels off the plateau, which ranges in height from about 61–80 m OD. The deposits have been considered to represent a Pliocene outlier with affinities to the Lower and Upper Greensand and with fossils derived from the Upper Chalk

(Chapter 3). However, the origin of the gravels is unknown. What does appear to be important is the lack of carriage of large flints to adjacent areas and the survival of about 8 m of sediments in an exposed position. There is no indication that the gravels represent a glacial deposit for no erratics or striated stones have been recovered, but it is suggested that the existence of the deposit may indicate that there has been no ice movement across this part of north Devon to reach a height of 80 m OD. This in no way precludes ice from having crossed Lundy Island (84–107 m OD), entered Barnstaple Bay to reach Fremington, and pressed against the north Devon coast.

BRANNAM'S CLAY PIT

S. Campbell and D. G. Croot

Highlights

Brannam's Clay Pit is one of South-West England's most important Pleistocene sites, providing the best exposures of the enigmatic Fremington Clay, the age and origin of which have been the subject of scientific debate for over 130 years. The material has been interpreted variously as the product of land-based ice, as a glaciolacustrine deposit and as glaciomarine muds. Estimates of its age have varied widely between Oxygen Isotope Stage 16 (pre-Anglian) and the Late Devensian.

Introduction

The Fremington area has long been known for a contentious sequence of deposits which has a major bearing on Pleistocene reconstructions in South-West England. Part of the sequence (often referred to as the Fremington Clay or Till) has been interpreted as the product of a pre-Devensian (Saalian Stage) glaciation, but recent evidence suggests that the deposits may not have been laid down directly by glacier ice and that they are older. The site was noted in an early study by Maw (1864) and since by Ussher (1878), Prestwich (1892), Dewey (1910, 1913), Balchin (1952), Taylor (1956), Zeuner (1959), Mitchell (1960, 1972) and Everard *et al.* (1964). Detailed accounts were provided by Stephens (1966a, 1966b, 1970a, 1974), Wood (1970, 1974), Edmonds (1972), Kidson and Wood (1974), Kidson (1977) and Kidson and Heyworth (1977). Recent excavations were undertaken by Croot (1987), Croot *et al.* (in prep.) and Gilbert (in prep.). The site has also been mentioned widely elsewhere (e.g. Waters, 1966b; Stephens, 1961a, 1961b, 1973; Gregory, 1969; Cullingford, 1982; Hunt, 1984; Campbell and Bowen, 1989; Eyles and McCabe, 1989; Bowen, 1994b; Campbell *et al.*, in prep.).

Description

Maw (1864) demonstrated that the Fremington Clay or 'boulder clay' extended in an oval area some 5.6 km long by 0.8 km wide (Figure 7.2), from Lake to Mullinger. Several small outliers of the clay were also noted. (The distribution of the Fremington Clay and related sediments has since been revised by Croot *et al.* (1996), although much of Maw's original mapping still holds good.) The clay reached a maximum thickness of 27 m and was described by Maw as a tough, homogeneous, smooth brown clay with stones towards the top and with blackened wood fragments at the base. Near Bickington the clay overlay a gravel similar to that exposed on the coast at Fremington. A comparable succession was also described by Ussher (1878).

Brannam's Clay Pit (SS 530316), sometimes known as Higher Gorse Clay Pits, lies off Tew's Lane near Bickington and is located almost centrally in the known extent of the Fremington Clay. The stratigraphic succession exposed in Brannam's Clay Pit over the years has revealed both lateral and vertical variation. However, most authors have recognized a sequence of basal gravel, capped by stoneless clay overlain by stony clay and head over quite wide areas. Figure 7.3 depicts the sequences described by Stephens (1966a, 1966b, 1970a), Croot (1987) and Croot *et al.* (1996). Stephens' sequence can be summarized thus:

9. Soil
8. Solifluction deposits with frost-cracks
7. Sand
6. Weathered till
5. Fresh till
4. Stoneless clays
3. Sand
2. Fresh till
1. Pebbles (raised beach deposits)

Broadly comparable sequences were described by Edmonds (1972) and Kidson and Wood (1974), although the interpretation of the origin and ages of individual beds has varied considerably. Croot *et*

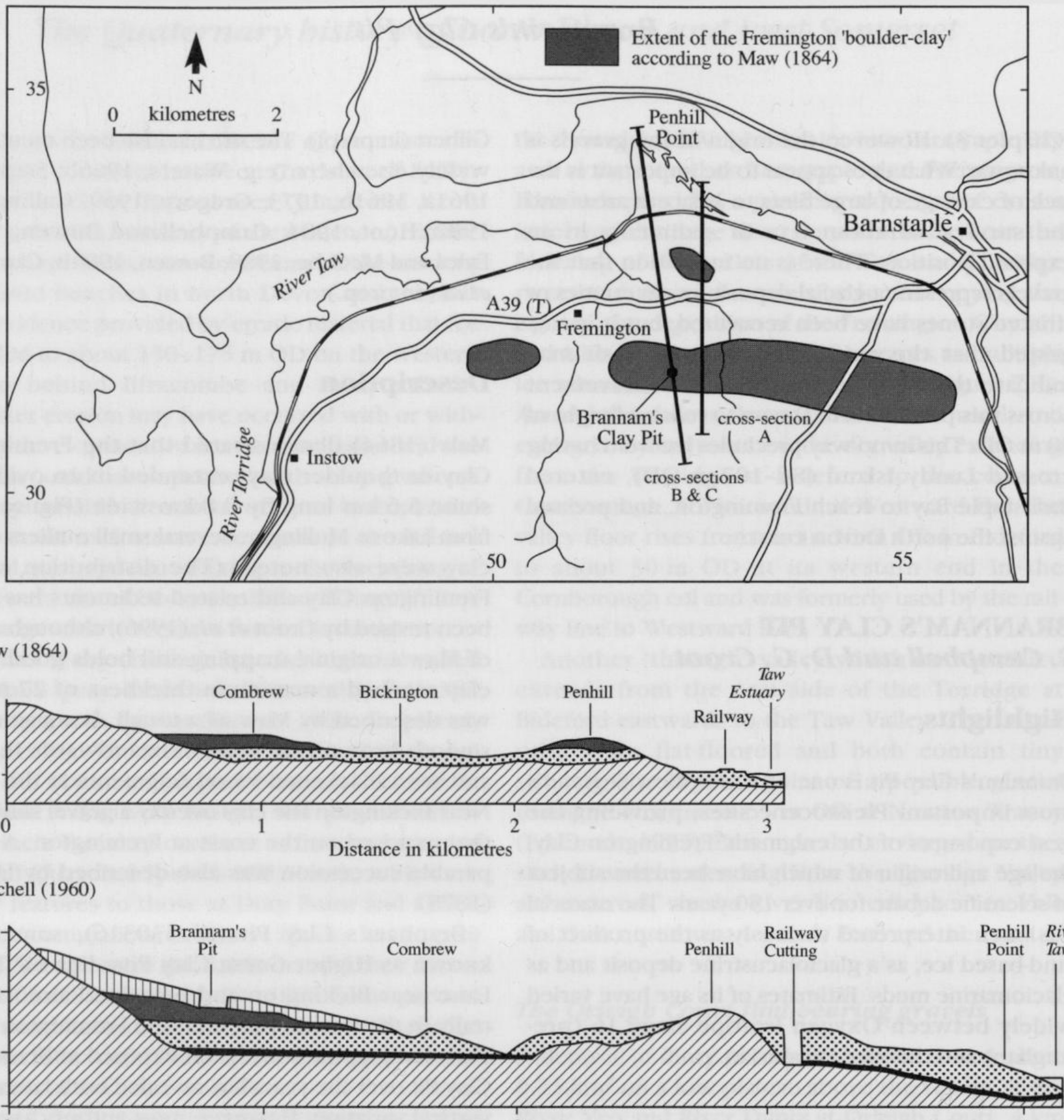

Figure 7.2 The extent of the Fremington 'boulder-clay' according to Maw (1864), and proposed stratigraphical relationships in the Fremington area. (After Maw, 1864, Mitchell, 1960 and Kidson and Wood, 1974.)

al. (1996) recorded the following sequence in Higher Gorse Clay Pits, within 50 m or so of the sections previously described by Stephens (1970a) and Croot (1987) (Figure 7.3c):

E. Gravelly sand and clay (head). A matrix-supported deposit with angular and subangular clasts of local bedrock set in a matrix of coarse yellow/brown clay. The deposit is uniformly 1.5 m thick across the exposed section and its contact with unit D is irregular and gradational (Figure 7.3b). (1.5 m*)

D. Clast-rich weathered clays. The material comprises more than 50% of clasts in a matrix of red clayey silt. Constituent clasts comprise mostly small gravels of lithologies identical to those in unit B. The matrix contains ill-defined and deformed silt-rich horizons. The unit is disrupted by irregular compressional and extensional stress patterns and clasts exhibit no consistent fabric. (1.0 m*)

C. Sand lenses within unit B. This unit comprises irregularly shaped lenses of sand and silt. The deposit consists mainly of medium-grained sand grading into coarse sand and medium silt. Grains are mainly of quartz but some of haematite and magnetite are present, together with clasts of sandstone, mudstone and, especially, lignite. The lenses exhibit no evidence of bedding or grading structures, and their contact with the surrounding clays of unit B is sharp and irregular. The sand bodies have no clearly defined channel form. (2.5 m*)

B. Dark brown clay. Contains occasional subrounded clasts and buff-coloured, irregularly spaced silt-rich beds. The proportion of clasts rises from 5% near the base of the unit to *c.* 40% where unit B grades into unit D. Contact between the silt bands and clay matrix is diffuse. Clasts within the unit lack any distinct fabric (orientation or dip) and do not appear to disturb the bedding of clays and silts. All but one of the clasts (sample size > 1500) are derived from bedrock lithologies found within 10 km of the site. The single exception is a cobble-sized, well-striated clast of microdolerite found *c.* 4 m below the surface of unit B. (9.0 m*)

A. Gravels. Comprises gravels in a sandy-silt matrix. The component clasts are dominantly subangular and comprise very locally derived sandstones, siltstones and shales of the Crackington Formation (Prentice, 1960); they exhibit a weak fabric with a north-west to south-east orientation but no discernible dip. (2.0 m*)

(*) denotes maximum bed thickness

Erratics associated with the Fremington Clay were described by Maw (1864), Dewey (1910), Taylor (1956, 1958), Vachell (1963) and M. Arber (1964). Maw (1864) recorded a large boulder of 'basaltic trap' which he believed had originated from the middle of the clay bed (probably unit B; see above). Dewey (1910) recorded boulders of hypersthene andesite and spilite which had apparently been derived from the 'till'; he suggested that the former had originated from the west coast of Scotland, the latter from north Cornwall. Taylor (1956, 1958) recorded boulders of quartz porphyry, quartz dolerite and olivine dolerite from the clay, and additional erratics were recorded by M. Arber (1964). Taylor noted that the erratic recorded by Maw was striated. However, Croot *et al.* (1996) argue that the microdolerite clast from unit B represents the first reported find of an ' ... unequivocally glacially-transported *in-situ* clast at the Brannam's clay pit site.' (Croot *et al.*, 1996; p. 20). This assertion, however, is strongly refuted by Stephens who cites his own observations and those of the old clay pit foreman, as evidence of *in situ* erratics in the clay (Stephens, pers. comm.).

Edmonds noted that the upper part of the sequence (beds 6–8; Stephens' description) contained numerous rock fragments and pebbles, mainly sandstone and quartzite, but also slate, vein quartz, chert, granite, dolerite and flint. Stephens (1966a, 1970a) recorded that the beds he interpreted as till (his beds 2, 5 and 6) and the stoneless clays (his bed 4) contained pieces of lignite, shell fragments (especially abundant according to Waters (1966b)), erratics and striated stones. Croot *et al.* (1996) record $CaCO_3$ values of between 10% and 20% for units B and D; sand from unit C, surprisingly, has a lower value (5.5%), but contains numerous small (+ 1ϕ to 0ϕ) shell fragments of undetermined species. Units B, C and D contain abundant pollen and spores but no material uniquely of Pleistocene age. Damaged palynomorphs of Mesozoic and Palaeozoic age are also present. Hunt (1984) identified and listed Carboniferous, Jurassic, Cretaceous and Palaeogene palynomorphs in samples from these units. The nannofossil assemblage is dominated by reworked Cretaceous forms (Croot *et al.*, 1996) although Wood (1970) records a varied fauna of foraminifera which he suggests rules out a freshwater origin.

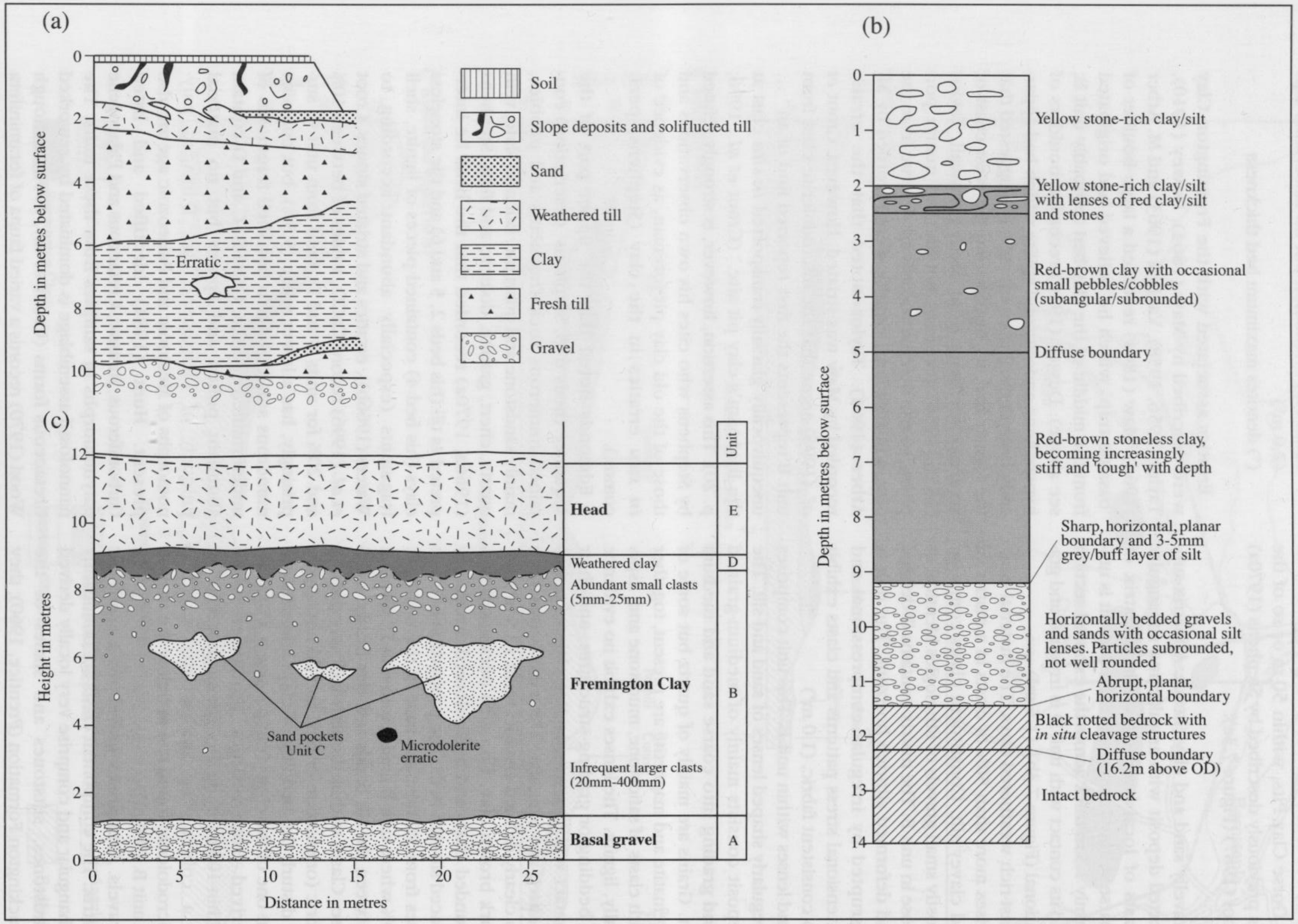

Figure 7.3 The Quaternary sequence at Brannam's Clay Pit, Fremington. (a) Composite section of the former eastern and southern working faces, adapted from Stephens (1966a, 1966b, 1970a). (b) The succession recorded by Croot in 1987. (c) The sequence recorded by Croot *et al.* (1996).

Kidson and Heyworth (1977) recorded laminae from stoneless clays in unit B. Croot *et al.* (1996), however, suggest that original sedimentary structures are only rarely visible even at a microscopic scale.

(Numerous descriptions of the sequence at Brannam's Clay Pit have referred to the 'Fremington Clay' or 'Till' without reference to specific beds within the sequence. This confusion was recognized by Wood (1970, 1974) and Croot *et al.* (1996) who adopted the term 'Fremington Clay Series' to describe the sequence of clays and stony clays at the site. The term 'Fremington Clay' is retained here to describe the clay and diamicton sequence (units B–D; Croot *et al.*, 1996) without implying specific origins.)

Interpretation

Maw (1864) correlated the gravel beneath the Fremington Clay in the Bickington area with shingle deposits exposed on the coast at Fremington. These had previously been interpreted by De la Beche (1839) as raised beach deposits (Figure 7.2). Maw noted the close correspondence in height of the gravel beds at some 10.6 m above HWM. He demonstrated the relationship of the clay and gravel deposits over a wide area (between Bickington and exposures on the south side of the Taw) – a practice followed by later workers including Mitchell (1960) and Stephens (1966a). However, he contrasted the uncemented and unstratified gravels at Bickington and Fremington with the layered and cemented raised beach sands and gravels at Hope's Nose (Torquay) and Croyde Bay which, in addition, contained abundant marine shell fragments. He entertained the possibility, therefore, that the gravels at Bickington were related more appropriately to the overlying clays which he considered, albeit tentatively, were glacial in origin. He argued that erratics at the base of the Croyde raised beach deposit and towards the top of the Fremington Clay were probably of the same age, and that the Fremington gravels were therefore older than the raised beach at Croyde, being '... separated by at least the interval in which most, if not all, of the Fremington clay-bed was deposited.' (Maw, 1864; p. 450). Ussher (1878) regarded the Fremington gravels and the local raised beaches as the same age (unspecified) and of estuarine origin.

Many subsequent authors (e.g. Prestwich, 1892; Dewey, 1910, 1913; Taylor, 1956, 1958; Vachell, 1963; M. Arber, 1964) established the petrology and sources of erratics associated with the Fremington Clay. Most of the boulders appear to have been derived from relatively local sources in Devon and Cornwall (Dewey, 1910, 1913; Taylor, 1956; M. Arber, 1964). Some, however, had more distant origins, including the hypersthene andesite recorded by Dewey (1910) which was believed to have originated from the west coast of Scotland. The precise stratigraphic context of many of the early finds, however, is doubtful, although Maw (1864), Dewey (1910) and M. Arber (1964) presented evidence to suggest that some of the larger erratics had been derived from within the Fremington Clay (unit B) itself. Although such evidence has been used to support a glacial origin for the bed (M. Arber, 1964), others have been more cautious. Taylor (1956) suggested that the erratics may have been transported by floating ice, and Dewey (1913) suggested that the clay had been deposited '... under such conditions as would permit large erratic boulders to be dropped in it.' (Dewey, 1913; p. 155).

The Fremington Clay was also briefly referred to by Balchin (1952) who regarded it as an alluvial infilling of reworked Keuper Marl.

The Fremington Clay was next referred to in regional stratigraphic correlations by Zeuner (1959) and Mitchell (1960). Zeuner regarded the clay as a 'bottom-moraine' of an ice sheet from the Irish Sea, which had penetrated inland on the southern shore of the Bristol Channel. Mitchell (1960) argued that the raised beaches of the area (at Fremington and Saunton) lay stratigraphically beneath the Fremington Clay, which he too regarded as a till, but of Gipping (Saalian) age (Figure 7.2). He correlated the 'Fremington Till' with the Ballycroneen Till of Ireland, and assigned the raised beaches of the area to the Hoxnian Stage, and not to the last (Ipswichian) interglacial as suggested by Zeuner (1959).

Mitchell's (1960) proposal for a Pleistocene chronology in north Devon was also upheld by Stephens (1961a, 1961b, 1966a, 1966b, 1970a, 1973). From evidence at Brannam's Clay Pit, Stephens argued that the pebbly gravels (his bed 1; unit A) could be correlated with raised beach deposits exposed at the coast; according to him, they contained well-rounded clasts and occurred at approximately the same height. These proposed Hoxnian-age marine sediments were overlain by a sequence of tills (his beds 2, 5 and 6) and lake clays (bed 4), the diagnostic characteristics of which (including pebble lithology and orientation,

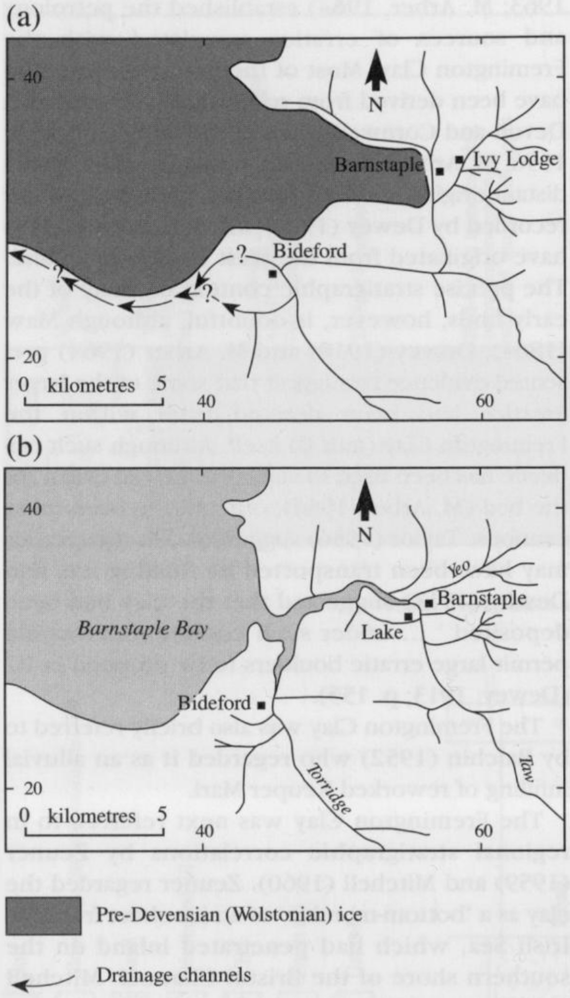

Figure 7.4 A reconstruction of the proposed Wolstonian (Saalian) glaciation of the Barnstaple Bay area, after Edmonds (1972), illustrating: (a) The development of ice-marginal drainage at the height of glaciation; (b) Present-day drainage.

texture, carbonate, shell and lignite content) indicated derivation from the Irish Sea Basin. Stephens correlated these beds with the Ballycroneen Till (Eastern General Till) of Eire of proposed Saalian age (cf. Mitchell, 1960). During the Ipswichian the surface of the till was chemically weathered (accounting for his bed 6), and during periglacial conditions in the Devensian the upper layers of the proposed till were soliflucted and mixed with locally derived head (bed 8). Frost-cracks were also formed during this periglacial phase (Stephens, 1966a, 1970a).

In marked contrast, Edmonds (1972) argued that the proposed raised beach deposits exposed around Fremington Quay were Ipswichian in age but were dissimilar to the gravels spasmodically exposed in the bottom of Brannam's Clay Pit (cf. Bowen, 1969); he thereby discounted Mitchell's and Stephens' stratigraphical correlations. He argued, however, that the overlying tills and lake clays were of Wolstonian (Saalian) age, suggesting that Wolstonian ice had moved south across the Irish Sea to the north Devon coastline, and in the process deposited erratics on Lundy (Mitchell, 1968). This ice was believed to have advanced across the Fremington area depositing till (bed 2 of Stephens), and then receded to an unknown position, but probably near Fremington (Figure 7.4). The ice front dammed surface waters, forming a lake basin to the east. The fine-grained sediments of the Fremington Clay (Stephens' bed 4; lower part of unit B) were believed to have been deposited in these relatively still lake waters (Edmonds, 1972). It was envisaged that the ice then readvanced perhaps as far as Barnstaple to deposit a further till (Stephens' beds 5 and 6) (Edmonds, 1972).

Wood (1970, 1974) and Kidson and Wood (1974) reinvestigated the Pleistocene deposits of the Barnstaple Bay area, and particularly those in the vicinity of Fremington, using boreholes and geophysical techniques. They demonstrated that the gravel (unit A) was distinctive in terms of clast lithology and roundness, and particle-size distribution, and that it was not therefore associated with the raised beach deposits exposed at the coast (e.g. at Fremington Quay). Instead, they suggested that the gravel at Brannam's Clay Pit was a glaciofluvial sediment – perhaps formed by the same ice lobe which deposited the overlying tills and clay (Kidson and Wood, 1974). They suggested that erratics in the proposed glacial beds at Brannam's Clay Pit could be correlated with the giant erratics at Croyde and Saunton – which rest on a shore platform and which are associated with raised beach and blown-sand deposits. They concluded that the raised beaches of the area were of Ipswichian age, and that the large erratics found along the Croyde–Saunton coast had been derived from glacial sediments of the same (Wolstonian/Saalian) age as the Fremington tills and clay. They did not discount the possibility, however, that large erratics farther south around the coast of South-West England (e.g. the Giant's Rock at Porthleven) had been ice-rafted into place during an earlier (Anglian) glacial phase (cf. Mitchell, 1960). During the Devensian, the upper layers of the proposed Saalian till were redistributed by solifluction and the upper beds were disrupted by frost-action (Kidson and Wood, 1974). A similar simple sequence of Middle to Late Pleistocene events was also followed in a series of papers by Kidson (1971, 1977) and Kidson and Heyworth (1977).

Bowen *et al.* (1985) and Bowen and Sykes (1988) applied amino-acid geochronological dating methods to the raised beach deposits at nearby Saunton and Croyde, establishing an Oxygen Isotope Stage 9 age for the oldest faunal elements within them. On the basis of local stratigraphic relationships, this placed the Fremington Clay, albeit very tentatively, in Stage 12 (Anglian). Later results on shell fragments recovered from the Fremington Clay itself indicated a range of ages from Early and Middle Pleistocene to Late Devensian (Bowen, 1994b). The latter provided some support for the suggestion by Eyles and McCabe (1989, 1991) and Campbell and Bowen (1989) that the Fremington Clay could have accumulated in a glaciomarine environment during the Late Devensian.

Excavations at Brannam's Clay Pit during 1986/1987 (Croot, 1987) and in 1994 (Croot *et al.*, 1996; Gilbert, in prep.) have provided significant new data regarding the character, age and depositional environments of the succession. Croot *et al.* interpret unit A (basal gravels) as a fluvial deposit, of uncertain age, that has undergone slight deformation since deposition. They cite the relative angularity and local lithology of clasts within the unit as evidence for its origin.

Interpretation of the overlying units B, C and D, however, is much more problematic. Croot *et al.* suggest that the lower levels of unit B (mainly clay) were deposited in a quiet-water environment. Clasts, which become more frequent towards the top of the unit, are regarded as dropstones; with a single exception, their origin is relatively local. Although micromorphological examinations of the clay show strong similarities with known glaciomarine deposits, the lack of a marine fauna and the local lithology of dropstones found within the clay are taken by Croot *et al.* to indicate deposition of units B and C in a glaciolacustrine setting. Although clasts in unit B are clearly dropstones, their means of transport to the quiet-water body remains unclear. With the single exception of the striated microdolerite cobble, the remaining locally derived clasts could have been introduced on or in floes of river ice: the single glacial cobble, however, must have been dropped from a mass of glacier ice. Whether this mass of ice was a single iceberg or a more continuous sheet of floating ice remains uncertain (Croot *et al.*, 1996).

Croot *et al.* also present data from micromorphological and engineering tests to demonstrate that units A, B and C were gently deformed and partially over-consolidated following deposition. This adds weight to the likelihood that units A, B and C were overridden by glacier ice, but does not accord with the interpretation (Croot *et al.*, 1996) of the overlying material (unit D) simply as a weathered variant of unit B. Although previous workers have interpreted unit D as a basal till (e.g. Stephens, 1966a, 1966b, 1970a; Edmonds, 1972), Croot *et al.* argue that the material demonstrates a weak fabric with clast lithologies identical to those in the underlying unit. Unit E, which caps the sequence, is interpreted as a typical head deposit formed by solifluction during periglacial conditions.

Dating of the sequence also remains highly controversial. Although recent work has shown that units B, C and D contain abundant pollen and spores, there is no material of uniquely Pleistocene age (Croot *et al.*, 1996). Indeed, some of the assemblage is directly comparable with that of the Bovey Basin clays and other Tertiary clays found in South-West England (Wilkinson and Boulter, 1980; Freshney *et al.*, 1982; Hunt, 1984; Croot *et al.*, 1996). The rest is derived from other sources to the north-west (Hunt, 1984). Equally, the nannofossil assemblage comprises a dominance of reworked Cretaceous forms and Croot *et al.* conclude that the fossil evidence alone would imply an early Tertiary age.

The application of Optically Stimulated Luminescence (OSL) dating techniques to sand samples from unit C, however, has provided potentially significant results (Croot *et al.*, 1996; Gilbert, in prep.). OSL measurements show that the sands are older than Oxygen Isotope Stage 2 (Late Devensian) and are more probably of Anglian (Stage 12) age. Large degrees of uncertainty associated with these dates, however, mean that deposition during any of the intervening evenly numbered (cold) Oxygen Isotope Stages 4, 6, 8 and 10 cannot be ruled out. On balance, however, these preliminary and unconfirmed results would point to the Fremington Clay (units B, C and D) being of Anglian (Stage 12) age.

Conclusion

Brannam's Clay Pit is undoubtedly one of the most important Pleistocene sites in Britain, and the

Figure 7.5 The Pleistocene sequence towards the western end of the Fremington Quay exposure. The vertical 'pipe' structures are infilled with lighter-coloured silt and clay, and penetrate beyond the base of the exposure: they may be frost or desiccation cracks (Wood, 1970). (Photo: S. Campbell.)

Fremington Clay has long been regarded as the '... most significant glacial deposit of the peninsula' (Kidson, 1977; p. 294). The oldest deposits at the site are gravels of probable fluvial origin. The overlying Fremington Clay, in fact a complex sequence of clay, silt, sand and stony clay, has traditionally been regarded as the product of a Wolstonian (Saalian) Irish Sea ice sheet. However, recent work suggests that the deposits are older, possibly of Anglian (Oxygen Isotope Stage 12) age, that they are overwhelmingly of local derivation, and that they may have accumulated, at least in part, in a glaciolacustrine environment. The evidence is still insufficiently precise to rule out a glaciomarine origin. The site may well prove to be one of the most southerly points of Britain to have been overrun by glacier ice.

FREMINGTON QUAY

S. Campbell and D. G. Croot

Highlights

Exposures at Fremington Quay show a complex and controversial sequence of stony clay, gravel, sand and silt which has long figured in reconstructions of regional Pleistocene history. Some authorities claim that the site shows raised beach deposits overlain by glacigenic sediments, others that the sequence comprises soliflucted and fluvially sorted materials. Recent evidence shows that the site may demonstrate glacially dislocated and thrusted 'rafts' of bedrock overlain by glaciofluvial materials.

Introduction

Exposures at Fremington Quay have figured prominently in interpretations of the Pleistocene history of the Barnstaple Bay area, particularly in establishing the crucial relationship between the raised beaches and possible glacial deposits. A sequence of gravels and stony clays has been interpreted as a Hoxnian raised beach deposit overlain by Wolstonian till (e.g. Stephens, 1966a). An alternative view, however, is that the raised beach deposits date from the Ipswichian and that the overlying stony clays are head deposits (including reworked till) emplaced during the Devensian. The site was referred to in early studies by Maw (1864), Ussher (1878) and Dewey (1913), and in regional

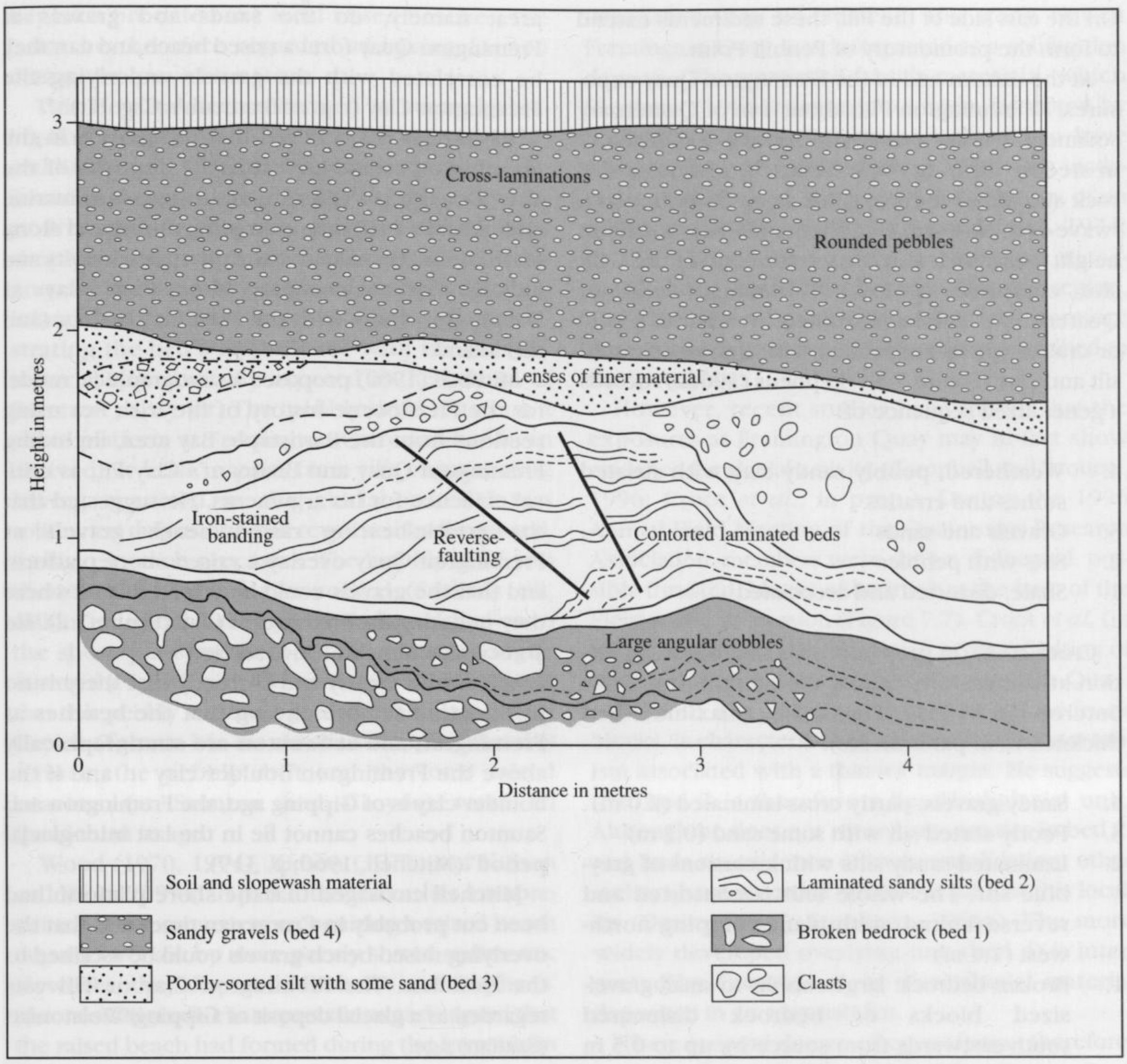

Figure 7.6 The Quaternary sequence at the eastern end of the Fremington Quay exposure. (After Croot *et al.*, in prep.)

Pleistocene syntheses by Zeuner (1959), Mitchell (1960, 1972) and Everard *et al.* (1964). More detailed interpretations of the site were provided by Stephens (1966a, 1974), Kidson (1971), Edmonds (1972) and Kidson and Wood (1974). The site was also referred to by Wood (1970, 1974), Stephens (1973) and Kidson and Heyworth (1977), and is the subject of current reinterpretation (Croot *et al.*, in prep.).

Description

The Fremington Quay exposures run for 0.5 km in a low coastal cliff on the south edge of the Taw Estuary, between SS 514332 and SS 509331. Despite having featured in numerous Pleistocene stratigraphic correlations, the exposures and sediments have not been described in great detail.

Edmonds (1972) stressed the sedimentary variability of the Quaternary deposits around Fremington Quay, and referred to them as the 'pebbly drifts of the estuary'. At SS 511331 he recorded that the pebbly clay, sand and silt enclosed a large clay lens (5 m × 1 m), and that at other locations stratification was evident. Seams and lenses of clay, silt and gravelly sand are a common feature of the beds (Edmonds, 1972). He recorded that the pebbly drift rises to 18 m OD, and that it underlies much of Fremington Camp.

On the east side of the Pill, these sediments extend to form the promontory of Penhill Point.

At the eastern end of the Fremington Quay exposures, at Fremington Pill, about 4 m of Quaternary sediment overlies a small cliff some 4–5 m high cut in steeply dipping shale bedrock. Although this rock surface is uneven, it has been described as a 'wave-cut' platform (Stephens, 1966a). It falls in height westwards and the western end of the GCR site comprises a low, 1–2 m-high, cliff of Quaternary sediment disrupted by vertical 'pipes' or cracks which are infilled with lighter-coloured silt and clay (Figure 7.5). Stephens (1966a) records a generalized sequence of:

4. Weathered, pebbly sandy clay with striated stones and erratics
3. Gravels and sands
2. Silts with pebbles
1. Shale, distorted and brecciated

Croot *et al.* (in prep.) records the following section at the eastern end of the Fremington Quay outcrop (SS 513332; Figure 7.6) (maximum bed thicknesses in parentheses):

4. Sandy gravels, partly cross-laminated (2.0 m)
3. Poorly sorted silt with some sand (0.2 m)
2. Laminated sandy silts with inclusions of grey-blue silt. The whole unit is contorted and reverse-faulted, with planes dipping north-west (1.4 m)
1. Broken bedrock: large cobble- to small gravel-sized blocks of bedrock dislocated south-eastwards from source by up to 0.5 m (1.5 m)

Interpretation

Raised beach deposits were first described in the Fremington area by De la Beche (1839), and a gravel bed was recorded at Fremington Quay by Maw (1864). Maw traced this shingle bed inland, via open-sections in the railway cutting west of Fremington Pill, through Bickington and Lake to Combrew, where he believed it underlay a considerable depth of clay – the Fremington Clay (Figure 7.2). Although he regarded the shingle as a raised beach deposit, he noted the possibility that the bed could also be related to the overlying clays which he regarded as glacial in origin. Maw's paper raises a critical issue which has been central to most subsequent studies of Pleistocene sediments in the area; namely, do the sands and gravels at Fremington Quay form a raised beach and can they be correlated with the gravels underlying the Fremington Clay (e.g. at Brannam's Clay Pit)?

Ussher (1878) believed that the gravels in the Fremington area were estuarine deposits of the Taw. Dewey (1913) regarded the gravels as marine and described them as overlain by head and stony clay. The latter contained deeply striated clasts and led Dewey to correlate the stony clay at Fremington Quay with the Fremington Clay (and till) inland.

Mitchell (1960) proposed a stratigraphical model for the Pleistocene history of the Irish Sea using sections from the Barnstaple Bay area, including Fremington Quay and Brannam's Clay Pit, as critical evidence for his arguments. He suggested that the erratic-bearing raised beach gravels at Fremington Quay overlay a raised shore platform and that the gravels could be traced inland where they underlay the Fremington Clay (Figure 7.2). He argued that Maw's (1864) section

'... shows clearly and correctly that there is no justification for pretending that the beaches at Fremington and at Saunton are stratigraphically above the Fremington boulder clay ... and if the boulder clay is of Gipping age, the Fremington and Saunton beaches cannot lie in the last inter-glacial period' (Mitchell, 1960; p. 319).

Mitchell envisaged that the shore platform had been cut probably in Cromerian times and that the overlying raised beach gravels could be ascribed to the Hoxnian. The Fremington Clay or Till was regarded as a glacial deposit of Gipping/Wolstonian (Saalian) age.

Stephens (1961a, 1966a, 1966b) examined the sections at Fremington Quay and at Brannam's Clay Pit in more detail, and independently came to the same conclusions as Mitchell (1960). However, his analysis showed that, unlike the Fremington Clay at Brannam's Clay Pit, the stony clay at Fremington Quay contained no shells and was non-calcareous; a glacial origin was nonetheless favoured. He proposed that the beds were subsequently weathered during the Ipswichian and then deeply cryoturbated in the Devensian when, he believed, glacier ice did not reach north Devon (Stephens, 1966a, 1966b).

Subsequent workers, however, have tended to follow Zeuner's (1959) interpretation of regional Pleistocene stratigraphy. Zeuner argued that there was no evidence for a raised beach anywhere in the region having been overridden by ice. He concluded that the glacial deposits of the Barnstaple

Bay area pre-dated the local raised beaches; the latter he therefore regarded as having formed during the Ipswichian Stage.

This view has been reiterated by others including Bowen (1969), Kidson (1971), Edmonds (1972) and Kidson and Wood (1974). Edmonds did not differentiate between raised beach and other deposits at Fremington Quay and referred to the beds simply as the 'pebbly drifts'. He argued that this gravelly drift could be traced a short distance inland, but certainly not to the point of demonstrating the bed's equivalence with the gravelly material spasmodically exposed in the bottom of Brannam's Clay Pit. The 'pebbly drift' rested on a shore platform at Fremington Quay and had been derived, at least in part, from till, some sorting having occurred as the glacial material was soliflucted downslope and reworked by fluvial and, finally, estuarine processes. The 'pebbly drift' was therefore regarded as reworked (Saalian) till, soliflucted and fluvially sorted, and emplaced on to the shore platform in an estuarine environment during the Ipswichian (Edmonds, 1972). He argued that this pebbly sediment graded inland into a river terrace (Terrace 1 in his classification), and that this terrace, the pebbly drift and the local raised beaches (at Saunton and Croyde) were all Ipswichian in age.

Wood (1970, 1974), Kidson (1971) and Kidson and Wood (1974) in part followed earlier interpretations of the sequence, recognizing a raised beach deposit overlain by more poorly sorted sediments. However, they disputed Mitchell's and Stephens' chronostratigraphic interpretations and argued that the raised beach had formed during the Ipswichian and that the overlying sediments were head deposits, soliflucted into their present position during cold conditions in the Devensian. They emphasized the importance of the stratigraphic relationship of the coastal Pleistocene sediments with those inland, particularly at Brannam's Clay Pit; a detailed analysis of gravel samples from both sites was undertaken (Wood, 1970). At Brannam's Clay Pit the gravels were composed predominantly of Culm grits and sandstones. No erratics were recovered, and the deposit was both more poorly sorted and contained more angular clasts than the gravel exposed at the coast (Wood, 1970; Kidson and Wood, 1974). This, they suggested, discounted Mitchell's and Stephens' assertion that the raised beach was traceable inland where it could be seen to underlie the Fremington Clay. They also discounted Stephens' correlation of the stony clay at Fremington Quay with the Fremington Clay at Brannam's Clay Pit. Instead, the stony clay at Fremington Quay was interpreted as a solifluction deposit. The upturned beach materials, which Stephens (1966a) argued had been disrupted by Wolstonian glacier ice, were believed to have resulted from periglacial activity. 'They are inadequate testimony to the powerful machinery of an advancing ice-front' (Kidson and Wood, 1974; p. 233). No glacial deposits *in situ* were recognized above raised beach material in the region, and the raised beach deposits were therefore demonstrably younger and accordingly ascribed to the Ipswichian.

However, recent studies have shown that the exposures at Fremington Quay may in fact show evidence for glacial activity (Campbell and Scourse, 1996; Croot *et al.*, in prep.). During the 1996 Annual Field Meeting of the Quaternary Research Association, members were shown dislocated, possibly thrusted, blocks of bedrock at the base of the Pleistocene succession (Figure 7.7). Croot *et al.* (in prep.) argue that the distinctive reverse-faulting of bed 2 at the eastern end of Fremington Quay, related to the localized transport of bedrock blocks, is characteristic of small-scale glaciotectonism associated with a thin-ice margin. He suggests that bed 2 is therefore a basal/subglacial unit. Although he does not record any erratics in bed 2, and finds no evidence of overconsolidation, other authors have recorded striated erratics at this locality (Dewey, 1913; Stephens, 1966a). The more widely developed overlying unit (bed 4) is interpreted by Croot *et al.* as glaciofluvial material deposited in an outwash fan.

There is some degree of equivalence, therefore, between Croot *et al.*'s record of Fremington Quay (east) and Stephens' record for Penhill. However, there is clear evidence that the gravels exposed at Penhill and Fremington Quay are quite different from the basal gravels at Brannam's Clay Pit. There is, therefore, no basis for establishing a common lithostratigraphy for these sites. However, the proposed glacial event responsible for the glaciotectonic structures at Fremington Quay may also have caused the overconsolidation of the Brannam's Clay Pit sequence. This event remains imprecisely dated (see Brannam's Clay Pit).

Conclusion

Fremington Quay is an important site for interpreting Pleistocene stratigraphy in South-West England. The origin of the sediments here has caused

Figure 7.7 Members of the Quaternary Research Association discuss possible evidence for glaciotectonism at the base of the Pleistocene succession towards the eastern end of the Fremington Quay exposures. (Photo: S. Campbell.)

considerable debate and has led to widely disparate opinions as to the sequence and timing of Pleistocene events in the region. Fremington Quay is an essential reference site for resolving two principal and crucial stratigraphic questions: firstly, whether the clay overlying the postulated raised beach deposits is an *in situ* till as claimed by Stephens (1966a); and whether the shingly gravel extends inland to underlie the Fremington Clay. Some workers have maintained that the sequence at Fremington Quay shows a Hoxnian raised beach deposit overlain by a Saalian-age till. Others have argued that the raised beach deposit is Ipswichian in age and that the overlying stony clay is a Devensian solifluction deposit. A recent proposal is that the site shows evidence of glacially thrusted (tectonized) bedrock, formed at a thin-ice margin, overlain by glaciofluvial sediments. However, there is still no firm agreement as to the age or origin of these controversial sediments. The interpretation of Pleistocene stratigraphy, and therefore of events and conditions in the Barnstaple Bay area, relies very heavily on exposed sequences at Brannam's Clay Pit and Fremington Quay. Together with exposures at Croyde and Saunton and at Westward Ho!, these stratigraphic reference sites are central to any reinterpretation of Pleistocene events in the region.

THE CROYDE–SAUNTON COAST

S. Campbell and A. Gilbert

Highlights

One of South-West England's most famous Pleistocene localities, the Croyde–Saunton Coast exhibits one of the finest compound shore platforms in Britain, a series of spectacular, possibly ice-rafted, erratics and a thick sequence of raised beach, blown sand and head deposits. Although the sections have been studied for over 150 years, the deposits still present major problems of interpretation. Optically Stimulated Luminescence (OSL) dates indicate an Early Devensian age (Stage 4) for the aeolian 'sandrock'.

Introduction

The extensive exposures of Pleistocene sediments between Saunton (SS 445378) and Baggy Point (SS

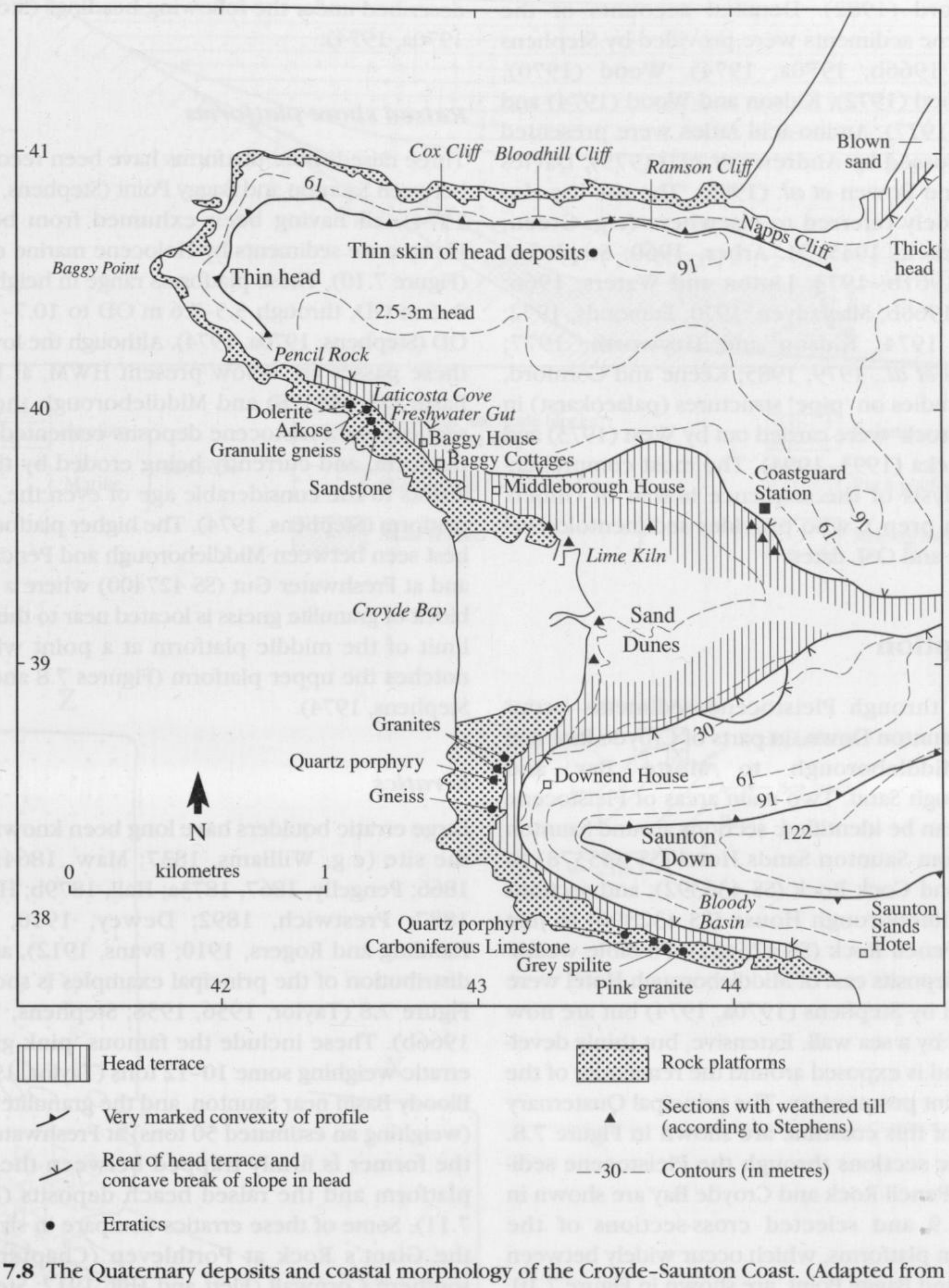

Figure 7.8 The Quaternary deposits and coastal morphology of the Croyde–Saunton Coast. (Adapted from Stephens, 1970a.)

419406), here referred to as the Croyde–Saunton Coast, are some of the best-studied in Britain, and they demonstrate significant evidence for interpreting Pleistocene events in South-West England. The raised beach deposits and erratics at the site first stimulated scientific interest in the early nineteenth century, and discussions have continued until the present day (e.g. Williams, 1837; De la Beche, 1839; Sedgwick and Murchison, 1840; Maw, 1864; Bate, 1866; Pengelly, 1867, 1873a; Ussher, 1878; Hughes, 1887; Dewey, 1910, 1913; Evans, 1912; Baden-Powell, 1927, 1955). Detailed descriptions of the erratics were later given by Taylor (1956, 1958), Madgett and Inglis (1987) and Sims (1996). Flint artefacts found in the Croyde Bay and Baggy Point areas were described by Whitley (1866). The site has been set in a wider context by Zeuner (1945, 1959), Mitchell (1960, 1972) and

Cullingford (1982). Detailed accounts of the Pleistocene sediments were provided by Stephens (1966a, 1966b, 1970a, 1974), Wood (1970), Greenwood (1972), Kidson and Wood (1974) and Kidson (1977). Amino-acid ratios were presented and discussed by Andrews *et al.* (1979), Davies (1983) and Bowen *et al.* (1985). The site has also been widely referred to elsewhere (e.g. Green, 1943; Arkell, 1945; M. Arber, 1960; Stephens, 1961a, 1961b, 1973; Linton and Waters, 1966; Waters, 1966b; Macfadyen, 1970; Edmonds, 1972; Kidson, 1974; Kidson and Heyworth, 1977; Edmonds *et al.*, 1979, 1985; Keene and Cornford, 1995). Studies on 'pipe' structures (palaeokarst) in the 'sandrock' were carried out by West (1973) and Morawiecka (1993, 1994). The most comprehensive analysis of the sequence is that of Gilbert (1996, in prep.), who provides sedimentological evidence and OSL dates.

Description

Sections through Pleistocene sediments occur around Saunton Down, in parts of Croyde Bay, and from Middleborough to Morte Bay and Putsborough Sand. Two main areas of Pleistocene interest can be identified: sections around Saunton Down from Saunton Sands Hotel (SS 445378) to just beyond Cock Rock (SS 436392); and sections from Middleborough House (SS 432396) to just beyond Pencil Rock (SS 423402). Possible weathered till deposits east of Middleborough Hotel were described by Stephens (1970a, 1974) but are now obscured by a sea wall. Extensive, but thinly developed, head is exposed around the remainder of the Baggy Point promontory. The principal Quaternary features of this coastline are shown in Figure 7.8. Schematic sections through the Pleistocene sediments at Pencil Rock and Croyde Bay are shown in Figure 7.9 and selected cross-sections of the marine-cut platforms, which occur widely between Saunton and Baggy Point, are shown in Figure 7.10. The generalized sequence for this part of the north Devon coast can be summarized thus:

5. Head
4. Cemented sand
3. Raised beach conglomerate
2. Erratic boulders
1. Shore platform(s)

However, considerable lateral and vertical variations occur, and the site's features are best described under the following headings (Stephens, 1970a, 1974):

Raised shore platforms

Three raised shore platforms have been recognized between Saunton and Baggy Point (Stephens, 1970a, 1974), all having been exhumed from beneath Pleistocene sediments by Holocene marine erosion (Figure 7.10). These platforms range in height from 0–6 m OD, through 5.5–7.6 m OD to 10.7–15.0 m OD (Stephens, 1970a, 1974). Although the lowest of these passes are below present HWM, at Bloody Basin (SS 438378) and Middleborough the thick sequence of Pleistocene deposits cemented to the platform, and currently being eroded by the sea, attests to the considerable age of even the lowest platform (Stephens, 1974). The higher platforms are best seen between Middleborough and Pencil Rock and at Freshwater Gut (SS 427400) where a 50 ton block of granulite gneiss is located near to the upper limit of the middle platform at a point where it notches the upper platform (Figures 7.8 and 7.10; Stephens, 1974).

Erratics

Large erratic boulders have long been known from the site (e.g. Williams, 1837; Maw, 1864; Bate, 1866; Pengelly, 1867, 1873a; Hall, 1879b; Hughes, 1887; Prestwich, 1892; Dewey, 1910, 1913; Hamling and Rogers, 1910; Evans, 1912), and the distribution of the principal examples is shown in Figure 7.8 (Taylor, 1956, 1958; Stephens, 1966a, 1966b). These include the famous 'pink granite' erratic weighing some 10–12 tons (Taylor, 1956) at Bloody Basin near Saunton, and the granulite gneiss (weighing an estimated 50 tons) at Freshwater Gut; the former is firmly trapped between the shore platform and the raised beach deposits (Figure 7.11). Some of these erratics compare in size with the Giant's Rock at Porthleven (Chapter 6) in southern Cornwall (Flett and Hill, 1912; Stephens and Synge, 1966; Stephens, 1970a, 1974) and with others elsewhere around the Devon and Cornwall coast (Prestwich, 1892; Worth, 1898; Ussher, 1904; Reid and Scrivenor, 1906; Reid, 1907).

Raised beach deposits

At this site, the raised beach sequence has frequently been described as consisting of two elements; a lower raised beach conglomerate and an overlying cemented shelly sand. The latter has

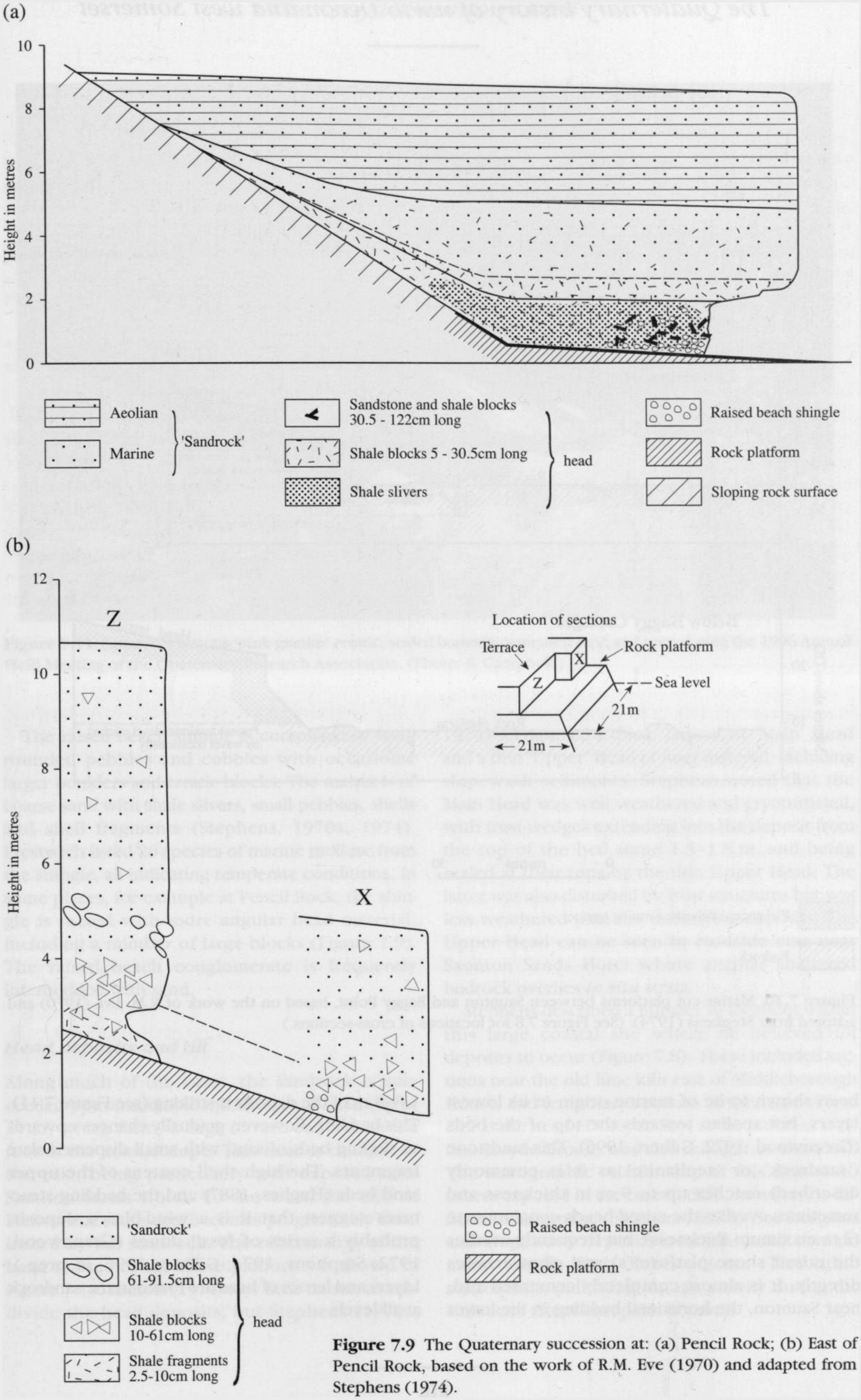

Figure 7.9 The Quaternary succession at: (a) Pencil Rock; (b) East of Pencil Rock, based on the work of R.M. Eve (1970) and adapted from Stephens (1974).

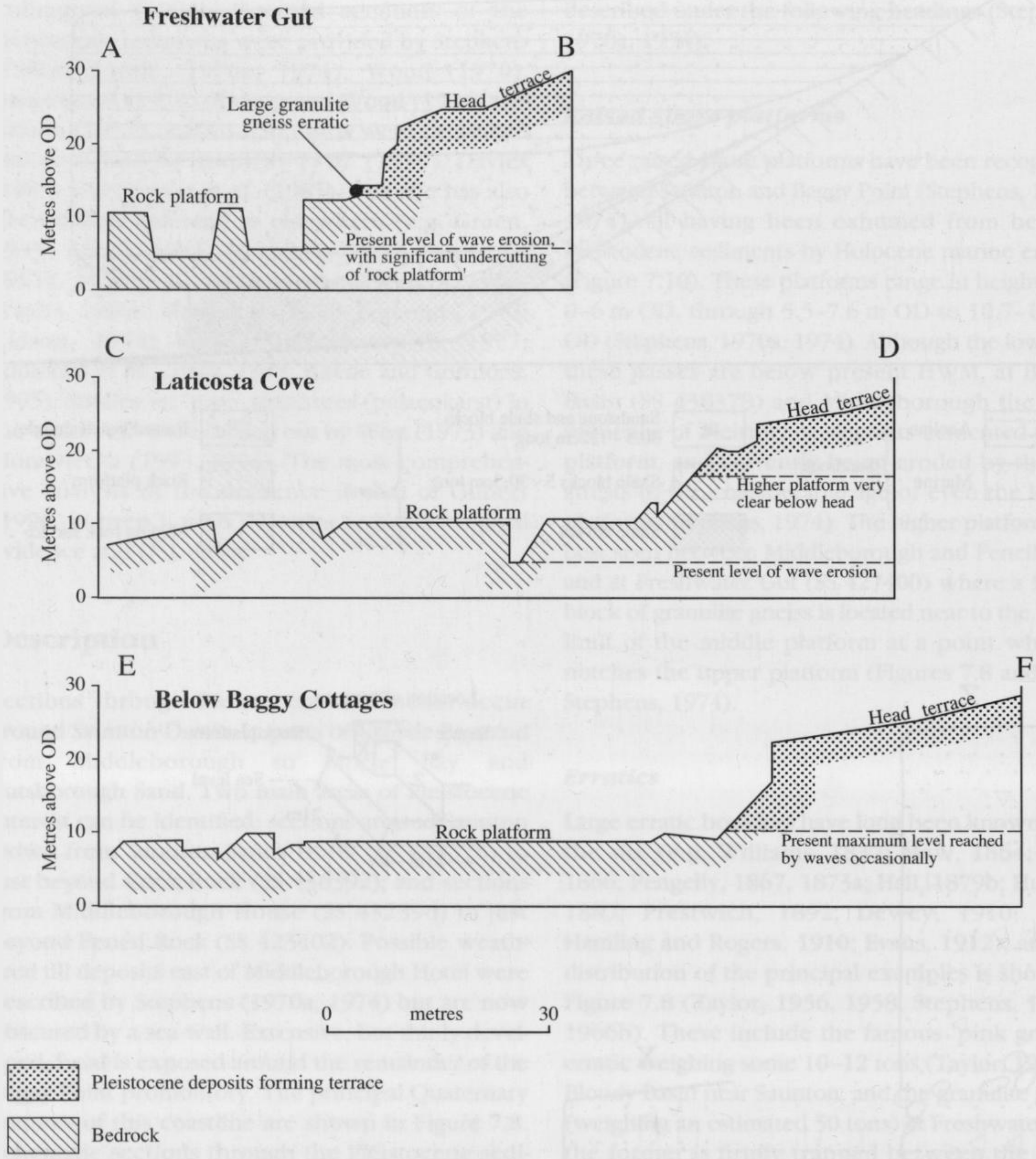

Figure 7.10 Marine-cut platforms between Saunton and Baggy Point, based on the work of R.M. Eve (1970) and adapted from Stephens (1974). (See Figure 7.8 for locations of cross-sections.)

been shown to be of marine origin in its lowest layers, but aeolian towards the top of the beds (Greenwood, 1972; Gilbert, 1996). This sandstone ('sandrock' or 'aeolianite' as it is commonly described) reaches up to 9 m in thickness and sometimes overlies the raised beach conglomerate (2 m maximum thickness), but frequently overlies the raised shore platform(s) and giant erratics directly. It is almost completely cemented and, near Saunton, the horizontal bedding in the lower 1.8–3 m of the deposit is striking (see Figure 7.11). This bedding, however, gradually changes upwards to sloping beds of sand with small dispersed slate fragments. The high shell content of the upper sand beds (Hughes, 1887) and the bedding structures suggest that it is a wind-blown deposit, probably a series of fossil dunes (Greenwood, 1972; Stephens, 1974; Gilbert, 1996, in prep.). Layers and lenses of head are found in the sandrock at all levels.

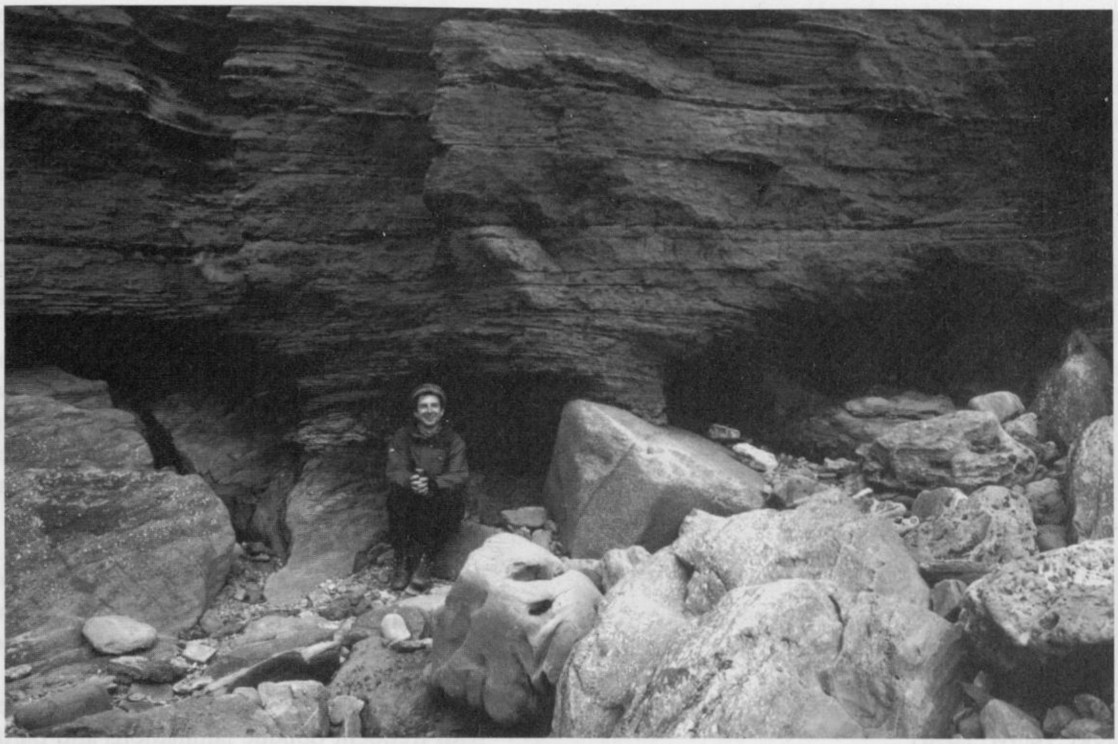

Figure 7.11 Saunton's famous 'pink granite' erratic, sealed beneath cemented sand and seen during the 1996 Annual Field Meeting of the Quaternary Research Association. (Photo: S. Campbell.)

The raised beach shingle is composed of well-rounded pebbles and cobbles with occasional larger boulders and erratic blocks. The matrix is of coarse sand with shale slivers, small pebbles, shells and shell fragments (Stephens, 1970a, 1974). Prestwich listed 26 species of marine mollusc from the shingle, all indicating temperate conditions. In some places, for example at Pencil Rock, the shingle is mixed with more angular head material, including a number of large blocks (Figure 7.9). The raised beach conglomerate is frequently interbedded with sand.

Head deposits and till

Along much of the coast, the sandrock is succeeded by considerable thicknesses of head (up to 21 m) which forms a large terrace or apron at the foot of the coastal slope. This head is thickest in the east, being particularly well exposed near Saunton Sands Hotel. To the west, the cliff of Pleistocene sediments becomes progressively dominated by the sandrock. The relationship of the head terrace to the shore platforms is shown in Figure 7.10. Kidson (1974) saw little reason to subdivide the head deposits, but Stephens (1970a, 1974) recognized a thick 'Lower' or 'Main' Head and a thin 'Upper' Head of finer material, including slopewash sediments. Stephens noted that the Main Head was well weathered and cryoturbated, with frost-wedges extending into the deposit from the top of the bed some 1.5–1.8 m, and being sealed at their tops by the thin Upper Head. The latter was also disturbed by frost structures but was less weathered than the underlying deposits. The Upper Head can be seen in roadside cuts near Saunton Sands Hotel where angular shattered bedrock overlies *in situ* strata.

Stephens described a number of localities within this large coastal site where he believed till deposits to occur (Figure 7.8). These included sections near the old lime kiln east of Middleborough House, and temporary sections farther east. A low cliff at the head of Croyde Bay, at the junction with the Croyde Brook, was also thought to show till. The stratigraphic relationship of this deposit to others exposed in the coastal cliffs, however, is difficult to determine (Stephens, 1974). Soil horizons and slopewash deposits over the head contain many small flint flakes (some Mesolithic microliths?), indicating human activity during the Holocene (Stephens, pers. comm.).

Interpretation

Interest in the Croyde–Saunton Coast was stimulated, in particular, by the large erratics which lie on the shore platforms and which are sometimes overlain by raised beach, sand and head deposits (Figure 7.11). Williams (1837) was the first to mention the large granite erratic at Saunton and, by the turn of the century, this, and other erratics strewn along the coast, had attracted considerable comment and debate (e.g. Bate, 1866; Pengelly, 1867, 1873a; Hall, 1879b; Hughes, 1887; Prestwich, 1892). Some of these early studies discussed possible sources for the boulders and mechanisms for their transport and emplacement. Dewey's detailed petrological work established that some of the large erratics were foreign to the region, a number having probable sources in north-west Scotland. This, and additional work (Hamling and Rogers, 1910; Evans, 1912), established something of a consensus that the erratics had probably been emplaced on ice floes, a mechanism also to find favour with later workers (e.g. Stephens, 1966a, 1966b, 1970a, 1974).

However, whether these large erratics were moved into their present position by a regional ice sheet (Mitchell, 1960; Kidson, 1971, 1977) or by floating icebergs in the Early Pleistocene (Stephens, 1966a, 1974) has not been satisfactorily resolved. Stephens (1974) nonetheless suggested that the widespread occurrence of such large erratics throughout the Bristol Channel coastlands and even as far south as the northern French coast, supported the latter hypothesis (Mitchell, 1965; Stephens, 1966b), particularly since very large erratics like the pink granite at Saunton and the Giant's Rock at Porthleven are confined to very narrow zones along the coast, below 9 m OD and within the reach of present-day storm waves. Had they been emplaced by a regional ice sheet, their expected distribution might be much less selective (Stephens, 1974). Madgett and Madgett (1974) refuted this argument, citing the occurrence of a large erratic of epidiorite (apparently of Scottish origin) on Baggy Point at some 80 m OD. It is possible, however, that this boulder was dragged up from Croyde Bay to act as a boundary marker. Comprehensive reviews of erratics in the Barnstaple Bay area are given by Taylor (1956), Madgett and Inglis (1987) and Sims (1996).

Early studies by Williams (1837), De la Beche (1839), Sedgwick and Murchison (1840) and Bate (1866), among others, established that the shingle and sand beds in section around the Croyde–Saunton Coast were similar to those found around the present shore. They interpreted the beds as ancient beach deposits and explained their present position by changes in the relative level of the land and sea. Hughes (1887), however, disputed this and maintained that although the beds comprised marine sediments overlain by blown sand and capped by talus, the marine material lay well within the reach of present-day waves; and thus that the deposits in section did not necessarily reflect a former higher sea level.

Prestwich (1892) summarized much of the earlier work and provided a comprehensive stratigraphic analysis of the sections, comparing them with others in southern England and Wales. He argued that three main types of deposit overlay the shore platform:

3. The 'usual local angular rubble', composed of large and small fragments of slaty Devonian rocks in a brown earth without apparent bedding (3–15 m) – 'head'.
2. Blown sands (1.5–9 m), horizontally bedded with frequent oblique laminations and partly or wholly concreted. The sands include large numbers of land snails with occasional weathered valves of *Mytilus* and '*Cardium*'. He interpreted these beds as old dunes and correlated them with the Fremington Clay – a deposit he regarded not as till, but as a lake clay.
1. Raised beach deposits consisting 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' and frequently cemented. He noted 26 species of marine mollusc from these beds, all of a 'temperate' character and indicating 'interglacial' conditions.

This simple stratigraphy has formed the basis for subsequent interpretations of the sequence; the origin of the beds as raised beach conglomerate and associated marine sand, blown sand, head and hillwash, is not generally disputed. Two very different schools of thought, however, have pertained regarding a chronology of events at the site, based principally on assumptions of the age of the raised beach deposits.

Workers including Mitchell (1960, 1972) and Stephens (1966a, 1966b, 1970a, 1974) have argued that the raised beach sediments accumulated in the Hoxnian, and that the overlying beds can be subdivided to represent the main remaining stages of

Figure 7.12 Extensively developed rock platforms at the western end of Saunton Down, looking north across Croyde Bay. (Photo: S. Campbell.)

Pleistocene time. Alternatively, Zeuner (1945, 1959), Edmonds (1972), Kidson (1974, 1977), Kidson and Wood (1974), Kidson and Heyworth (1977) and Edmonds *et al.* (1979), among others, have ascribed the raised beach deposits to the Ipswichian Stage, and invoked a different sequence of events.

Mitchell (1960) attempted to correlate the drifts of South-West England with those in Ireland. He suggested that the rock platform at Croyde and Saunton (Figure 7.12) had been cut in the Early Pleistocene, probably in the Cromerian, and he believed that the large erratics had been placed directly on to the platform by an ice sheet of Anglian age. He later revised this view on the extent of the Anglian ice sheet (Mitchell, 1972) and acknowledged that the erratics could have arrived on ice floes, becoming incorporated and buried by raised beach sediments during high sea levels in the Hoxnian.

Stephens (1966a, 1966b, 1970a, 1974) re-examined the sections around Barnstaple Bay including those along the Croyde–Saunton Coast. Like Mitchell, he concluded that the raised beach conglomerate and associated marine sands had been deposited during temperate, high sea-level conditions in the Hoxnian. He argued that where the raised beach sediments were mixed with more angular material, a reworking of an ancient head deposit had taken place, this head perhaps having formed in the same cold period in which the giant erratics were emplaced by ice floes (?Anglian). Alternatively, and more simply, he suggested that the head may have accumulated contemporaneously as cliff fall material during the period of raised beach formation. As sea level fell towards the end of the Hoxnian, substantial areas of sea floor were exposed and sand was blown inland and banked up against the old cliffline. Thin layers of head found interbedded with the sandrock at all levels probably attest to intermittent falls of cliff material. However, as environmental conditions deteriorated into the Saalian, periglacial conditions pertained and head formation became the dominant process, and a massive terrace of head was formed seawards of the old cliffline (Stephens, 1974).

The dating of this thick (Lower or Main) head as 'Wolstonian' (Saalian) by Stephens rests very largely on analogies with head sequences (and thicknesses) in Ireland. There, he argued, no great thickness of solifluction deposits was associated with deposits of the last glaciation (Devensian).

This was in contrast to the thick head associated, stratigraphically, with the pre-Devensian (suggested Saalian Stage) Ballycronneen Till. To reinforce this dating, Stephens argued that the head at Croyde and Saunton showed evidence for a considerable length of weathering (in the ensuing Ipswichian). He noted that the head was also disturbed by cryoturbation, fossil ice-wedge casts and festoon structures, and he interpreted this as indicating that head material had ceased downslope movement by the time renewed periglacial activity had churned and disturbed the upper layers of the deposit. This phase of freeze-thaw activity could have taken place in either of the Saalian or Weichselian (Devensian) cold stages (Stephens, 1974). During the Devensian, less severe periglacial conditions returned and a further, but thinner (Upper), head accumulated together with hillwash sediments.

The sections showing possible till deposits in Croyde Bay and near Middleborough (Stephens, 1974) are difficult to interpret, and are not easily related to the coastal stratigraphy elsewhere within the site. Stephens (1974) nonetheless was convinced of the presence of till in Croyde Bay, since the deposit contained erratics and striated clasts. It is not clear, however, if this weathered deposit rests *in situ*. It may, for example, be mixed with head and, near the base of the bed, even with beach shingle (Stephens, 1974). In the absence of absolute dates and detailed sedimentological data, little more can be gleaned from these limited exposures which lie away from the main and extensive coastal sections.

The second main school of thought regarding a chronology of events at this site stemmed from Zeuner's claim that there was no evidence in the region for glacier ice having overridden any of the raised beaches; the latter could thus be assigned to the last (Ipswichian) high sea-level event. Following this premise, Kidson (1971, 1974), Kidson and Wood (1974) and Kidson and Heyworth (1977), among others, proposed the following scheme of Pleistocene events. A shore platform, being the oldest of the Pleistocene features, was likely to be composite in age, formed during high sea levels probably in the Hoxnian and earlier 'interglacial' events. The large erratics lying on the surface of this composite platform were believed to have been emplaced in the same (Wolstonian/Saalian) glacial event which deposited the nearby Fremington Clay (also containing some large erratics from comparable sources). The raised beach conglomerate and sands (including the sandrock) which directly overlie some of the erratics were believed to be of Ipswichian (not Hoxnian) age. It followed that the succeeding head deposits which, according to Kidson (1974), showed little sign of differentiation, were periglacial deposits formed during the following Devensian Stage. Such a chronological interpretation was also followed by Edmonds (1972) and Edmonds *et al.* (1979), although these workers favoured that the large erratics had been emplaced during the Anglian rather than the Saalian.

More recently, fossil marine molluscs from the site have been subjected to analysis by both radiocarbon and amino-acid dating techniques. An infinite radiocarbon age determination on *Balanus balanoides* (Linné), taken from the surface of a shore platform, and a clearly unrealistic date of 33 200 + 2800/− 1800 BP (I-2981) (Kidson, 1974) from shells in the raised beach conglomerate, failed to determine the age of the raised beach sequence.

On the other hand, amino-acid ratios obtained from shells in the raised beach conglomerate and overlying sand (Andrews *et al.*, 1979; Davies, 1983; Bowen *et al.*, 1985) have provided significant results. Andrews *et al.* (1979) showed that most of the shells subjected to the technique gave ratios that were higher than the two principal groups of ratios obtained from shells at other raised beach sites in South-West England and Wales. The latter were believed to have lived and then been deposited during Oxygen Isotope Stage 5e (Ipswichian); such ratios were calibrated by Uranium-series dating to a high sea-level event at *c.* 125 ka BP (Keen *et al.*, 1981). The significantly higher amino-acid ratios from Saunton were interpreted as indicating a greater age (or significantly different temperature history) for the raised beach there (Andrews *et al.*, 1979). However, a single shell yielding a typical Stage 5e ratio introduced the possibility that the raised beach could be the product of two distinct (but similar in height) sea-level (interglacial) events. Davies (1983) provided additional amino-acid ratios from Saunton which were also significantly higher than most of those derived from sites elsewhere. This led to the correlation of the Saunton raised beach with the Inner Beach at Minchin Hole Cave, Gower: both were tentatively ascribed to Oxygen Isotope Stage 7 (*c.* 210 ka BP) (Davies, 1983).

Bowen *et al.* (1985) published amino-acid ratios on shells taken from the raised beach sequence both at Pencil Rock (near Baggy Point) and at Saunton. Shell samples were taken from both the raised beach conglomerate and overlying sands at

Figure 7.13 Thick cemented sand (marine and aeolian) and overlying head deposits near Saunton Sands Hotel. (Photo: S. Campbell.)

these sites. This work confirmed the earlier ascription of the beds (Davies, 1983) to Stage 7. However, younger shells were also present in the samples. It was suggested that these had been banked up against the older Stage 7 beach deposits during a high sea-level event in Stage 5e (Ipswichian) (Bowen *et al.*, 1985). In addition, some ratios from the overlying sandrock were grouped with those from the 'unnamed' D/L stage at Minchin Hole Cave, but these were also ascribed to some part of Stage 7 (Bowen *et al.*, 1985), although other possible correlations were discussed.

These data have significant repercussions for interpreting the succession at Croyde and Saunton. An Oxygen Isotope Stage 7 age for the raised beach and associated sands allows the possibility that the overlying head deposits date from a variety of Pleistocene cold phases as Stephens (1974) originally suggested.

Gilbert (1996, in prep.) argues that previous interpretations of the raised beach-sandrock sequence (Figure 7.13) have been over-simplified. Instead, he proposes that five facies, widespread along the coast here, can be recognized in the deposits. These show the progression from: an initial marine transgression (facies 1 – the well-cemented raised beach conglomerate described by numerous previous workers); to a foreshore environment dominated by nearshore intertidal activity (facies 2); to a deeper-water environment on the flank of a wave-/tide-dominated river-fed embayment (facies 3); to a backshore environment with palaeosol development (facies 4); finally to a backshore dune environment (facies 5). He presents OSL dates which place the lowest marine deposits in Stage 5e (Ipswichian) and the aeolian sediments in Stage 4 (Early Devensian; *c.* 70 ka BP). These data conflict with previously published amino-acid ratios (Andrews *et al.*, 1979; Davies, 1983; Bowen *et al.*, 1985) which would point to a Stage 7 age for Gilbert's facies 1 and 2 (Campbell and Scourse, 1996).

Conclusion

The exposures at Croyde and Saunton provide a key stratigraphic record and exhibit a number of features crucial to the reconstruction of Pleistocene history in South-West England. First, the shore platform between Croyde and Saunton is one of the finest examples anywhere in Britain; the extensive development at this site graphically demonstrates its compound nature and age, with at least three main platform surfaces (of unknown age) having been recognized.

Second, the site is also particularly important for the profusion of large erratics which are found overlying the shore platforms and below raised beach, blown sand and head deposits. Although sporadic examples (such as the Giant's Rock in Cornwall) occur elsewhere, those between Croyde and Saunton have proved especially important in reconstructions of earlier Pleistocene conditions in the region. Their lithological diversity, confined coastal location and limited altitudinal range, and their stratigraphic context have stimulated debate concerning their origins and mode(s) of emplacement. Whether these large erratics were introduced to this coast by a regional ice sheet or on ice floes (ice-rafted) has not been satisfactorily established; these examples will undoubtedly play an important role in the resolution of this debate.

Third, the raised beach sequence at the site shows a transition from fully marine conditions (raised beach conglomerate and marine sand) to terrestrial conditions (blown sand and fossil dunes). Amino-acid ratios reveal a complex age for the raised beach sequence (probably reflecting high sea-level conditions in both warm Oxygen Isotope Stages 7 and 5e). The overlying beds of blown sand are some of the best and most extensive examples in Britain, preserving a rare and detailed record of terrestrial conditions. Recent OSL dates have shown that most of the blown sand accumulated during the Early Devensian (Stage 4; *c.* 70 ka BP).

Finally, the stratigraphic importance of the Croyde–Saunton Coast cannot be seen in isolation. Although providing a crucial record of Pleistocene conditions including evidence for glacial, interglacial and periglacial climatic cycles, the true value of the sections lies in their relationship to others in the Barnstaple Bay area, particularly critical exposures at Brannam's Clay Pit, Fremington Quay and Westward Ho! These form a core of stratigraphic sites indispensable to any reconstruction of Pleistocene history in the region.

WESTWARD HO!

S. Campbell

Highlights

Westward Ho! is a classic site for studies of the Quaternary in South-West England. It provides both an important Pleistocene stratigraphic record and detailed evidence, in the form of submerged forest and associated beds, for the Holocene evolution of the Barnstaple Bay area.

Introduction

The submerged forest beds at Westward Ho! have featured in numerous studies (e.g. De la Beche, 1839; Ellis, 1866, 1867; Pengelly, 1867, 1868a; Hall, 1870, 1879a; Rogers, 1908; Worth, 1934; Rogers, 1946; Churchill, 1965; Churchill and Wymer, 1965; Stephens, 1970a, 1973, 1974; Jacobi, 1975, 1979; Kidson and Heyworth, 1977). The definitive account of the Holocene sequence, however, is that of Balaam *et al.* (1987) which integrates detailed archaeological and palaeoenvironmental evidence. The Pleistocene features, including a spectacular cobble raised beach, have been referred to by Ussher (1878), Dewey (1913), Rogers (1946), Everard *et al.* (1964), Stephens (1966a, 1970a, 1973), Kidson (1974), Kidson and Heyworth (1977) and Campbell *et al.* (in prep.).

Description

The Pleistocene sequence

Raised beach deposits were first described in the area by De la Beche (1839) and Sedgwick and Murchison (1840), who noted that they extended along much of the Appledore coastline and Taw Estuary. They are particularly well developed between SS 420291 and SS 422291. The Pleistocene sediments (mainly raised beach and head deposits) overlie a cliffed and elevated rock shore platform (at 8–9 m OD) cut in near-vertically bedded Carboniferous sediments, and with a surface lying approximately 6 m above the present tidal platform (*c.* 2–3 m OD) (Stephens, 1970a; Kidson and Heyworth, 1977). The old wave-cut notch at the back of the elevated platform lies at an estimated 12.2–13.7 m OD.

The most detailed description of the sequence was given by Stephens (1966a, 1970a) who recorded:

9. Soil
8. Sandy clay with stones, including flint and granite erratics
7. Angular head in sandy matrix
6. Head

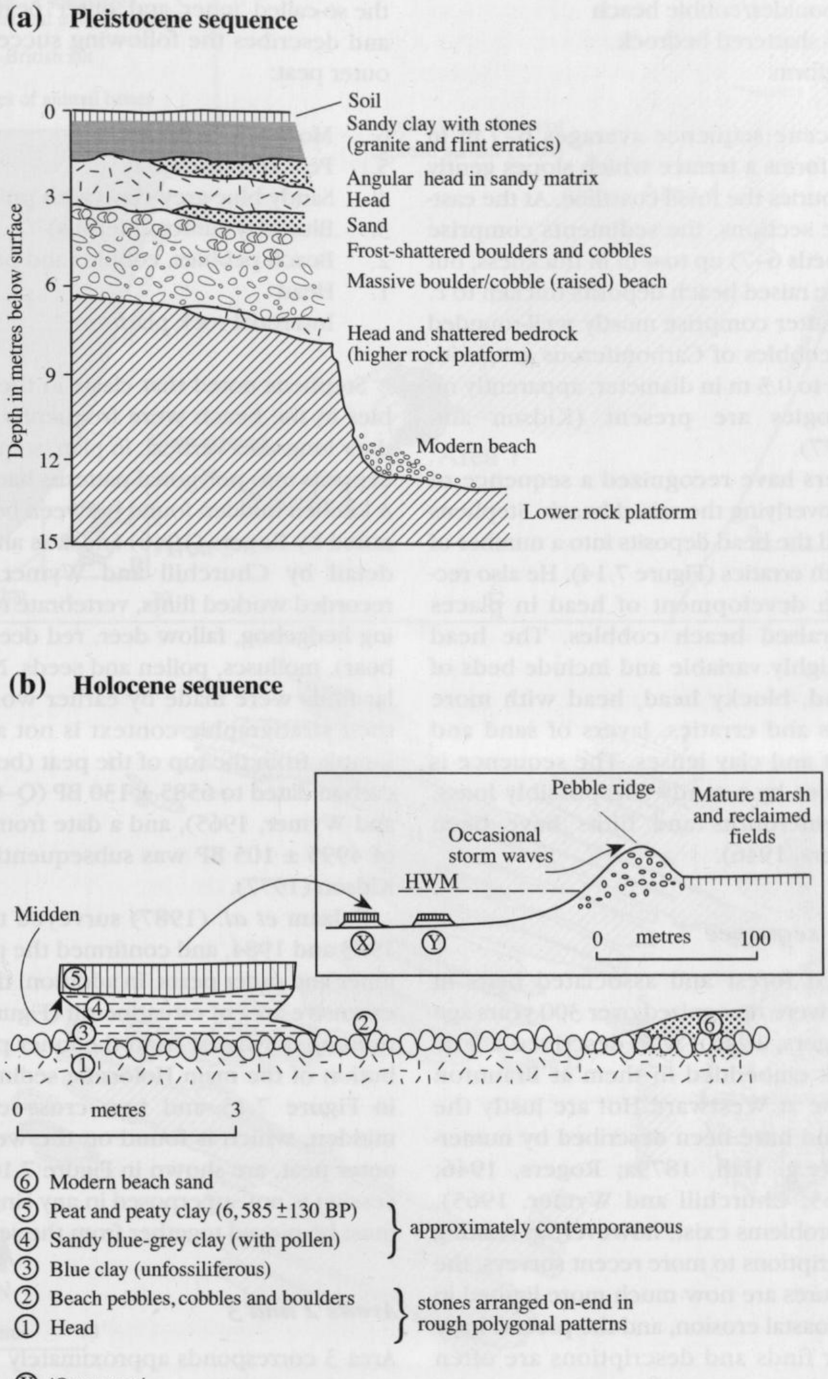

Figure 7.14 Quaternary landforms and deposits at Westward Ho! (Adapted from Stephens 1970a.)

5. Sand
4. Frost-shattered boulders and cobbles
3. Massive boulder/cobble beach
2. Head and shattered bedrock
1. Rock platform

The Pleistocene sequence averages 6–7 m in thickness and forms a terrace which slopes gently seawards and buries the fossil coastline. At the eastern end of the sections, the sediments comprise mostly head (beds 6–7) up to 4 m in thickness, but to the west, the raised beach deposits thicken to *c.* 2.5–3 m. The latter comprise mostly well-rounded boulders and cobbles of Carboniferous grit, with some clasts up to 0.3 m in diameter; apparently no erratic lithologies are present (Kidson and Heyworth, 1977).

Most workers have recognized a sequence of head deposits overlying the raised beach. Stephens (1970a) divided the head deposits into a number of beds, some with erratics (Figure 7.14). He also recognized a thin development of head in places beneath the raised beach cobbles. The head deposits are highly variable and include beds of fine shale head, blocky head, head with more rounded clasts and erratics, layers of sand and gravel, and silt and clay lenses. The sequence is capped in places by a sandy silt, possibly loess, from which microliths and flints have been recorded (Rogers, 1946).

The Holocene sequence

The submerged forest and associated beds in Barnstaple Bay were recognized over 300 years ago by Ridson (Rogers, 1946), who described a 9 m-long oak trunk embedded in them at Braunton Burrows. Those at Westward Ho! are justly the most famous and have been described by numerous workers (e.g. Hall, 1879a; Rogers, 1946; Churchill, 1965; Churchill and Wymer, 1965). Considerable problems exist, however, in relating the earlier descriptions to more recent surveys; the seaward exposures are now much more limited in extent due to coastal erosion, and the precise locations of earlier finds and descriptions are often extremely unclear. Two descriptions of the Holocene sequence are given here: Stephens' (1966a, 1970a) representation of the sequence is useful in showing the relationship of the main Holocene deposits both to the Pleistocene succession and to more recent landforms (Figure 7.14); the description given by Balaam *et al.* (1987) is by far the most comprehensive and up-to-date. Stephens follows Rogers' (1946) account by illustrating two main exposures of Holocene sediment, the so-called 'inner' and 'outer' peats (Figure 7.14), and describes the following succession from the outer peat:

6. Modern beach sand
5. Peat and peaty clay
4. Sandy blue-grey clay (with pollen)
3. Blue clay (unfossiliferous)
2. Beach pebbles, cobbles and boulders
1. Head

Intertidal rock platform

Stephens noted that clasts in the head and cobbles in the beach were frequently arranged with their long-axes vertical; in plan, some sorting of the deposits into polygonal patterns had also occurred. A kitchen midden found between beds 4 and 5 was noted by Rogers (1946) and was analysed in some detail by Churchill and Wymer (1965), who recorded worked flints, vertebrate remains (including hedgehog, fallow deer, red deer, pig and wild boar), molluscs, pollen and seeds. Numerous similar finds were made by earlier workers although their stratigraphic context is not always clear. A sample from the top of the peat (bed 5) was radiocarbon dated to 6585 ± 130 BP (Q–672) (Churchill and Wymer, 1965), and a date from the same bed of 4995 ± 105 BP was subsequently recorded by Kidson (1977).

Balaam *et al.* (1987) surveyed the site during 1983 and 1984, and confirmed the presence of the inner and outer peats. In addition, they mapped an extensive area of estuarine silt (Figure 7.15; Area 4) running north-east from the inner peat. The distribution of the main Holocene sediments is shown in Figure 7.15 and two cross-sections of the midden, which is found on the west edge of the outer peat, are shown in Figure 7.16. The full succession is not superposed in any single section and must be pieced together from the separate outliers.

Areas 2 and 3

Area 3 corresponds approximately with the outer peat described by earlier workers, but in fact comprises a fourfold sequence (maximum bed thicknesses in parentheses):

4. Upper clay (0.7 m)
3. Outer peat (0.8 m)
2. Mesolithic midden (*c.* 0.2 m)
1. Lower blue clay (1.1 m)

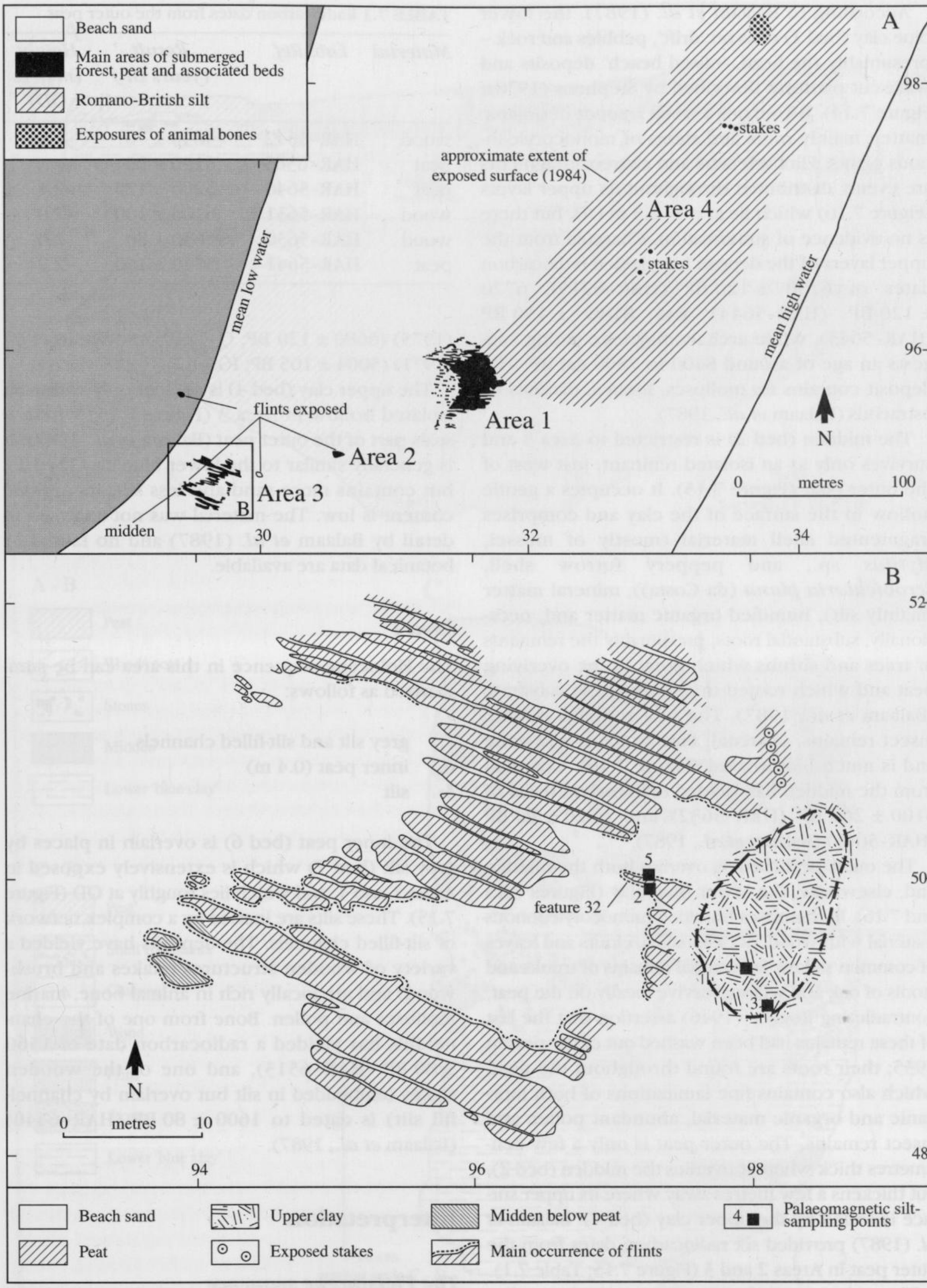

Figure 7.15 The distribution of Holocene deposits at Westward Ho! (Adapted from Balaam *et al.*, 1987.)

According to Balaam *et al.* (1987), the lower blue clay (bed 1) rests on 'drift', pebbles and rock – presumably the head, 'raised beach' deposits and wave-cut platform described by Stephens (1970a; Figure 7.14). It contains a small amount of organic matter, mainly roots and stems of monocotyledonous plants. Flint artefacts and charcoal fragments are evenly distributed throughout its upper layers (Figure 7.16) which lie at *c.* − 2.5 m OD, but there is no evidence of stratification. Charcoal from the upper layers of the deposit has yielded radiocarbon dates of 6250 ± 120 BP (HAR-6215), 6770 ± 120 BP (HAR-5644) and 8180 ± 150 BP (HAR-5643), while archaeomagnetic dating suggests an age of around 8400 to 7800 cal BP. The deposit contains no molluscs, forams, diatoms or ostracods (Balaam *et al.*, 1987).

The midden (bed 2) is restricted to Area 3 and survives only as an isolated remnant, just west of the outer peat (Figure 7.15). It occupies a gentle hollow in the surface of the clay and comprises fragmented shell material (mostly of mussel, *Mytilus* sp., and peppery furrow shell, *Scrobicularia plana* (da Costa)), mineral matter (mainly silt), humified organic matter and, occasionally, substantial roots, presumably the remnants of trees and shrubs which grew in the overlying peat and which rooted in a more stable substrate (Balaam *et al.*, 1987). The bed contains pollen, insect remains, charcoal, flint artefacts and bone and is much bioturbated (Figure 7.16). Charcoal from the midden has yielded radiocarbon dates of 6100 ± 200 BP (HAR-5632) and 6320 ± 90 BP (HAR-5645) (Balaam *et al.*, 1987).

The outer peat (bed 3) overlies both the midden and, elsewhere, the lower blue clay (Figures 7.15 and 7.16). It comprises humified monocotyledonous material with wood, occasional hazelnuts and leaves of common sallow. Substantial remains of trunks and stools of oak and willow survive locally on the peat, contradicting Rogers' (1946) assertion that the last of these remains had been washed out of the peat in 1935; their roots are found throughout the peat, which also contains fine laminations of both inorganic and organic material, abundant pollen and insect remains. The outer peat is only a few centimetres thick where it overlies the midden (bed 2), but thickens a few metres away where its upper surface is sealed by the upper clay (bed 4). Balaam *et al.* (1987) provided six radiocarbon dates from the outer peat in Areas 2 and 3 (Figure 7.15; Table 7.1).

TABLE 7.1 Radiocarbon dates from the outer peat

Material	*Lab. Ref.*	*Result (years BP)*	*Height (metres OD)*
wood	HAR-5642	4840 ± 70	-1.0
peat	HAR-6363	5190 ± 80	—
peat	HAR-5640	5200 ± 120	-2.1
wood	HAR-5631	6100 ± 100	-2.0
wood	HAR-5630	5630 ± 80	-2.0
peat	HAR-5641	5740 ± 100	-2.2

These dates complement those provided earlier from materials in the same bed by Churchill and Wymer (1965) (6585 ± 130 BP; Q-672), Jacobi (1975) (6680 ± 120 BP; Q-1249) and Welin *et al.* (1971) (5004 ± 105 BP; IGS-42).

The upper clay (bed 4) is present only within an isolated hollow in Area 3 (Figure 7.15) where it seals part of the outer peat (Balaam *et al.*, 1987). It is generally similar to the lower blue clay (bed 1), but contains more sand and less silt; its organic content is low. The material was not analysed in detail by Balaam *et al.* (1987) and no faunal or botanical data are available.

Area 1

The Holocene sequence in this area can be summarized as follows:

7. grey silt and silt-filled channels
6. inner peat (0.4 m)
5. silt

The inner peat (bed 6) is overlain in places by grey silt (bed 7) which is extensively exposed in Areas 1 and 4, and which lies roughly at OD (Figure 7.15). These silts are incised by a complex network of silt-filled channels. The deposits have yielded a variety of wooden structures (stakes and brushwood) and are locally rich in animal bone, marine molluscs and pollen. Bone from one of the channel-fills has yielded a radiocarbon date of 1560 ± 80 BP (HAR-6513), and one of the wooden stakes (embedded in silt but overlain by channel-fill silt) is dated to 1600 ± 80 BP (HAR-6440) (Balaam *et al.*, 1987).

Interpretation

The Pleistocene sequence

The Pleistocene sequence at Westward Ho! was described by numerous early workers (e.g. De la

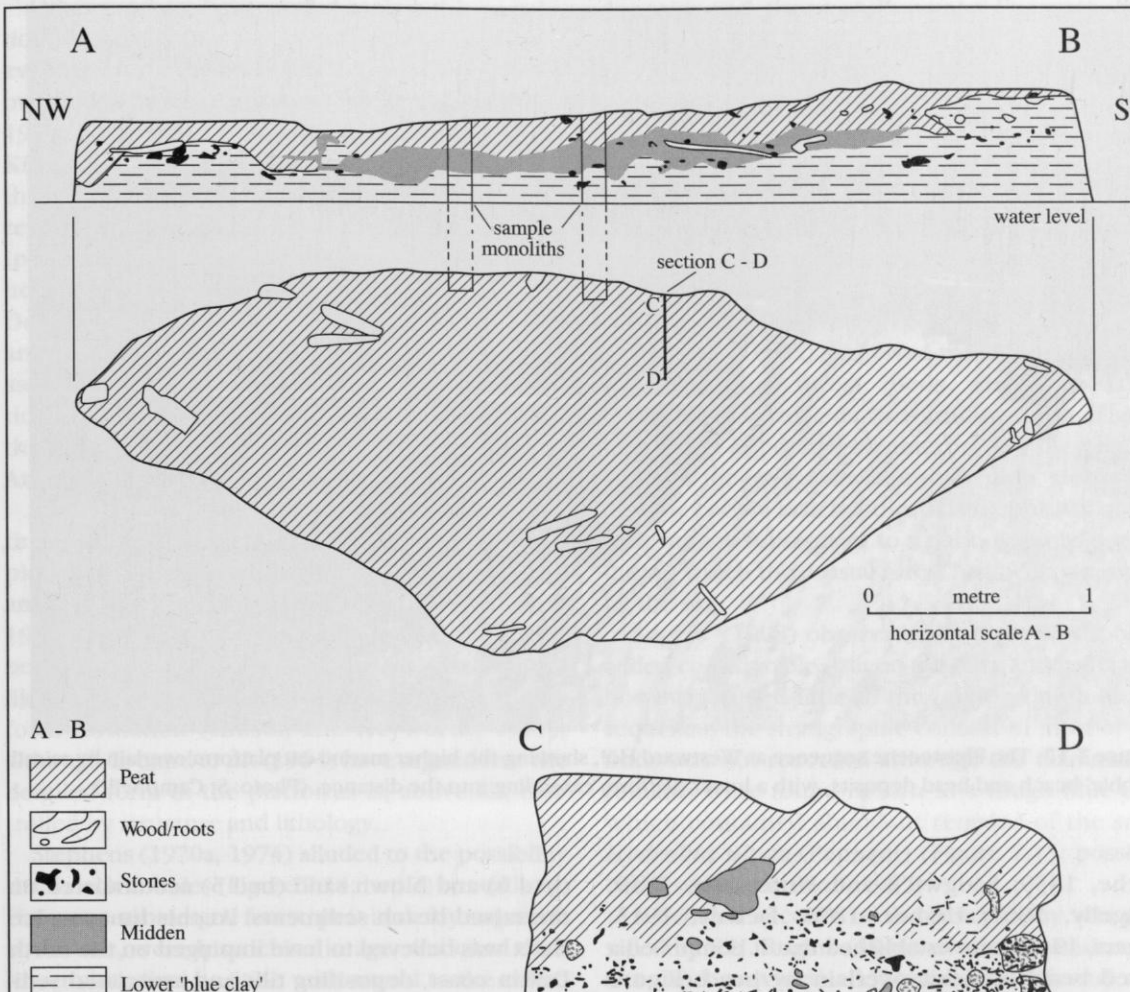

Figure 7.16 Plan and section of the midden 'island' at Westward Ho! (Adapted from Balaam *et al.*, 1987.)

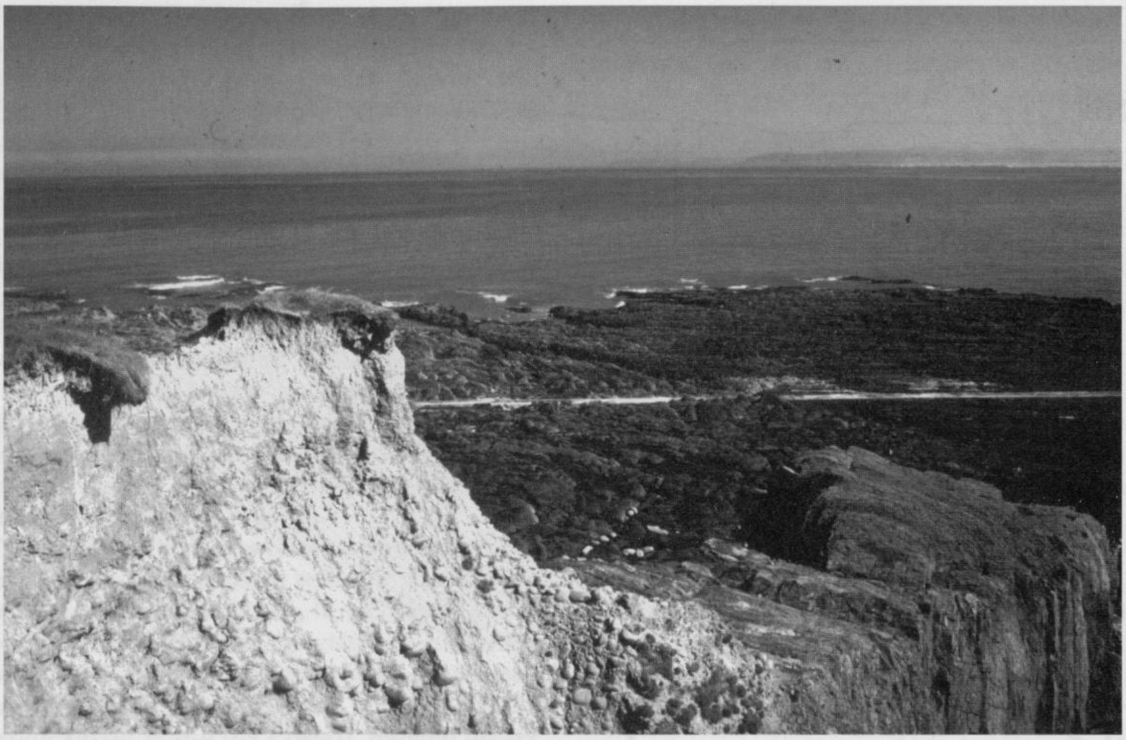

Figure 7.17 The Pleistocene sequence at Westward Ho!, showing the higher marine-cut platform overlain by raised 'cobble' beach and head deposits, with a lower platform extending into the distance. (Photo: S. Campbell.)

Beche, 1839; Sedgwick and Murchison, 1840; Pengelly, 1867; Ussher, 1878; Dewey, 1913; Rogers, 1946) who established that it comprised a raised beach deposit overlain by head (Figure 7.17). Mitchell's (1960) study of Pleistocene sequences throughout the Irish Sea Basin and in South-West England provided a considerable stimulus for further work. A detailed interpretation of the sequence at Westward Ho! was provided by Stephens (1966a, 1970a, 1974) who upheld Mitchell's arguments and suggested the following sequence of Pleistocene events.

The elevated platform was believed to have been planed during the Cromerian (cf. Mitchell, 1960), and its surface to have been shattered during an ensuing cold phase (?Anglian) when large erratics were believed to have been ice-rafted into position around the coast of South-West England. During this stage, cold-climate head (bed 2) accumulated on the platform. The arrangement of the raised beach sediments (beds 3 and 4), deposited during the Hoxnian, suggested a period of sea level higher than at present. This was followed by climatic conditions sufficiently severe to disturb and crack the upper layers of the beach cobbles (bed 4). During this proposed Wolstonian (Saalian) event, head (bed 6) and blown sand (bed 5) accumulated on the raised beach sediments. At this time, an ice sheet was believed to have impinged on the north Devon coast, depositing tills and associated sediments in the Fremington area. The lower head (bed 6) was weathered during warmer conditions in the Ipswichian. During cold conditions in the Devensian, when glacier ice did not reach the north Devon coast, an upper head (beds 7 and 8) containing erratics reworked from glacial deposits equivalent to the Fremington Clay, was deposited under periglacial conditions. Such an interpretation was founded on the belief that the raised beach deposits found widely around the coastlands of the Irish Sea Basin and South-West England were Hoxnian in age. This chronostratigraphic interpretation was reinforced by the perceived relationship of deposits at Fremington Quay and at Brannam's Clay Pit. The proposed raised beach (Hoxnian) at Fremington Quay was correlated on the basis of altitude and sedimentary characteristics with a gravel sporadically exposed beneath till and lacustrine sediments at Brannam's Clay Pit; the latter were therefore believed to be of Wolstonian age (e.g. Mitchell, 1960; Stephens, 1966a, 1966b, 1970a).

Other workers have argued against this correlation, suggesting that nowhere in the region is there evidence for a raised beach deposit having been overridden by ice (e.g. Zeuner, 1959; Kidson, 1971, 1974; Edmonds, 1972; Kidson and Wood, 1974; Kidson and Heyworth, 1977). These workers have therefore assigned raised beach deposits in the region, such as those at Westward Ho!, to the Ipswichian, and have considered the overlying head deposits to have accumulated during the Devensian. In this scheme, the giant erratics around the coast and the Fremington Clay were assigned to the same, Wolstonian (Saalian), glaciation - although such an event has now been thrown into considerable doubt (Chapter 2; Anglian and Saalian events).

In addition to the present-day shore platform and the elevated platform at 8-9 m OD, two further platform remnants at Westward Ho!, at − 1.5 m and + 5.0 m OD, have been recognized (Kidson, 1977; Kidson and Heyworth, 1977), the latter being represented by isolated stacks. It is therefore likely that there was more than one phase of platform formation (Kidson and Heyworth, 1977), although Everard *et al.* (1964) have argued that the detailed form of the platforms is, above all, controlled by structure and lithology.

Stephens (1970a, 1974) alluded to the possibility that beach cobbles (Figure 7.14; bed 2) beneath the Holocene submerged forest, peat and clay sequence at the site, were Ipswichian in age, and cited their lower altitudinal position with regard to the cliffed raised cobble beach deposits farther west, as support for such a dating. The polygonal sorting and vertical-stone structures observed in this bed were believed to have formed under periglacial conditions in the Devensian Stage. The underlying head (Figure 7.14; bed 1) was correlated tentatively with bed 6 (Pleistocene site description) in the cliff sections, and was believed to be of Saalian age (Stephens, 1970a). Wood (1970), however, observed that locally the beach cobbles (bed 2) are intermixed with the blue clay (bed 3), implying a Devensian late-glacial age for both.

The Holocene sequence

The Holocene sediments have attracted much attention. Hall (1879a) recorded 70-80 tree stumps in the peat. He demonstrated that some of their roots penetrated up to 1.2 m into the deposits, thereby establishing that the forest had grown *in situ*. Bate (1866) described the stratigraphy of the site and ascertained the relationship between the deposits and those at Braunton Burrows. Ellis (1866, 1867) recorded bones, teeth, flint flakes and cores, marine shell fragments (largely *Ostrea edulis* Linné and *Cerastoderma edule* (Linné)) from the beds, and although he established that the deposit of oyster shells (up to 0.6 m thick) was mixed up with the bones, their stratigraphic context was not given. It seems likely, however, that such a bed was probably part of the once more extensive kitchen midden later described by Churchill and Wymer (1965) and Balaam *et al.* (1987).

Pengelly (1868a) suggested that the relationship between the forest beds and the large pebble/cobble ridge on their landward side (Figure 7.14), was important for interpreting the relative levels of the land and sea in the region. He argued that the cobble beach indicated an upheaval of the land surface subsequent to a period of subsidence, during which the coastal forest had been swamped by the sea.

Rogers' (1908) observations on the forest beds added considerable data on the flora and fauna but, however, added little to the interpretation of the sequence; the stratigraphic context of most of the finds was not recorded although the mammalian remains were found *in situ* in a tough blue clay which contained abundant remains of the snail *Hydrobia ulvae* (Pennant) (Figure 7.15; possibly bed 7 of Balaam *et al.*, 1987).

A detailed account of the stratigraphy was provided by E.H. Rogers (1946) who excavated at the site, and provided additional floral, faunal and archaeological finds. He noted that the seaward outlier of the peat (outer peat) overlay a shelly calcareous mud containing numerous split bones, teeth, flint flakes and cores. The peat also yielded a microlith, flakes and a core.

Churchill and Wymer (1965) provided a detailed account of the kitchen midden establishing its 'Mesolithic' character, and arguing that it had been formed in the zone between neap and spring high tides. Seeds and fruits extracted from the overlying peat (presumably the outer peat of Balaam *et al.* (1987)) showed a plant succession from a dry fen with *Quercus* and a ground flora of *Ajuga reptans*, *Carex*, *Ranunculus* and *Rubus fruticosus*, to an even drier fen with *Corylus avellana*, *Cretaegus monogyna*, *Populus*, *Prunus spinosa*, *Thelycrania*, *Sanguinea* and *Solanum dulcamara*. Such an assemblage was considered characteristic of present-day fen woods, with no traces of saltmarsh plants or deposits as recorded by Rogers (1946). An early Atlantic age was suggested for the peat on the basis of a radiocarbon date of 6585

± 130 BP (Q–672) derived from a sample near the top of the peat bed. The presence of *Plantago lanceolata* pollen was taken to be an indicator of progressive forest clearance by Neolithic humans (Churchill and Wymer, 1965), although flint artefacts from the midden, the peat and the nearby clay surface are Mesolithic in character.

Churchill and Wymer (1965) and Churchill (1965) argued, on the basis of estimates of mean sea level derived from radiocarbon-dated submerged forest and associated marine beds around the coast of Britain, that there has been no measureable tectonic displacement at Westward Ho! (and much of South-West England) since *c.* 6500 BP. This contrasted, they suggested, with sites to the north-west in the Irish Sea Basin (such as Ynyslas and Borth), which revealed an upward vertical displacement of *c.* 3 m, since that time, and sites in eastern England and The Netherlands which they argued had fallen by up to 6 m since then. This has since been strongly disputed by Kidson (1977) and Heyworth *et al.* (1985), among others, who have shown there to have been no significant differential movement of the west Wales and South-West England land surfaces during the Holocene.

Balaam *et al.* (1987) concluded, despite a lack of fossils, that the lower blue clay (their bed 1) found in Area 3 (Figure 7.15) was an estuarine deposit. They argued that the artefacts and charcoal found in its upper layers were not necessarily the same age as the clay. The age of the latter was enigmatic, and it could not be presumed that it immediately pre-dates the overlying midden material. However, they favoured an age for the clay of at least *c.* 8000 BP (based on archaeomagnetic dating) and believed that a lack of evidence for weathering and soil development indicated that the clay and midden materials were not greatly separated in time (Balaam *et al.*, 1987).

These workers also confirmed that bed 2 was a Mesolithic shell midden, pollen, molluscan and insect remains providing significant evidence of environmental change during its deposition. They argued that the midden had started to accumulate amidst a fairly dense fen carr closely surrounded by mixed oak woodland with a few herbs, of which grasses and sedges were dominant. The mollusc and insect remains are taken to indicate that the midden accumulated as domestic rubbish in a stagnant (but not brackish) pool: the insect remains show strong evidence for decaying wood and other vegetable matter.

Pollen from the upper layers of the midden showed evidence for a change in local vegetation with higher levels of willow, birch and ivy. There was no evidence, however, for the modification of the local vegetation by humans. An environment of relatively closed, damp woodland was further suggested by the remains of *Anguis fragilis* Linné (slow worm), the scales and bones of *Rana* sp. (frog) and bones of *Clethrionomys glareolus* (Schreber) (bank vole). Insect remains indicate that open country and sand dunes lay beyond the woodland and midden at no great distance (Balaam *et al.*, 1987), contradicting Churchill's and Wymer's (1965) and Rogers' (1946) assertion that the midden lay at or near the strandline.

The human origins of the midden were confirmed, however, by the accumulation of marine molluscs (including *Scrobicularia*), charcoal and flint artefacts. The bones of red deer, roe deer and fish were also probably introduced by humans. Balaam *et al.* (1987) noted that 1074 flints had been recovered from Area 3 indicating that Mesolithic people had knapped local flint (?beach cobbles) to make microliths for hunting and various blades and scrapers for more domestic activities.

Radiocarbon dates show that the overlying peat sequence (outer peat; bed 3) accumulated during a roughly 500- to 800-year timespan. Both radiocarbon and pollen evidence confirm its Atlantic (Godwin Zone VIIa) age (Balaam *et al.*, 1987). The pollen and plant evidence indicates a willow-dominated fen carr amidst a vegetation of deciduous woodland, with oak, elm, ash, hazel and willow strongly represented. Both plant macrofossil and insect evidence confirms the presence of deciduous woodland with only localized waterlogging and small streams; laminae within the peat probably attest to minor flooding episodes. According to Balaam *et al.*, the outer peat shows surprisingly little evidence for human activity. However, although hazelnuts found in the bed appear to have accumulated naturally, pollen in the upper layers of the peat show a decline of elm and ash and the appearance of goosefoot and ribwort plantain. Such changes may be associated with human activity within the catchment, reducing evapotranspiration and increasing surface flows (Balaam *et al.*, 1987). The reduction in the levels of ash and elm could also be associated with increased wetness (climatic) and waterlogging caused by a rising groundwater table which would have heralded the marine transgression responsible for the overlying upper clay (bed 4). The evidence afforded by bones of Bovid and Cervid animals, fish bones and artefacts found in the outer peat is also equivocal: these may have been derived from the underlying midden by bioturbation (Balaam *et al.*, 1987). The overlying clay (bed 4) denotes a dramatic change in conditions and demonstrates marine/estuarine inundation of the outer peat by *c.* 5200 BP (Balaam *et al.*, 1987).

Importantly, Balaam *et al.* demonstrated clearly that the outer and inner peats at Westward Ho! are of different ages. (It appears likely that some of the earlier accounts have referred to material from both the Mesolithic midden and later Romano-British deposits without apparent differentiation.) Archaeomagnetic measurements from silt (bed 5) underlying the inner peat (bed 6), show the latter to date from the Romano-British period; the pollen spectra also corroborate a much later date for the inner peat (Balaam *et al.*, 1987). The latter appears to have accumulated in a more open environment than the outer peat: similar floral elements are present but in different abundances. The vegetation of the inner peat is of a sedge/grass fen community, not the *Salicetum* of the outer peat. Pollen of trees and shrubs are also substantially fewer. Although there is no direct evidence of human activity, the upper levels of the inner peat show significant increases in the amount of *Plantago lanceolata* and cereal pollen (Balaam *et al.*, 1987).

The overlying silts (bed 7) are discontinuous and difficult to interpret. Molluscan assemblages, which include *S. plana* and *H. ulvae*, however, suggest an estuarine origin for the deposits and this is supported by the pollen evidence which also indicates a saltmarsh and seashore environment; radiocarbon evidence points to a Romano-British age. The presence of cattle, sheep/goat and dog bones in these deposits, and the stake and brushwood structures, provides clear evidence of human activity. However, it remains unclear if the stakes were driven into the silts or whether the silts accumulated around them. Balaam *et al.* suggested, tentatively, that some of the stakes may have been used for mooring while others may have formed some part of a fish trap. No other artefacts are recorded by Balaam *et al.* from these deposits, although numerous flints have been recovered *ad hoc* from this general area over the years.

Conclusion

The interpretation of the classic raised beach and head sequence at Westward Ho! has proved controversial, with claims being made for either Ipswichian or Hoxnian ages for the raised beach deposits. Unfortunately, the latter are unfossiliferous and their relative age cannot therefore be resolved by amino-acid geochronology.

The site also provides one of the finest examples of a compound shore platform in western Britain. The extensive development of two principal platforms which lie at significantly different heights, and possibly two more which can be identified from more isolated remnants (Kidson and Heyworth, 1977), clearly disproves the earlier concept of a single platform planed during the Cromerian. It is clear from this evidence that there was more than one phase of platform formation, the ages of which are unknown, and that lithology and structure may have been controlling factors. The beach deposits overlying the highest of these platforms are one of the best examples of a raised cobble beach in Britain. The age and stratigraphic relationships of beach material (possibly soliflucted) underlying the submerged forest, are also a subject of debate and enhance the scientific value of the site.

Westward Ho! also provides perhaps the most famous and best studied of South-West England's coastal Holocene deposits, interest in the site having been stimulated by its evidence for Mesolithic occupation. The site reveals an important record of changing terrestrial and coastal conditions in the Holocene, demonstrating clear evidence for the transition from the very low sea-level conditions of the Late Devensian, through the initially rapid rise of the Holocene sea and the swamping of the coastal forest that had developed by about 6000 BP, to a late stage in which the rate of sea-level rise slowed and the present-day coastal configuration, including the landwards migration of the massive cobble ridge, was established. Its radiocarbon-dated peat and forest bed is important for establishing the pattern of relative land (isostatic) and sea (eustatic) movements around the coast of Britain.

THE VALLEY OF ROCKS
S. Campbell

Highlights

The Valley of Rocks is one of Devon's most spectacular and controversial landforms. Some authorities maintain that it was cut by glacial meltwater, others that it was formed by marine capture of a formerly more extensive East Lyn River.

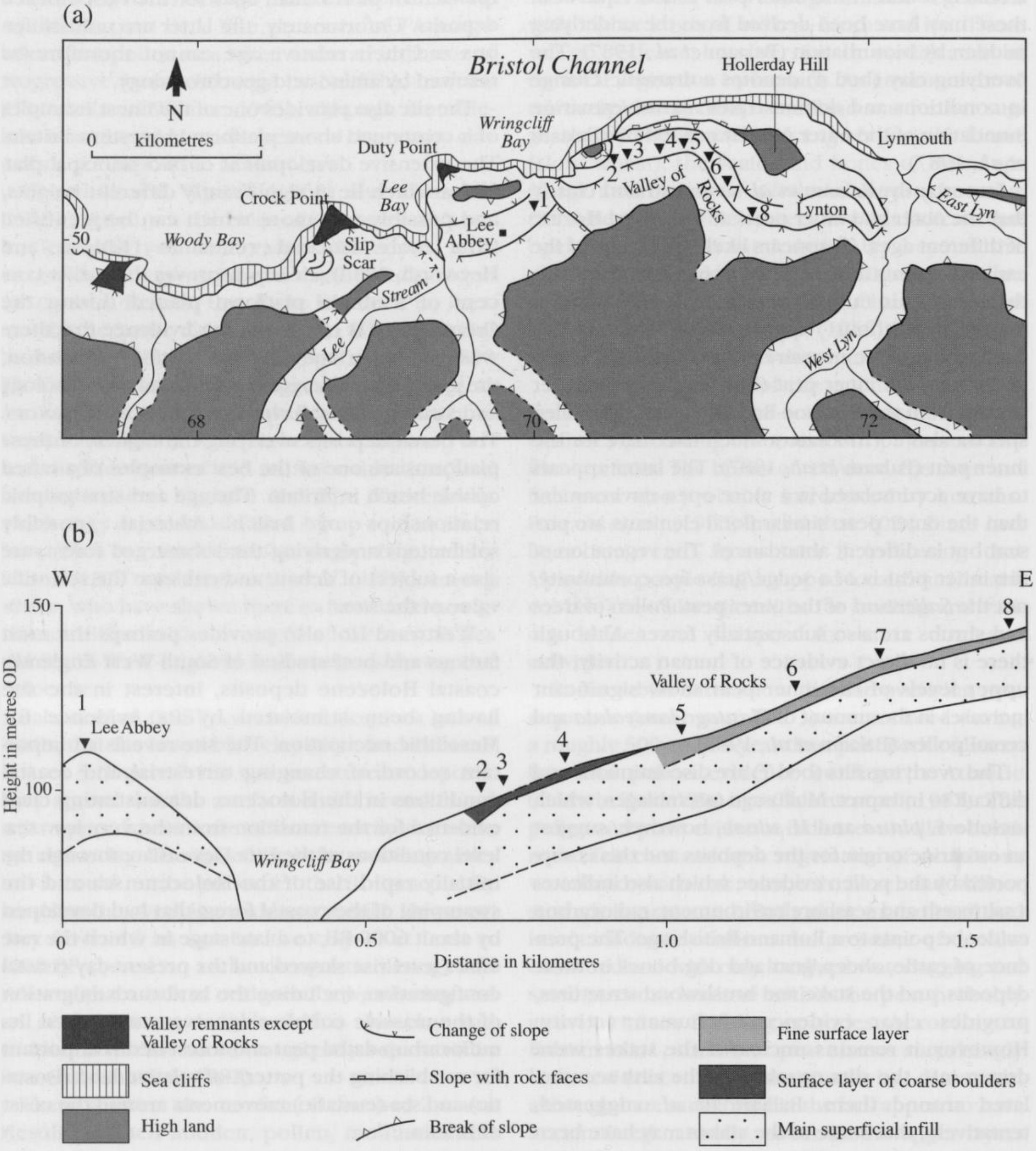

Figure 7.18 (a) Landforms and Pleistocene deposits between Lynmouth and Woody Bay. (b) Profile of Pleistocene deposits within the Valley of Rocks and at Lee Abbey. (Adapted from Dalzell and Durrance, 1980.)

Figure 7.19 The Valley of Rocks, looking east from Wringcliff Bay. (Photo: S. Campbell.)

Introduction

The Valley of Rocks is noted for a large dry valley and a series of periglacial features. The origin of the valley is much disputed, but has a major bearing on coastal and drainage evolution in north Devon. The site has been referred to by E. Arber (1911), Steers (1946), Simpson (1953), Mottershead (1964, 1967, 1977c), Stephens (1966a, 1966b, 1970a, 1974, 1990), Gregory (1969), Pearce (1972, 1982), M. Arber (1974) and Cullingford (1982). A detailed description and reinterpretation of the landforms was given by Dalzell and Durrance (1980).

Description

The Valley of Rocks or 'the Danes' (SS 700495) extends some 2 km from Wringcliff Bay in the west to the western side of Lynton, and lies roughly parallel with the east-west-trending north Devon coastline (Figures 7.18 and 7.19). It is cut in the sandstones and slates of the Devonian Lynton Beds. On its southern margin it is backed by the high ground of Exmoor which locally rises from *c.* 260 m to 318 m OD. To the north, the valley is separated from the sea by the mass of Hollerday Hill and a narrow westward-running ridge, precipitous on its seaward side, capped by tor-like buttresses and mantled with scree. Although the Valley of Rocks terminates at Wringcliff Bay, its perceived course continues west to Lee Bay through a col in which Lee Abbey is situated. The principal 'tors' crop out on the valley's northern margin and are of both the crestal and valley-side types. These include the castellated turrets of rock known as Castle Rock, Rugged Jack and Chimney Rock. Valley-side tors also crop out on the south-facing slopes of the valley (e.g. the Devil's Cheesewring).

Considerable thicknesses of head are exposed in the coastal cliffs. Mottershead (1967, 1977c) recorded up to 25 m of such deposits comprising angular slate and sandstone fragments in a poorly sorted matrix of fines. At Lee Bay, a thick sequence of Pleistocene sediments is exposed in the coastal cliff at the head of the bay (Dalzell and Durrance, 1980). This sequence overlies a rock platform at *c.* 7 m OD and comprises (maximum bed thicknesses in parentheses):

4. Coarse angular rock fragments with some subrounded pebbles (*c.* 18 m) (head)

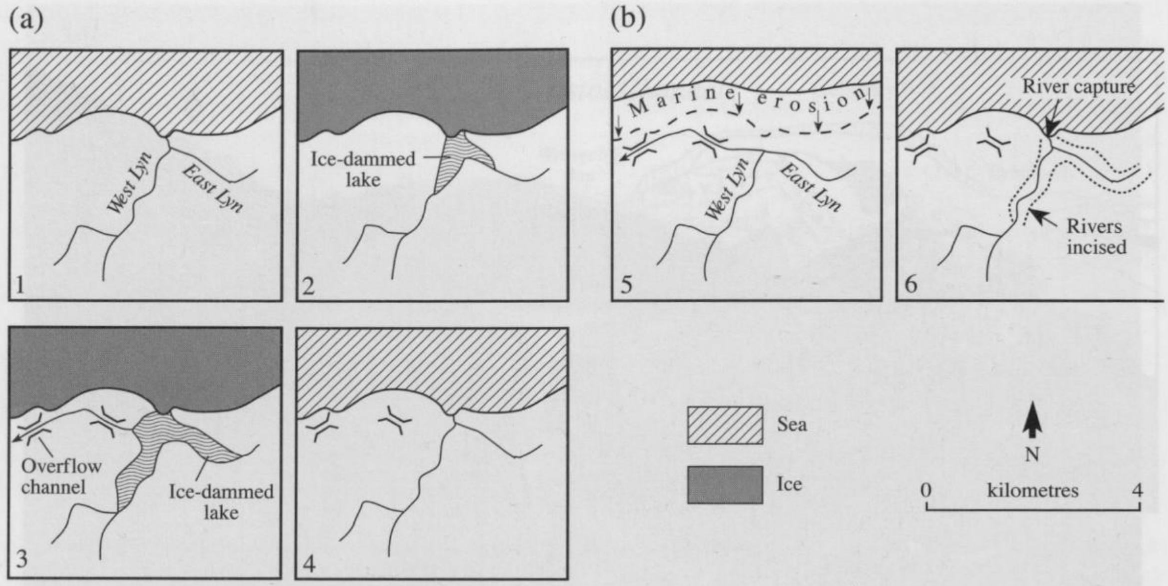

Figure 7.20 The evolution of the Valley of Rocks by: (a) Pre-Devensian glacial meltwaters; (b) Marine erosion and river capture. (Adapted from Mottershead, 1967, 1977c.)

3. Subrounded pebbles (*c.* 3.5 m)
2. Mixture of well-rounded and subrounded pebbles with sand layers (*c.* 3.0 m)
1. Well-rounded pebbles in a sandy matrix (*c.* 3.5 m)

Beds 1–3 were described by Dalzell and Durrance (1980) as waterlain, comprising a mixture of fluvial and marine materials. They also showed that the Valley of Rocks and the smaller valley near Lee Bay (the Lee Abbey gap) have a substantial infill of Pleistocene scree and solifluction deposits.

Interpretation

Following Balchin's (1952) work on the erosion surfaces of Exmoor, Simpson (1953) put forward the view that the dry valley remnants could be explained by marine erosion and capture of a formerly more extensive River Lyn, which then flowed west. He concluded that the East Lyn river originally flowed from Lynmouth through the Valley of Rocks, the Lee Abbey gap, Crock Point and Martinhoe Manor to Heddon's Mouth. Such an interpretation, based entirely on the present form and location of the remnant dry valley floors, was followed by Mottershead (1964, 1967, 1977c) (Figure 7.20) who stressed the similarity between the channel form and direction of the present East Lyn river east of Lynmouth, and the Valley of Rocks. Thus, he suggested that the Valley of Rocks represents the former course of the East Lyn before it cut down to its present level, and before its outlet at Lynmouth existed. As a result of the capture of the East Lyn and the abandonment of the Valley of Rocks, the course of the East Lyn to the sea was dramatically shortened. Initially, it probably reached the sea via large waterfalls, but with continued erosion upstream, the course became graded and more subdued to its present, but still sharply incised, form (Mottershead, 1977c).

In marked contrast, Stephens (1966a, 1966b) suggested that the valley remnants had formed as ice-marginal drainage channels cut in Wolstonian times (Saalian Stage) when glacier ice was believed to have reached Barnstaple Bay – and consequently may have impinged upon the north Devon coast for substantial portions of its length. Stephens' model implies that the pre-Wolstonian drainage pattern must have been substantially similar to that of today. As ice advanced and fringed the Exmoor coast, a lake formed in the Lyn Valley behind present-day Lynmouth (Figure 7.20). The Valley of Rocks was believed to have been cut by water spilling westwards from this impounded lake. As the ice wasted, the rivers reverted to their original courses and the Valley of Rocks was left dry. A meltwater origin was also considered plausible by Gregory (1969), but Mottershead (1967, 1977c) reviewed this mechanism and although he, and

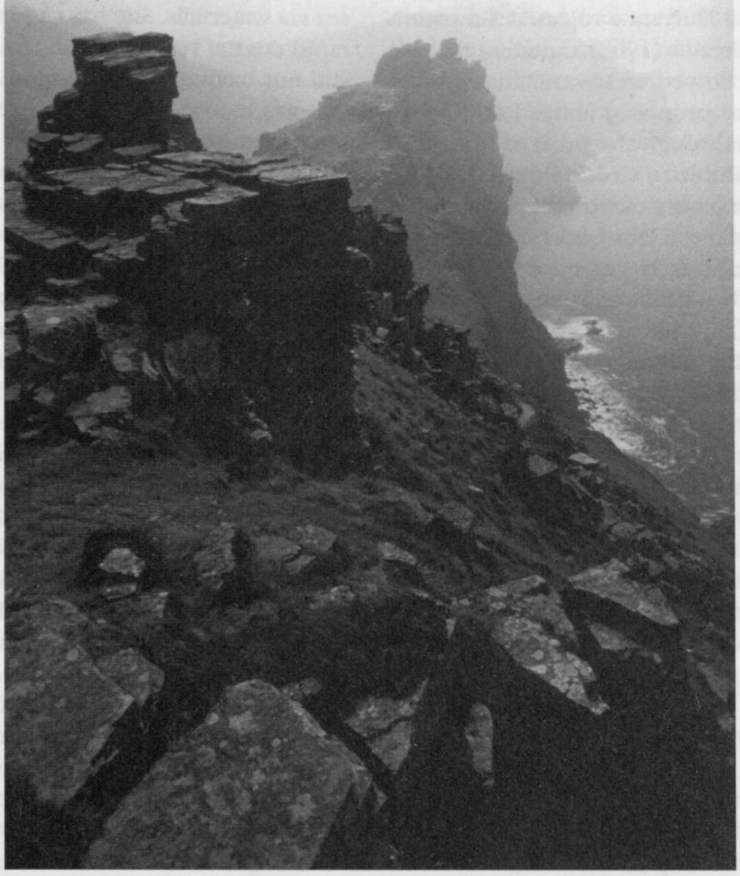

Figure 7.21 Tor-like buttresses and precipitous rock slopes on the northern margin of the Valley of Rocks, looking west. (Photo: S. Campbell.)

subsequent workers, have found no positive evidence against it, he argued that the concept of marine capture was probably more straightforward. In support of his model, Stephens noted that erratics and striated pebbles had been found in the area (including an example of the renowned Ailsa Craig microgranite), and that a number of often abrupt and now dry channels in the area had probably been formed in the same manner.

Dalzell and Durrance (1980) used electrical resistivity techniques to establish the origin of the dry valley system at the Valley of Rocks and Lee Bay (Figure 7.18). Their results showed that considerable, but variable, depths of Pleistocene deposits capped the Devonian strata. For the most part, the infill was interpreted as solifluction material derived from the valley sides, distinguished by a high proportion of fine sediment. A coarse surface layer of boulders and blocks, averaging between 2–5 m thickness, was discerned to the west end of the Valley of Rocks (Figure 7.18). At the eastern end a similar layer, but of finer material, was also noted. The thickness of superficial material in the Valley of Rocks increases west from 27 m at the highest point in the valley floor to 35 m at its lowest point. The pattern at the west end, however, is complicated by mass movement caused by marine erosion; here the rock-head profile is obscured (Dalzell and Durrance, 1980).

These results led Dalzell and Durrance (1980) to suggest that the rock-floor profile of the Valley of Rocks shows a gradation to a level lower than that of the Lee Abbey gap. Instead, the Valley of Rocks grades more readily to the heights and erosional remnants at Duty Point and Crock Point (Figure 7.18), which were therefore regarded as fluvially rather than marine-eroded surfaces. At the same time, the present Lee stream, with its gently profiled upper section, appears to grade more naturally with the rock-floor profile of the Lee Abbey gap (Figure 7.18).

Thus, Dalzell and Durrance rejected Simpson's (1953) and Mottershead's (1964) argument that the East Lyn had once flowed westwards through the Lee Abbey gap, and proposed instead that it had flowed in a course through the present Wringcliff Bay around Duty Point to Crock Point. The Lee stream would then have flowed east through the Lee Abbey gap to join the East Lyn as a tributary. A first stage of river capture by marine erosion in the Lynmouth area left the Valley of Rocks dry, save for the Lee tributary. Subsequent marine erosion, which formed Lee Bay, then captured the Lee to its present course. Since the platform of Devonian rocks in Lee Bay is overlain by raised beach and fluvial deposits (of presumed Ipswichian age) and then by periglacial head, Dalzell and Durrance argued that the coastal dissection had happened, at latest, in Ipswichian times; aggradation of head deposits in both the Valley of Rocks and the Lee Abbey gap could not have occurred if these valleys had been fluvially active throughout the Devensian.

Conclusion

The Valley of Rocks is a spectacular landform, the age and origin of which have been much disputed. The site has nonetheless played a focal role in the development of ideas concerning coastal and drainage evolution in north Devon. Two main theories have been put forward to account for the dry valley system. One explanation is that the Valley of Rocks was formed by marine capture of a formerly more extensive East Lyn River; another is that the feature is a marginal glacial drainage channel cut as water overspilled from an ice-impounded lake. Recent work graphically shows the problems of interpreting landforms such as this from their present surface morphology. The Valley of Rocks, and also that at Lee Abbey, are in fact underlain by considerable thicknesses of Pleistocene solifluction and head deposits which mask the true profiles and gradients of the rock floors. The application of electrical resistivity techniques shows that the Valley of Rocks and its perceived extension into Lee Bay (the Lee Abbey gap) could in fact be the result of a more complex sequence of marine erosion and river captures, with the Lee Abbey gap being the abandoned channel of a tributary of the East Lyn.

No detailed evidence to reject the glacial drainage hypothesis has, however, been put forward. Nonetheless, in favour of the river capture theory, M. Arber (1974) has argued that many streams flowing northward off Exmoor fall to the sea via waterfalls. She has cited this as evidence for rapid coastal retreat in the Pleistocene, the rivers still not having adjusted significantly to the most recent change in base level (but see Chapter 7; Introduction).

The conservation value of this site is enhanced by the well-developed tor-like buttresses and scree slopes on the margins of the dry valley system (Figure 7.21), and by the head and solifluction deposits which infill the valleys. The head deposits are well exposed in the sections at Lee Bay, and their association with raised beach deposits of proposed Ipswichian age there provides rare stratigraphic evidence for the relative dating of such landforms. Much of the head which infills the dry valleys is believed to have accumulated under periglacial conditions in the Devensian, when glacier ice is not thought to have reached this part of the Peninsula. Although the tor-like features have not yet been studied in detail, they are believed to have been significantly modified at this time, although in common with granitic tors, it is likely that they evolved in response to processes operating over more protracted timescales.

DONIFORD
S. Campbell

Highlights

Doniford displays the finest sections through Quaternary periglacial river and associated mass movement deposits in South-West England. Its sequence of loams, sands and gravels has yielded artefacts and mammal bones, and exhibits well-developed periglacial structures.

Introduction

This site shows Quaternary sediments, including fluvial deposits and head, formed in a periglacial environment. The deposits were first described by Ussher (1908) and mapped by Thomas (1940). Accounts of archaeological and mammalian remains from the site were given by Wedlake (1950) and Wedlake and Wedlake (1963). A detailed stratigraphic interpretation was provided by Gilbertson and Mottershead (1975) and the site has also been referred to by Norman (1975, 1977), Kidson (1977), Mottershead (1977a), Edmonds and Williams (1985) and Campbell *et al.* (in prep.).

Description

Quaternary sediments crop out more or less continuously for 2 km along the north Somerset coast. They are particularly well exposed between Helwell Bay (ST 078434) and the Swill (ST 091433), and occupy a valley which runs eastwards from Watchet Station (ST 072433), through Helwell Bay to the Swill (Figure 7.22). To the east, gravels are exposed continuously on the foreshore as far as grid line 100 and, beyond there, discontinuously (Mottershead, 1977a).

In Helwell Bay, the gravels rest on a platform of Liassic shale and limestone beds (Figure 7.23). In the western part of the bay, the rock surface reaches 10–12 m OD, and the overlying Quaternary deposits are only about 2 m in thickness. This rock platform falls in height eastwards to *c.* 5 m near the concrete jetties (ST 082431) and to around 3 m OD at the Swill where the junction between the platform and gravels is obscured by beach and recently tipped materials. Here, the entire cliffline was formerly cut in Quaternary sediments some 5 m in thickness (Gilbertson and Mottershead, 1975). *In situ* Quaternary sediments are also present along the now overgrown western bank of the Swill (Figure 7.24). The Doniford exposures are constantly affected by marine erosion, and several stretches of the coastline have been obscured in recent years by coast protection works. Although the present sections are very different to those decribed by Gilbertson and Mottershead (1975), the same basic sequence can be seen (maximum bed thicknesses in parentheses):

6. Brown loam – generally structureless with occasional pebbles and sometimes thinly bedded (0.6 m)
5. Red clay-silt (red loam) – with marked prismatic fracture and frequent angular pebbles of Liassic material (0.6 m)
4. Buff silty loam (buff loam) – with less well-defined prismatic structure and with layers and lenses containing angular stones (0.6 m)
3. Red sandy silt – thinly laminated with fine gravel throughout (0.3 m)
2. Cobbly gravels – partially rounded to angular cobbles and boulders, often split, in a matrix of platy pebbles and fine silt; generally poorly bedded and sorted (2.9 m)
1. Rock platform (Lias)

Although the stratigraphy is complex, several more or less continuous beds can be traced along the coast, the cobbly gravels (bed 2) being the most distinctive and extensive. While they usually show little bedding, some stones lie with their long-axes in the horizontal plane (Gilbertson and Mottershead, 1975). In addition, lenses of well-sorted, cross-stratified sand and gravel occur in the otherwise massive beds; near the Swill, particularly in the river sections, channels up to 8 m across contain cross-stratified deposits (Gilbertson and Mottershead, 1975; Figure 7.24).

These coarse gravels (2–60 mm), with common cobbles (60–200 mm) and occasionally boulders (> 200 mm), comprise mainly purple and green slates, sandstones and cherts derived from Devonian strata in north-west Somerset (Gilbertson and Mottershead, 1975). Blocks of Lias clay have also been recorded from bed 2 (one measuring 2 m × 0.3 m). Most clasts are subangular to subrounded, although fresh fractures on otherwise rounded cobbles suggest post-depositional breakage. Clast long-axis measurements show a dominant orientation in the range between *c.* 320–360°, but there is no clear-cut pattern of clast orientation in relation to the directions of local slopes, and clast dip values appear random (Gilbertson and Mottershead, 1975). Many clasts, however, give the impression of lying with their long-axes vertical, and the lower *c.* 2 m of the bed is sometimes affected by involutions. At the west end of Helwell Bay, large involutions (1–2 m in wavelength and amplitude) affect the surface of the Lias platform and the cobbly gravels above, and also disturb the overlying loams (Gilbertson and Mottershead, 1975). At one locality, a 'raft' of Lias clay has been suspended in a large involution.

The cobbly gravels (bed 2) have yielded the remains of tusks and molars of *M. primigenius* (woolly mammoth) (Wedlake, 1950). Over the last 60 years or so, this bed has also yielded a substantial number of Palaeolithic artefacts, collected mainly between high and low water marks from the surface of the gravels exposed to the east of the Swill (Wedlake, 1950). These include over 20 hand-axes of Acheulian Culture made mostly from Greensand chert, and some large flakes. All the implements are heavily rolled. More recently, Norman (1975, 1977) discovered flint artefacts *in situ* in gravel (bed 2) exposed in cliff sections near

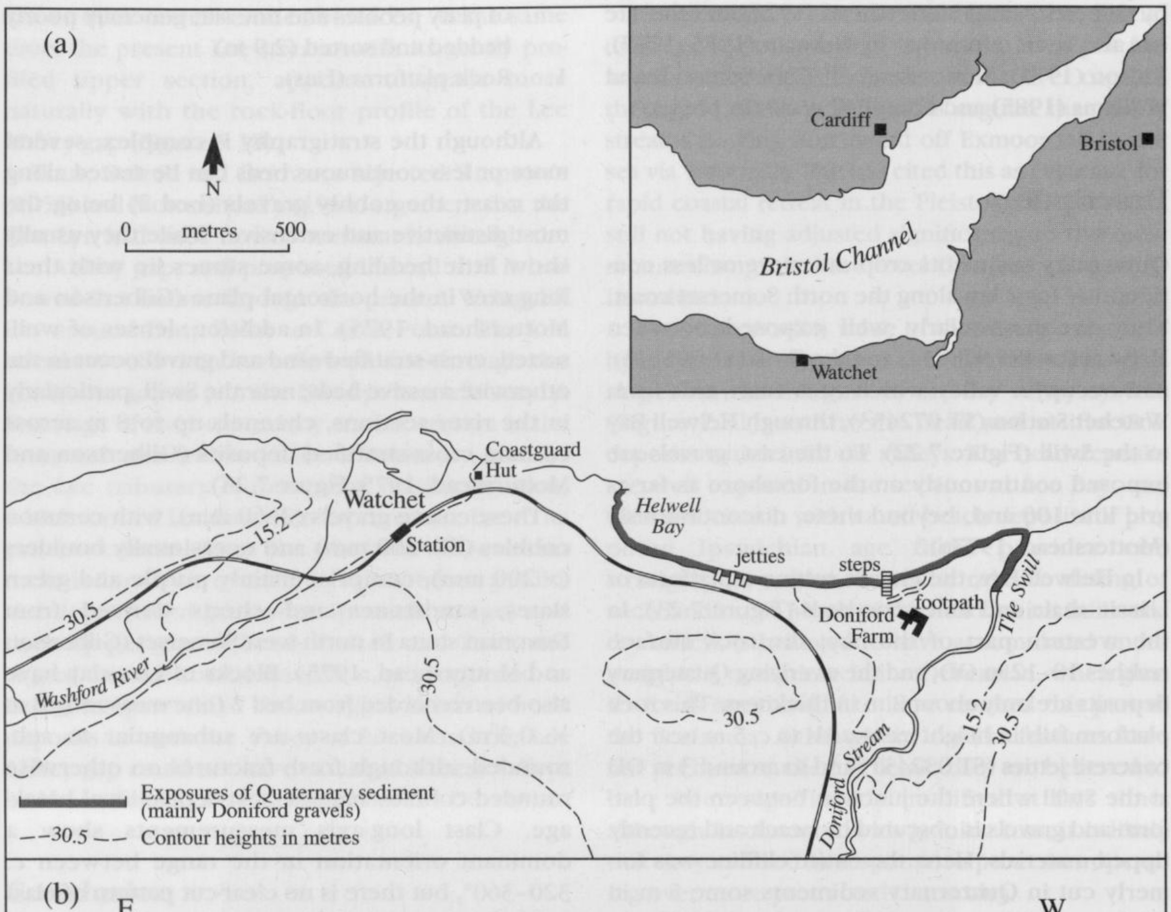

Figure 7.22 (a) The location of the Doniford gravels. (b) Typical section through the Doniford gravels west of the footpath. (Adapted from Gilbertson and Mottershead, 1975.)

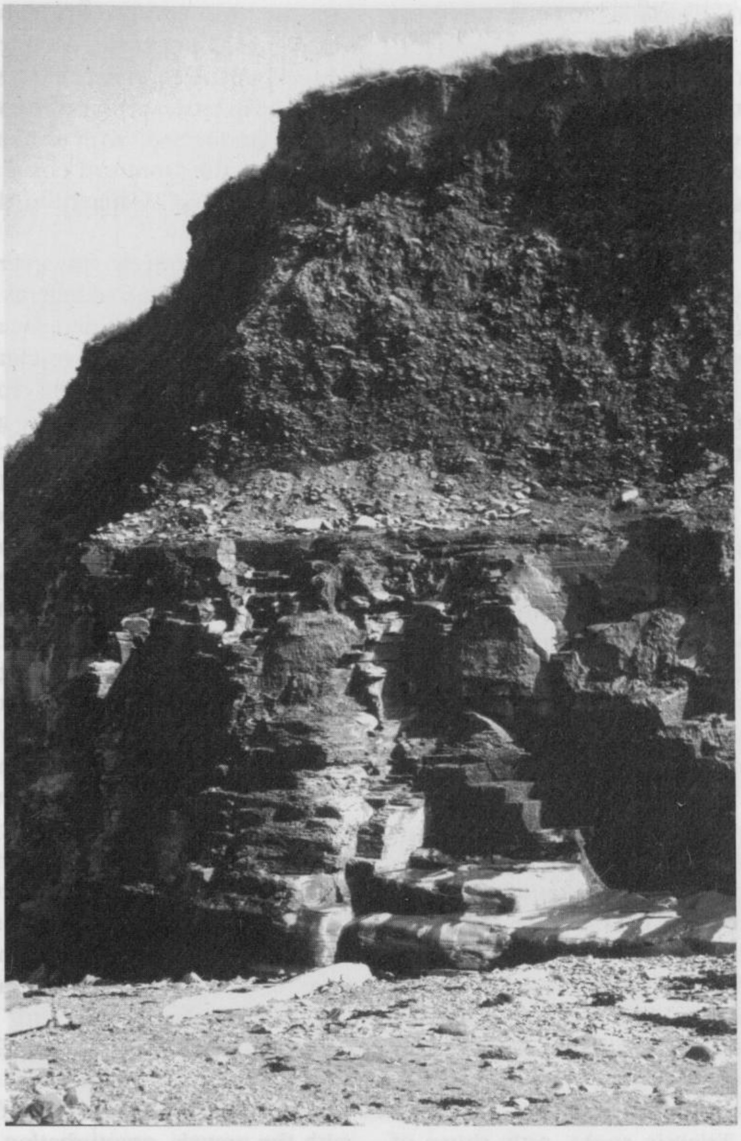

Figure 7.23 The Doniford gravels overlying Liassic bedrock at the eastern end of Helwell Bay. (Photo: S. Campbell.)

the Swill. The largest was an incomplete blade (10.5 cm in length) found in a lens of fine, well-sorted gravel. The smallest was another segment of a large blade found at the junction of the same lens with the more poorly sorted overlying gravels.

The succeeding beds (3–6) comprise sandy silt and loam and can be distinguished by colour, structure and stone content. These beds are discontinuous but are best seen to the west of the old lime kiln (ST 087431). The red sandy silts (bed 3) are often thinly laminated, and contain fine gravel throughout, including many strongly weathered clasts of Jurassic sediment (Gilbertson and Mottershead, 1975). The overlying buff silty loam (bed 4) is highly calcareous (nearly 32% calcium carbonate) and contains scattered lenses and seams of angular chips and fragments of Lias limestone. The deposit has a prismatic structure, although not so pronounced as the succeeding red loam (bed 5). The latter contains up to 27% clay in a matrix which supports sand and gravel, apparently derived from Devonian strata, and which itself appears to have been derived from more local Triassic rocks. Clasts in this bed show a marked preferred orientation downslope; mean values change progressively as the beds are traced around the variable local slopes. The orientation values are stronger in this bed than in the cobbly gravels (bed 2) (Gilbertson and Mottershead, 1975).

Finally, a brown loam (bed 6) lies with marked unconformity on the lower deposits. It incorporates fragments of weathered local limestones, and has yielded profuse Mesolithic artefacts. These include microliths, scrapers, burins and a crude tranchet axe (Wedlake, 1950; Norman, 1975, 1977).

Beds 3–6 are frequently affected by involutions and, in several places, the loams are let down into the cobbly gravels (bed 2) in pipes and V-shaped wedges; dislocated boulders and gravel clasts sometimes occur within these pipes (Figure 7.22; Gilbertson and Mottershead, 1975).

Interpretation

Although mapped, described and interpreted by Thomas (1940) as river gravels, the Quaternary deposits at Doniford were first studied in detail by Gilbertson and Mottershead (1975); a précis of this work was given by Mottershead (1977a) with an accompanying account of the archaeological finds by Norman (1977).

Since far-travelled erratics found in northern Somerset have been used as evidence for ice sheets moving eastwards up the Bristol Channel, and penetrating well inland near Weston-super-Mare (Hawkins and Kellaway, 1971), Gilbertson and Mottershead (1975) reinvestigated the Doniford sections to ascertain if glacier ice had played any part in their formation. They found that no clasts in either the gravel (bed 2) or overlying loams (beds 3–6) were foreign to the area. Apart from local Jurassic and Triassic rocks, only those of Devonian age were found, even these implying a not too distant source. A glacial origin was therefore ruled out for any part of the sequence, and analyses of the sediments and structures indicated that the beds were most likely periglacial in origin, consisting of a series of alluvial gravel, head and slopewash sediments (Gilbertson and Mottershead, 1975; Mottershead, 1977a).

Gilbertson and Mottershead (1975) argued that the gravels occupied a valley running from the west beyond Watchet Station, through the Memorial Ground and Helwell Bay and then parallel with the Doniford coast to the Swill. The gravels are believed to occupy an ancestral valley of the Washford River which once had a confluence in the area of the present Swill, this valley system having now been dismembered by marine erosion causing the Washford River to flow directly into the sea at Watchet (cf. Mottershead, 1967). The gravels of the former river system are therefore exposed in cross-section at the west end of Helwell Bay and in the Swill river sections, and in long-profile along the Doniford coast as far as the Swill (Gilbertson and Mottershead, 1975; Mottershead, 1977a).

The cobbly gravels, however, cannot simply be regarded as fluviatile sediments since they also display characteristics of periglacial mass movement. Fluvial characteristics are clearly shown by the degree of bedding, including cross-stratification and sorting in parts of the bed. The gravel clasts are also significantly more rounded than typical periglacial head deposits in the region (Mottershead, 1976). Similarly, their non-local (but not distant) provenance also mitigates against an origin solely as periglacial head. Alternatively, Gilbertson and Mottershead suggested that parts of the gravel bed showed little evidence for sorting, having undergone mixing and reworking in a periglacial environment. In places, clast orientation measurements showed a preferred orientation downslope, indicating possible mass movement of gravels from higher ground located to the south of the sections. The evidence for fluvial activity is strongest near the Swill, where well-sorted, cross-stratified sands pick out channels presumably cut and filled by surface streams. In this area, deposition was effected by streams trending generally north, perhaps running off local hillslopes, but primarily by a forerunner of the present Doniford stream (Gilbertson and Mottershead, 1975). The presence of Lias 'rafts' incorporated into the overlying gravels, the intimate contortion of the Lias platform with the gravels, cryoturbation and vertical stone structures found at all levels elsewhere in the beds and the presence of many cracked clasts (Mottershead, 1977a) were taken to show that periglacial conditions had predominated throughout the accumulation of the sequence.

Gilbertson and Mottershead (1975) noted that loams (beds 3–6) which overlie the gravels, although differing in composition and structure, are also poorly sorted and show a consistent downslope orientation of clasts, characteristic of solifluction deposits. These sediments form an 'apron' sloping off adjacent hillsides, the red loam (bed 5) probably having been derived by erosion and subsequent redeposition of adjacent red Triassic rocks, and the buff loam (bed 4) consisting largely of redeposited (highly calcareous) Lias clays and Jurassic and Rhaetic limestone fragments. Thin

Figure 7.24 Quaternary deposits (mainly fluvial cobbly gravels; bed 2) exposed on the western bank of the Swill in 1980. (Photo: S. Campbell.)

bedding in some of these sediments suggests local deposition by slopewash, probably in a sparsely vegetated, periglacial environment.

Dating of the beds is more problematical. The capping brown loam (bed 6), interpreted as hillwash sediment (Gilbertson and Mottershead, 1975), is the stratum from which the Mesolithic artefacts were recovered. Norman (1975, 1977) has argued that these artefacts are probably divisible on typological grounds, and may represent both earlier (*c.* 10 000–8500 BP) and later (*c.* 8500–6000 BP) Mesolithic industries in the area. There is every likelihood, therefore, that the brown loam, upon which the modern soil has developed, is Holocene in age.

The artefacts and mammalian remains from the cobbly gravels (bed 2), however, only give a vague maximum age for these deposits. Lower Palaeolithic material of Acheulian Culture has traditionally been regarded as of Hoxnian and early 'Wolstonian' (Saalian) age. (Recent evidence from Waverley Wood, Warwickshire, shows that the Acheulian Culture extends back to pre-Anglian times (Shotton *et al.*, 1993).) The highly abraded and rolled condition of the artefacts shows that they are derived and renders them of limited use for dating the gravels, which must simply be 'no older'. Similarly, woolly mammoth remains elsewhere are first recorded in deposits assigned to the Wolstonian Stage (*sensu* West, 1968). The species was also present in the latest Ipswichian and became more common in the Devensian (West, 1968). It is impossible, in the absence of reliable absolute dates, to assign the remains at Doniford with certainty to any of these stages. There are, however, other indirect clues as to the age of the sediments (beds 2–5). If the upper loam (bed 6) is ascribed to the Holocene, as seems likely, and the underlying sediments are accepted as representing a cold environment, then a pre-Devensian age (?Saalian) would mean that considerable breaks in sedimentation occur in the sequence. The sedimentological data show no evidence for such a protracted hiatus (Gilbertson and Mottershead, 1975). Under such circumstances, it is most likely that beds 2–5 (the gravels and most of the loam sequence) at Doniford were formed during cold conditions in the Devensian when sea levels were lower (Gilbertson and Mottershead, 1975; Mottershead, 1977a).

Conclusion

The Doniford sections show a classic example of deposits and structures formed by fluvial and mass movement processes in a periglacial environment, probably during the Devensian. The sediments lie along the former course of the Washford River and consist largely of reworked river gravels including Devonian material probably brought from the Brendon Hills by an ancient Washford river (Gilbertson and Mottershead, 1975). The sediments, now exposed by marine erosion, show a complex interaction between fluvial, mass movement and freeze-thaw processes. There is clear evidence that much of the sediment has been subject to solifluction, although the lenses and channel-fills of better-sorted sediment, particularly near the Swill, demonstrate reworking of deposits by small, temporary streams running over the aggrading sediment surface (Gilbertson and Mottershead, 1975). As such, Doniford is an excellent fossil analogue of modern periglacial environments, where spring meltwater release plays an important role in reworking deposits of previous seasons (e.g. McCann *et al.*, 1972). The sediments at Doniford also confirm that glacier ice did not reach the north Somerset coast during the Devensian.

Finally, the site is notable for the discoveries of mammal remains and artefacts. The remains of *M. primigenius* (woolly mammoth) are an important palaeontological record, but are of little use for dating the sequence. Similarly, the Lower Palaeolithic artefacts recovered provide important evidence for the Acheulian Culture in this part of Somerset. They too, however, provide little additional evidence regarding the age of the sediments. The later Palaeolithic artefacts, however, raise the interesting possibility of human activity in the Doniford Valley in latest Devensian times. Discoveries of Mesolithic artefacts in the sections at Doniford are significant, showing two distinct typological assemblages and fixing a Holocene age for the uppermost bed of the sequence.

THE CHAINS
S. Campbell and R. Cottle

Highlights

The Chains GCR site provides a detailed pollen record, calibrated by radiocarbon dating, of mid- to late Holocene vegetational and environmental changes on Exmoor. It permits comparisons with other upland sites in South-West England and demonstrates the impact of humans on the landscape from Neolithic times onward.

Introduction

The peat mires of the Chains provide an important record of the changing vegetation cover on Exmoor during the last 5000 years or so. Radiocarbon dating of the deposits has allowed the pollen record to be correlated with periods of human activity in the area, thereby throwing light on the problem of anthropogenic activity in the initiation of blanket peat. The site was studied in detail by Merryfield and Moore (1974), and its evidence has been reviewed by Moore (1973), Crabtree and Maltby (1975), Bell *et al.* (1984) and Moore *et al.* (1984).

Description

The Chains is an upland plateau ridge running approximately 10 km from Radworthy (SS 700435) in the west to Raven's Nest (SS 780406) in the east, at an average height of 475 m. The ridge acts as the

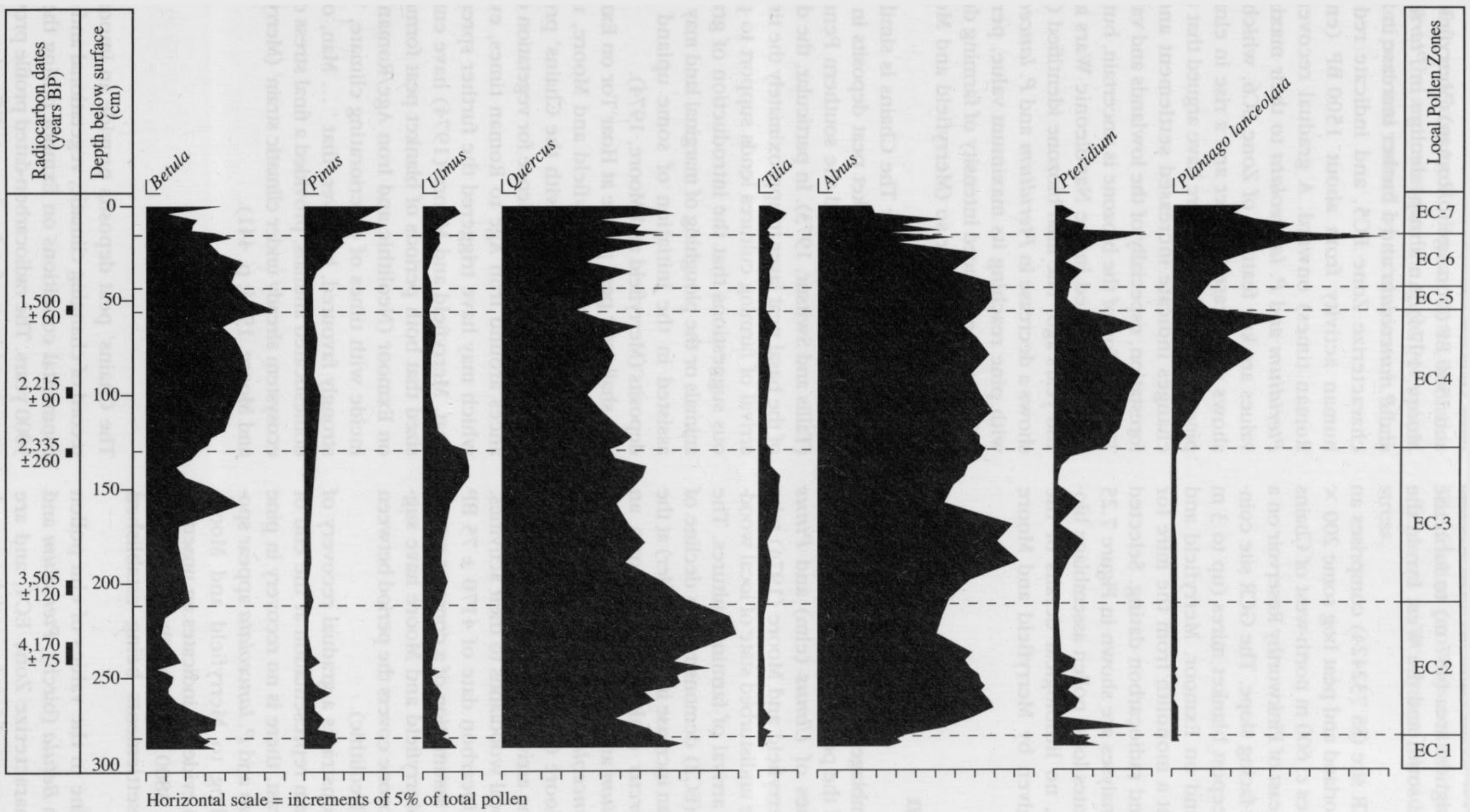

Figure 7.25 Selected pollen data and radiocarbon dates from a peat profile at The Chains, Exmoor. (Adapted from Merryfield and Moore 1974.)

major watershed for north Exmoor, with streams running off the highest area (487 m) to form the River Barle in the south and the West Lyn in the north.

The Chains GCR site (SS 732424) comprises an area of rough moorland and peat bog some 200 × 150 m. The site lies *c.* 600 m north-west of Chains Barrow and 1 km east of Pinkworthy Reservoir on a gentle north-west-facing slope. The GCR site coincides with the deepest blanket mires (up to 3 m thick) so far found on Exmoor. Merryfield and Moore (1974) cut a monolith from the mire for pollen analysis and radiocarbon dating. Selected results of these analyses are shown in Figure 7.25 which also illustrates local pollen assemblage biozones. However, no lithological details of the succession are given by Merryfield and Moore (1974).

Interpretation

Local pollen assemblage zone EC1, identified from the basal layers of the peat, is characterized by relatively high values of *Ulmus* (elm) and *Pinus* (pine) pollen. Merryfield and Moore (1974) take this to indicate the undisturbed state of local woodland prior to the arrival of farming cultures. The succeeding zone (EC2) demonstrates a decline of pine and elm and an increase in *Alnus* (alder) at the expense of *Quercus* (oak). It also shows an increase in *Pteridium* and the consistent presence of *Plantago lanceolata* (ribwort plantain). Merryfield and Moore (1974) suggest that these changes denote the arrival of farming cultures and the response of local woodlands to their activities. Based on the radiocarbon date of 4170 ± 75 BP (UB-821) and the assumption of a constant rate of peat formation, Merryfield and Moore have suggested that this biozone covers the period between 5000 to 3800 BP (Neolithic).

Zone EC3 demonstrates a gradual recovery of elm to its maximum representation at the end of the zone. In contrast, there is no recovery in pine and both *Pteridium* and *P. lanceolata* appear sporadically. According to Merryfield and Moore (1974), the pollen evidence indicates an unsettled period between *c.* 3800 and 2300 BP, with no permanent human settlements being established (Bronze Age).

A sudden decline in the values of elm pollen and an increase in *Betula* (birch), *Pteridium* and *P. lanceolata* characterize Zone EC4, and are taken to indicate increased farming activity, woodland clearance and settlement between *c.* 2300 and 1500 BP (Iron Age to Roman) (Merryfield and Moore, 1974). An abrupt decline in *Pteridium* and *P. lanceolata* and a further increase in birch characterize Zone EC5, and indicate reduced human activity from about 1500 BP (end of Roman times) onward. A gradual recovery of *Pteridium* and *P. lanceolata* to their maximum values are key features of Zone EC6, which also shows a decrease in alder and a rise in elm and pine. Merryfield and Moore have argued that these changes indicate increased settlement and deforestation, especially of the lowlands and valleys. The duration of the biozone is uncertain, but may have culminated in the Napoleonic Wars about 180 years ago. The final biozone identified (EC7) shows a decrease in *Pteridium* and *P. lanceolata* with pine reaching its maximum value, perhaps reflecting the reduced intensity of farming during the last 180 years or so (Merryfield and Moore, 1974).

The pollen record for The Chains is similar to others derived from blanket peat deposits in mid-Wales (Moore, 1968) and the southern Pennines (Tallis and Switsur, 1973). In particular, the dating of the basal peat layer to approximately the time of arrival of farming cultures lends support to previous suggestions that the introduction of grazing animals or the ploughing of marginal land may have assisted in the initiation of some upland peat deposits (Merryfield and Moore, 1974).

A shallower peat profile at Hoar Tor on Exmoor was correlated by Merryfield and Moore, using pollen biostratigraphy, with the Chains' profile. Both showed marked evidence for vegetation clearances around Iron Age to Roman times, events which may have triggered the further spread of peat. Merryfield and Moore (1974) have emphasized that both periods of blanket peat formation on Exmoor (Neolithic and Iron Age/Roman) coincide with times of deteriorating climate. They strongly favoured, however, that '... Man, or his domesticated animals, provided a final stress on an ecosystem already under climatic strain' (Merryfield and Moore, 1974; p. 441).

Conclusion

The Chains' peat deposits provide an important record of changing climatic, vegetational and environmental conditions on Exmoor during the last 5000 years. The radiocarbon-dated profile provides strong evidence for human modification of the local vegetation and landscape during both Neolithic and Iron Age to Roman times, and adds weight to the argument that the spread of upland blanket peat was caused by a combination of climatic and anthropogenic factors. Evidence from The Chains provides a stark reminder of human effects on an ecosystem already under climatic stress.