Some Aspects of the Pleistocene Succession in Areas Adjoining the English Channel

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Abstract

Middle and Upper Pleistocene sea level and climatic successions for the shores of the English Channel are proposed. The sequence is based on the examination of an area of fluvial deposition in south Hampshire and an area of marine, colluvial and aeolian deposition in the Channel Islands.

Five main conclusions are proposed: I, the terrace gravels of south Hampshire are entirely of fluvial origin and were deposited by the Pleistocene River Solent. These terraces are of end interglacial age and were formed by the large discharges associated with cooling climates, but before glacio-eustatic effects caused sea level to fall greatly from the interglacial level; II, the Hoxnian interglacial sea level was around 100 ft. (30 m.) O.D. not at the much lower levels previously suggested on the basis of evidence from the coasts of the Western Channel; III, an episode of high sea level at around 60 ft. (18 m.) O.D. is dated to a period within the Wolstonian glaciation. It is suggested that this episode may be the "Ilfordian" interglacial tentatively identified in the valley of the lower Thames; IV, the low level rock platforms of the Channel coasts are the result of erosion at several stages of the Middle and Upper Pleistocene; V, the presence of glacial ice in the English Channel at any stage of the Pleistocene is discounted.

Correlations and parallels with the Pleistocene sequences of other areas of Britain are suggested.

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Total no. of pages in text 209, + 42 figures, 53 plates & 6 tables

* Chapter V, Part I, forms the text of a paper published in the Proceedings of the Geologists' Association, vol.86, 1975, by R.C. Brown, D.D. Gilbertson, C.P. Green and the present author. Parts of the chapter not written by the present author are marked in the text.

Introduction

The object of this study is to recognise the sequence of changing climate and sea level in the Middle and Upper Pleistocene for areas in southern Britain unaffected by glaciation. Accordingly two areas on the shores of the English Channel are examined, the New Forest, an area of mainly fluvial and estuarine deposition, and the Channel Isles, an area of mainly marine and periglacial deposition. In these two areas many of the typical characteristics of non-glacial Pleistocene deposition can be recognised. Several sites dated archaeologically or by pollen analysis provide the basis for an absolute chronology.

An attempt is also made to provide a generally applicable statement on the nature and sequence of marine and fluvial deposition at the end of interglacials and thus on the origin of Pleistocene river terraces and on the inter-relationship between climatic change and the change in sea level.

a) South Hampshire

In Hampshire the area chosen for study is the southern New Forest from Southampton Water in the east to the valley of the Avon in the west. The northern limit of the area studied is approximately that of the Bournemouth to Southampton railway line. In this area may be found the large tracts of gravel and brickearth with which the first part of this study is concerned. The southern boundary of the area studied lies mostly beneath the water of Christchurch and Poole Bays but the largest remnant of the south bank of the Pleistocene River Solent, the Isle of Wight, is also included in the area studied. The area is portrayed on sheets 179 and 180 of the Ordnance Survey's one inch series. In view of the fragmentary nature of the evidence for Lower Pleistocene deposition only deposits below 130 ft. (40 m.) were closely studied so that this account is primarily one of Middle and Upper Pleistocene events. Below 130 ft. (40 m.)

extensive terrace surfaces occur and almost all the available sections are below this height while above 130 ft. (40 m.) only isolated deposits of gravel can be found with very few clear sections in them.

The two main questions faced in examining the south Hampshire gravels are as follows: a) are the gravels and the benches on which they rest of fluvial or marine origin?; and b) if the deposits are regarded as of fluvial origin, as in this thesis, what was their environment of deposition?

Workers over the past century have presumed either a marine or a fluvial origin for the gravels of the New Forest. Typical of the advocates of a marine origin has been Everard (1954b), who suggested that the gravels were formed as beaches in a shallow Solent Bay which existed before the breaching of the Wight-Purbeck Monocline. By contrast the exponents of a fluvial hypothesis have attributed the gravels to an easterly extension of the Frome and Avon-Stour flowing in a valley to the north of the unbroken monoclinal Isle of Wight ridge (White, 1915; Green, 1946). The former existence of the Solent River was first suggested by Fox in 1862 and this basic concept, as an explanation of the Pleistocene geomorphology of south Hampshire, is upheld by this thesis.

If it is accepted that the gravels and their associated brickearths occupy terraces of this Solent River and are not marine deposits the problem of their exact environmental origin then arises. As the terraces mainly occur above present sea level they were attributed (Zeuner, 1959) to interglacials in the Pleistocene because it was assumed that only in these warm episodes could the sea level rise above that of the present. Some authors, notably White, saw that the gravels of the terraces were far coarser than any being deposited in the streams of the area at present and suggested that the gravels were deposited by "shifting channels fed by a volume of water exceeding that carried by the local streams at the present day" (White, 1915, p.49). This estimation by White of the conditions under which the gravels were deposited suggests a climatic regime more rigorous than that of the present which is generally considered to be a full interglacial (Luttig, 1965; Suggate, 1965). However, the height of the gravels above modern sea level seems to indicate some stage in an interglacial and thus by definition a warm climate. It is with this paradox regarding the origin of the gravels of south Hampshire that Part One of this thesis deals. At the same time a climatic and stratigraphic sequence for the Middle and Upper Pleistocene is suggested.

The methods used in the Hampshire area involved sampling the gravel and brickearth for mechanical analysis, cartographic analysis based on the 1:25,000 map, the mapping and levelling of the interglacial deposit at Stone, shallow augering and the use of a compass/clinometer to determine current bedding flow directions. No mapping of the terrace surfaces was attempted as maps of the terrace flats have been published in Green (1946) and Everard (1954b) and while inaccuracies of detail are present in both these maps, remapping was thought to be unnecessary.

The gravels were sampled by Wentworth's method (Wentworth, 1922) by taking the largest stone and then about two pounds of sand and gravel of all calibres from around this stone. The gravel was sampled either from the base of the gravel or at a measured distance above it to provide a datum for comparison purposes.

It was hoped that comparison of size and composition of the gravels would give an indication of the origin of the gravels and whether they were fluvial or marine but sieving by hand in the laboratory to find the grain-size distribution and composition analysis proved inconclusive, there being little variation in composition or size in samples from the extreme west to the extreme east of the area under consideration, or indeed from one terrace to the next. Tables of size and composition from these analyses can be found in Table 2.

Grainsize analysis of the brickearth proved more rewarding and indeed provided one of the main lines of evidence in determining the origin of this deposit. Samples of the brickearth were collected from several sections and analysed by means of a settling column and pipette (for the exact method followed see Appendix A). The results from these Hampshire samples were compared with analyses from other areas and the cumulative curves and histograms drawn up from the information obtained may be found as figs. 8 and 9.

A series of profiles was drawn across the 1:25,000 map to try to elucidate the minor drainage development in the Forest. Most of these profiles were discarded but several of the clearer examples of valley incision were retained as illustrations (see fig. 10). The interglacial site at Stone Point was mapped and levelled by means of a tachyometric survey and a large scale map (fig. 12) was drawn from this survey. The making of this map was facilitated by shallow augering with a 4 inch bucket auger (to a maximum depth of 12 ft., 3.7 m.) and the digging of numerous test pits. Augering at other sites was impractical because of the depth of gravel to be penetrated. However the exposures in pits and cliff sections proved adequate for the examination of the area. Several of these exposures exhibited current bedding structures which were measured for direction by means of a "Suunto" compass/clinometer and the results plotted on the map (fig. 6).

Previous literature on the Pleistocene deposits of Hampshire is limited. The main part of the area under consideration is forest and farmland with only a few gravel pits to provide inland sections. (This lack of sections may be contrasted with the, in many ways similar, London Basin, where large amounts of brickearth and gravel have been dug in many areas and the spread of the city across the terraces of the Thames has provided many temporary sections in foundation trenches, etc..) Because of this lack of information the Hampshire area has attracted few previous workers.

In Hampshire the one topic in which interest has been maintained is the concept of a Pleistocene River Solent. This idea was first advanced by W. Darwin Fox in 1862. Further evaluation of this River Solent was made by the officers of the Geological Survey (Strachan, 1898; Reid, 1902; White, 1915) and by Green in the 1930's and 40's and finally by Everard in 1954 (b).

The Pleistocene deposits of the area, however, received little attention. Green was mainly concerned with the area to the west of the Avon and his excursions to the area east of that river were concerned almost entirely with the terrace surfaces rather than their deposits. Everard's main concern too was the surface of the terraces and his paper (1954b), despite its advocacy of a marine origin for the terraces, is a good example of the methods current in the 1950's for the examination of river terraces (see also Hare, 1947 and Sealy, 1955 for similar examples). Thus the deposits of the terraces were largely ignored by such workers as examined the area. The one deposit in south Hampshire which has been examined from a stratigraphic point of view is the interglacial deposit at Stone Point. The deposit (first described by Reid in 1893) has a small fauna and a rather larger flora which have been dated by West and Sparks (1960) as Ipswichian in age and this date provides a useful datum to which other deposits in the area can be related.

b) Channel Islands

In the Channel Islands the evidence of the Middle and Upper Pleistocene sequence is largely found in the islands of Jersey, Guernsey and Alderney as shown on Admiralty Chart No.2669 (1968). The smaller islands and many of the reefs and islets shown on this chart were visited in the course of this study but the main evidence from which the sequence of events can be built is found in the cliff sections and sea caves of the three larger islands. The large islands are portrayed individually on maps, Jersey on a 1:25,000 map produced by Hunting Surveys (1968); Guernsey on a 1:21,120 (three inches to the mile) Ordnance Survey sheet (1963); and Alderney on a Department of Military Survey 1:10,560 sheet (1966).

The Channel Islands, despite their containing in a small space evidence of many of the elements of Middle and Upper Pleistocene sequences which elsewhere are spread over wide areas, have also largely been neglected from the point of view of the study of the Pleistocene. This is in part due to the islands' constitutional status and partly due to the islands' geographical position in being English islands off the French coast. They have been to some extent ignored by both British and French geologists. Most of the publications on the islands have been in the Bulletins of the island societies (the Société Guernesiaise and Société Jersiaise). This fact has in itself assisted in hiding details of the Pleistocene sequence from a wider audience.

The only comprehensive treatments of the islands' Pleistocene sequence prior to the present study have been a review of the evidence previous to 1933 by Mourant (1933) and a chapter in Elhaï (1963) in his wider study of the Pleistocene of Normandy. Individually the islands have been studied more recently, Guernsey by George (1972 unpub.) and Jersey, principally in relation to the unrivalled Palaeolithic site at La Cotte de St. Brelade, by Burdo (1966) and McBurney and Callow (1971). However, the present study is the first attempt since that of Mourant (1933) to treat the islands as a whole and the first attempt ever to conduct a survey based on mapping and detailed fieldwork. It is also the first attempt to relate the islands' sequence to that in an area on the northern side of the English Channel and so use this information to build a sequence for the Middle and Upper Pleistocene of the English Channel coasts.

In contrast to the problems of environment and origin encountered during the examination of the south Hampshire gravels, the Channel Islands Pleistocene deposits are far less ambiguous. The raised beaches have always been regarded as interglacial in age and complicated schemes of sea level change have sometimes been erected around the field evidence (see Collenette, 1916). Cold climates in the islands have always been held responsible for the head and loess (Dunlop, 1911; Derrick, 1892).

The solid geology of the islands, composed as it is of hard granite and gneiss and indurated sediments, preserves the evidence of high sea levels much better than the soft Tertiaries of south Hampshire. This, together with the presence of many sea caves containing rock-cut notches and bench deposits, makes it possible to build up a long sequence of high sea levels. As in Hampshire the sequence can be seen to include all the raised beach levels below 130 ft. (40 m.) and so take in much of the Middle, and all of the Upper Pleistocene. Above this level no in situ marine deposits have been found and details of the sequence are less clear than below 130 ft. (40 m.).

The deposits of the Channel Islands were somewhat easier to examine than those of Hampshire. Many excellent coastal sections occur and these were closely examined. The information from these sections was supplemented by shallow augering which was particularly necessary on the higher raised beaches in Guernsey which are partly covered by soliflucted loess. As no geological maps of the Pleistocene deposits of the Channel Isles exist (the prime purpose of the work in the islands was the production of maps for publication by the Institute of Geological Sciences) all of the islands were mapped and the manuscript maps deposited with the Institute. The composition of the raised beach gravels was investigated by means of stone counts, although the higher beaches have too few exposures to allow counts to be made, so composition analysis was restricted to the 25 ft. (8 m.) raised beach.

Reference to the height of a bench or terrace remnant in the text refers not to an exact measured height unless stated but to the height envelope into which the deposit falls (see figs.17& 35). In the Channel Isles the three main height envelopes at 100 ft. (30 m.), 60 ft. (18 m.) and 25 ft. (8 m.) can be separated by the occurrence of ancient cliffs and the amount of dissection of the landscape providing three clear groups for the deposits to fall into. In Hampshire such a division is not so clear although again evidence of terrace flats occurs at 100 ft. (30 m.), 60 ft. (18 m.) and 25 ft. (8 m.). In the case of deposits which occur between the heights mentioned above a careful examination of the topographical and stratigraphical context of the deposit is conducted before placing the deposit in any of the groups above. As will be seen below the rise and fall of the level of the sea through the Pleistocene has caused the evidence of marine and fluvial erosion to appear at all heights in the landscape. Some stillstands produced more prominent features than others and it is suggested that the three main Middle and Upper Pleistocene stillstands are described by the three height envelopes above.

Reference to these levels does not necessarily imply any correlation with the sea level sequence devised by Zeuner (1945, 1946) although the present author agrees with Zeuner in regarding the three height envelopes cited above as the three major stillstands of the Middle and Upper Pleistocene.

Where possible in the present work the names of stages with which certain deposits can be correlated follow the nomenclature of Mitchell, Penny, Shotton and West (1973). Although the sequence in the Channel Islands is so extensive that a good case can be made for regarding it as a type area for the marine sequence in non-glacial areas of western Britain, no attempt has been made to put forward new stage names because of the already overcrowded mass of names in the literature (see Lexique Stratigraphique

International, Fasc. 3a, XIII). The only name not used by Mitchell et al. is the name Ilfordian, which following Kurten (1968) is used for the terrace and raised beach at around 60 ft. (18 m.) O.D.

PART I

Chapter I. South Hampshire - Introduction

a) Solid Geology

The area studied lies within the Hampshire Basin syncline and the solid geology is composed in the main of soft Tertiary sediments. On the Isle of Wight the steeply folded Chalk of the Isle of Wight - Purbeck monocline outcrops as the southern edge of the Hampshire Basin and this is the closest that the Cretaceous or earlier rocks come to the area. (A large part of the centre of the Hampshire Basin is submerged, either under Poole and Christchurch Bays or Spithead.) The Chalk forms the rim of the Hampshire Basin and the original drainage of the basin was from the "rim" inwards. This has had an important bearing on the constituents of the Pleistocene deposits in that a major part of these deposits is flint.

The main bulk of the Tertiary rocks in the New Forest area are of Upper Eocene and Oligocene age. These rocks form a variable series of fluvial, estuarine and shallow marine clays, silts and sands. Within these deposits are thin seams of lignite (especially in the Lower Headon beds of Hordle cliff), thin limestones (the Bembridge Limestone of the Isle of Wight is best known), and horizons of septarian nodules, some of very large size, which are especially well marked in the Lower Barton beds of Highcliffe. At this last mentioned site these iron concretions may reach a length of over 2 ft. (60 cm.) for elliptical nodules and even larger for the tabular masses sometimes exposed to examination on the foreshore by cliff falls. At Becton Bunny (SZ 252926) the Middle Barton beds also exhibit spectacularly large iron concretions (see Plates 30 and 31).

Because of the soft nature of the Tertiary deposits and their lack of resistance to erosion, they have few natural outcrops inland from the coast. The only sustained section is in the cliffs from Highcliffe (SZ 202929) to Milford (SZ 284916) where, except at the eastern end of the section, very active cliff erosion causes a near vertical cliff to occur. Inland virtually the only places where the Tertiaries are exposed are in excavations such as the gravel pits at Pennington west pit (SZ 308930) where the green (when freshly dug) clay of the Headon beds can be seen in the floor of the pit (see Plates 9 and 10).

The Pleistocene gravels of the New Forest show only slight evidence of erosion of the underlying Tertiaries in their constituents. The large septaria of the coastal sections mentioned above quickly break down and only very occasional fragments occur in the gravels, and these invariably occur in the finest part (3350 microns) of the gravel fraction. The soft sands and clays probably provide much of the material which makes up the sandy and silty lenses in the gravel. It is also likely that much of the sand in the brickearth is of Tertiary origin and locally derived although some of the material in the brickearth may be of distant derivation and have been brought to south Hampshire by wind action.

The Tertiary deposits of the area studied contain very little flint or chert and indeed only very occasional bands of pebbles in otherwise sandy or clayey deposits*. As the Lower Tertiary outcrop is traced westwards it becomes increasingly stony until in Dorset both the Reading and Bagshot Beds are primarily gravel (Geol.Surv. Regional Handbook, 1936). Most of the very round and generally small (one inch, 2.5 cm.) calibre pebbles in the Pleistocene gravels must have come via the Upper Solent River (or present R. Stour and R. Frome) from the Bagshot Beds outcrop around Wareham and the Reading Beds outcrop near Dorchester. These derived pebbles are mostly quartz, chert and flint but some far travelled material also occurs

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* Such pebbly bands can be seen in the Upper Bracklesham beds of Barton cliff. The pebbles there, which are typical of those in the local Tertiary deposits, are small (2.5 cm.) and are very well rounded.

including schorl, veined grit and radiolarian chert. These pebble types make up a small but persistant constituent of the Pleistocene gravels throughout the south Hampshire area (Green, C.P., 1965, 1973, 1974). (Tables of grain-size and composition will be found in Table I.) The presence of the chalk has had a great influence on the Pleistocene deposits of the area in that it has supplied up to ninety per cent of the material in these deposits (the flint) although the chalk is entirely absent itself from these deposits.

b) Relief and drainage pattern development

The present drainage pattern of south Hampshire is the result of the influence of the mantle of superficial deposits coupled with the frequent climatic and base level changes of the Pleistocene. The relief of the Tertiary outcrop is due to the effects of these changes rather than any lithological differences.

The New Forest gravels rise to the north-west from the present coastline. The maximum heights attained by them are 420 ft. (128 m.) in the north-west at Bramshaw Telegraph (SU 230142) and 427 ft. (130 m.) on the northern side of Arreton Down (SZ 548872) and Mersley Down (SZ 558874) on the Isle of Wight. These very high gravels cover small areas only as do those at around 360 ft. (109.7 m.) on St. George's Down (SZ 513865) on the Isle of Wight, and indeed as do all the areas of gravel mapped by Everard (1954b) above 150 ft. (45.7 m.). Below 150 ft. (45 m.) the gravels become much more extensive and Everard (1954b) cites five levels below this height trending south-west to north-east inland from the coast from Barton (SZ 239930) to Southampton Water.

The two main descriptions of the terraces (as distinct from the deposits) were by Green (1946) and by Everard (1954b). In the area below 150 ft. (45 m.) Everard describes terraces at 150 ft. (45 m.), 100 ft. (30 m.), 70 ft. (21 m.), 35 ft. (10.7 m.) and 15 ft. (4.6 m.) above O.D.

Green, who worked in the Bournemouth area, prefers to attribute the terraces to a "Boyn Hill" terrace at 150 ft. to 120 ft. (45 m. to 36.6 m.), an "Upper Taplow" terrace at 120 ft. to 90 ft. (36.6 m. to 27.4 m.), a "First Lower Taplow" terrace at 100 ft. to 50 ft. (30 m. to 15.2 m.) (Green correlates this terrace with the Bransgore terrace of the Avon at 70 ft., 21.3 m.) and a "Second Lower Taplow" terrace below 50 ft. (15.2 m.) and in the floors of the north-south streams cutting the Bournemouth chines.

As can be seen from these heights it is not clear exactly what are the limits of each terrace. Complications in measuring the height of terrace remnants abound. The fact that individual terraces are without bluffs to back them has long been realised and indeed the mapping of the Geological Survey in referring to the gravels as plateau gravel clearly shows the place the gravels occupy in the landscape. Bury (1923) suggested that the gravel-free areas, such as that of the upper Beaulieu River, were due to the gravel "protecting" the Tertiaries by allowing precipitation to percolate through it without eroding the surface. The impermeable Tertiaries on the other hand were exposed to the full force of erosion and so were reduced in level. This suggestion was later restated by Everard (1954b). Whether this process occurs or not (and there is no clear evidence for or against it), some authors, notably Everard (1954b) have followed it further by suggesting that the water percolating through the gravel lowers the Tertiaries and cambers the edges of the gravel "blocks" and hence causes confusion in identification of terrace levels*.

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* It seems that this cambering does not in fact occur under climatic conditions as they are at present. In the long cliff exposure from Highcliffe to Milford despite the presence of many springs and seepages from below the gravel no cambering of the gravel can be seen. These seepages are often perennial (or quasi-perennial) and even in the driest weather still continue to flow, with the greatest flow rates, as would be expected, occurring over the clayey facies of the Barton beds at Barton (SZ 239930).

The transverse slopes of the terraces are often large. Some examples are given by Green (1946). He states (1946, p.95) "The Boyn Hill near Bournemouth shows falls in places of over 15 ft. (4.6 m.) per mile, the Upper Taplow falls 12 ft. (3.6 m.), and the First Lower Taplow consistently falls about 18 ft. (5.5 m.) per mile". These slopes are in some contrast to the longitudinal slopes which are often slight or absent as far as they can be measured. Green (1946) generally refers to the terraces to the east of the Avon as the "horizontal segments" because of this low slope. Everard (1954b) suggests that if any downstream gradient exists in these terraces it is below 6 inches per mile (15 cm. per 1.6 km.) which for his purposes he regarded as imperceptible. The examination of an area of separated blocks of gravel, which in many respects seems to be a continuous sheet of gravel divided only by recent erosion, is greatly complicated by the greater transverse than longitudinal slope. Correlations across the terrace may make for artificially wide limits for the upper and lower edges of a terrace while the extremes of Pleistocene erosion and base level change may make the inclusion of levels of different ages in the same terrace possible. Even the precise measurements of Everard do not give sufficient grounds on their own for dating certain levels and they may even lead to the assumption of

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In fact where slope failure in the cliffs occurs the gravel collapses into its constituent pebbles rather than staying in a coherent mass to take part in any cambering. The gravel in fact will withstand little undermining before it collapses and the bulldozing of parts of the cliff at Barton in 1969 as a stabilisation work had, by 1971, resulted in the formation of large talus cones, but no cambering of the gravel had occurred and in the areas between the talus cones a still vertical cliff profile remained.

Under a different climate in the Pleistocene, however, it is possible, with frozen ground conditions, that the cambering described by Bury could take place as freezing would perhaps give the gravel the cohesion necessary to keep it in a block while the underlying Tertiaries were sapped. (It may be, however, that the very conditions necessary to consolidate the gravel so that cambering could take place, namely freezing of the ground, would inhibit percolation of water and sapping of the Tertiaries.)

spurious degrees of accuracy. The small differences in the heights of some of the terraces mentioned by both Green and Everard may be of little significance and separated by only short periods of time within one episode of deposition.

In the landscape of south Hampshire there are three main groups of terraces. The highest occurs between 150 ft. and 90 ft. (45 m. and 27 m.) with a possible break between the two levels around 110 ft. (34 m.). Into this "height envelope" comes Green's "Boyn Hill" and "Upper Taplow" and Everard's 150 ft. (45 m.) and 100 ft. (30 m.) terraces. The intermediate terrace lies between 65 ft. (19 m.) and 50 ft. (15 m.) and takes in Green's "First" and "Second Lower Taplow" terraces and Everard's 70 ft. (21 m.) terrace. The lowest terrace occurs below 30 ft. (9 m.) and takes in Everard's 35 ft. (10.7 m.) and 15 ft. (4.6 m.) terraces.

The separation of these three terrace groups by the present author is largely based on the recognition in the field of the most significant slope breaks in what seems at first to be a continuous sheet of gravel. These breaks between the terraces can be seen most clearly in the long cliff section between Milford and Highcliffe but even here they are obscure. Further east differentiation of terraces is very difficult except in rare cases (see Plate 2) and even exact measurements such as those undertaken by Everard are of little use. The work of Green and Everard in mapping the deposits has, however, provided a valuable base from which all subsequent work can start.

The main streams bounding the area under study (Avon, Test and Itchen) have occupied their present valleys for a considerable period of time, perhaps throughout the Pleistocene, but the smaller streams between these systems show two main directional components which may represent at least two periods of drainage pattern development. Reid, 1902b, p.33, figures a map which shows the Upper Avon flowing into Southampton Water and the Lower

Avon being only a small tributary of the Stour. It is extremely doubtful if this drainage pattern ever occurred - as Reid later realised, see White, 1917 - because the Lower Avon valley gives every indication of great antiquity in its present course.

However, the mechanism proposed by Reid (1902b) for the capture of his upper Avon by the lower, namely headward erosion of streams due to a fall in base level, and hence the shortening of the route to the local base level for north-south trending streams, has operated fairly recently. Preferential rejuvenation of the north-south drainage at the expense of the north-west to south-east streams has been responsible for several captures on the small streams of the Beaulieu and Lymington River systems.

The main component in the original drainage pattern of the area between the two main rivers was a north-west to south-east one. The upper Lymington and upper Beaulieu rivers both exhibit this trend and indeed may both represent the dismembered parts of the same system (Tremlett, 1965). The Avon Water and the upper parts of the several small streams feeding Sowley Pond (SW 378965) and Pylewell Pond (SZ 361954) also follow this north-west to south-east trend. This pattern has been dismembered by a later element trending in a north to south direction exemplified by the lower Lymington and lower Beaulieu Rivers. This disruption of a north-west to south-east system by a north-south one was originally suggested by Tremlett (1965) for a small area of the Beaulieu River system but the principle seems to be applicable to all the minor streams between the Avon and Southampton Water. Careful examination of the 1:25,000 map shows several examples in each of the Lymington River, Beaulieu River, and Avon Water systems of capture of minor streams by headward erosion from the south.

The two main trends of the minor stream pattern follow the two components of slope of the terraces of the Solent River. This coincidence between the slope of the terraces and the direction of flow of the minor streams is very marked. The north-west to south-east streams follow the downstream slope of the Solent River (at least to the west of Beaulieu) while the capturing north-south element follows the transverse slope at nearly right-angles to the trunk stream. These minor streams were probably initiated on a cover of gravel or alluvium of the Solent River and proceeded to evolve their present pattern in response to the changes in base level of the Solent. While the trunk stream flowed at levels over 100 ft. (30 m.) above the present, the direction of the minor drainage seems to have been parallel to the Solent. As base level changes caused the Solent to cut its channel down and to flow at a lower level, large expanses of steeply sloping (relative to the gentle downstream slope) transverse terrace surfaces were left free from periodic disturbance by the shifting, braiding channels of the Solent and so developed their own "pseudo-consequents". These streams, with the advantage of steeper slope and shorter course to the local base level (i.e. the local level of the Solent River) eroded progressively northwards to dissect the earlier north-west to south-east system.

The evidence for these captures can be seen on any of the streams from the area between the Avon and Southampton Water. Tremlett (1965) describes a wind gap at (SU 325035) east of Balmer Lawn where the north-south section of the Lymington River has captured the north-west to south-east trending headwaters of the Beaulieu River. Whether this dry valley described by Tremlett is a true wind gap or not, a sharp southwards bend in the Lymington River occurs at this point and a distinct change in valley form from a wide, open valley to a narrow steep sided trough occurs at this point (see photos and cross profiles, Fig. 10, Plates 4-6). A similar change in valley cross profile occurs on the Dane's Stream and Avon Water and several extremely sharp and right-angled junctions can be seen where the Walkford Brook has captured many of the first order headstreams of the

Dane's Stream. (Many of this series of captures can be seen on the 1:25,000 map and have been examined on the ground.)

These valley excavations and captures were conducted on a cover of gravel deposited by the Solent River probably under a more severe climate than the one in the area at present. Discussion of the exact climatic regime under which the north-south sections of these valleys were cut will take place below. The form of these valleys such as that of the Dark Water (SZ 453985) however is trough-like with steep sides and very flat bottoms over which a very reduced stream, compared to the size of the valley, proceeds. These streams may best be described as climatic (or run-off) misfits because their discordant relationships with their valleys is due to climatic change and a great decrease in run-off. (Some of the streams in these deep trough valleys are very small indeed. The valley cut through the 60 ft. (18 m.) stage near Norleywood (SZ 355974) has a small stream in it which is easily fordable by ordinary motor vehicles while the small valley below Nelson's Place (SU 471005), although of considerable size (25 ft. (8 m.) deep by 300 ft. (91.4 m.) wide) has all its drainage contained in an 8 ft. (2.4 m.) wide "cut" (see Plate 8).

While the minor drainage of the area is of late development with its final stage being perhaps very recent (see below, Chap. VI) as has been stated above, the basic pattern of the major streams has probably remained unchanged through the Pleistocene. However, considerable detail changes in the courses of the Avon and Stour particularly seemed to have occurred. The Avon may have been the major contributor to the flow of the Solent River, and it was certainly one of the main contributors of sediment to the trunk stream (see above). Because of the power of the Avon it seems to have diverted the Solent River southwards at its point of entry of the main stream. The junction of the Stour and Avon must certainly have been farther south even beyond the present coast as the several terrace levels on

Hengistbury Head (SZ 178907) and below Highcliffe Castle (SZ 202931) demonstrate. A fine example of a buried river cliff occurs in the 25 ft. (8 m.) stage below Highcliffe Castle where a gravel filled channel, backed by a bluff, can be seen. The ancient bluff and terrace below it are covered by coarse sand which is probably soliflucted from the local Bracklesham beds in which the bluff is cut*. This bluff provides evidence for the junction of Avon and Solent being beyond the present coast in 25 ft. (8 m.) times at least.

The stream junctions being further to the south than at present may have pushed the Solent south also causing it to impinge on the chalk of its south bank so hastening the final break-up of the Solent system. The entry of the Test and Itchen into the Solent may also provide an example of powerful tributaries diverting the main stream to the south. The role of these diversions in the final destruction of the Solent will be discussed more fully below (Chap. VI).

The Isle of Wight drainage system has been subject to the same influences as that of the New Forest but the north-south element is more dominant than on the mainland and the basic pattern may be of greater antiquity than the relatively youthful mainland drainage net. On the Island very little of the south-west to north-east element of the mainland exists. This may be due in part to the greater influence of the solid geology on the drainage pattern. A considerable amount of the Island's drainage rises on the chalk and flows on its outcrop for some distance and it is probable that the original watershed on the chalk was in position early in the Pleistocene and subsequent events modified it but slightly leaving a greater part of the Island, particularly at its western end, subject to the more normal processes of drainage development on a solid rock base rather than to development from superimposition on a homogenous cover of gravels as on

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* See sketch in White, 1917.

the mainland.

The lower courses of the Island's streams are more drowned than those of the mainland, i.e. the Newtown River (SZ 417919), western Yar or Medina. To the north of the chalk outcrop none of the streams has any large tributaries and the north-south trench-like valleys are similar to those of the mainland and well marked. The Medina below Blackwater (SZ 506864) is only joined by two second order streams out of a total of thirteen tributaries of first or second order joining this stream. This may indicate a recent origin for the lower courses of the major north-south streams with no stream having had time to establish ascendancy over its neighbours. A similar lack of tributaries can be seen on the lower Lymington and Beaulieu Rivers though here the discordant relationship of the lower courses of these streams to the upper courses is more readily apparent. It may be that while the lower Medina and the other north flowing streams of the Island were initiated on a cover of Solent gravel like the lower Lymington and Beaulieu Rivers, the course they followed was merely a re-occupation of their old courses from the era before the Solent gravels were deposited rather than entirely new courses like those followed by the north bank tributaries of the Solent.

Despite the greater simplicity of the drainage net on the Island some captures have occurred. At Merstone (SZ 528842) the eastern Yar seems to have captured the headwaters of the Medina. This capture may be more due to the structural influences of the outcrop of the lower Greensand than to any differences in slope as on the mainland. Headward erosion along the impermeable Greensand may have been assisted by accelerated coastal erosion in the Sandown area sending successive rejuvenations up the Yar without a change in sea level. Similarly coastal erosion has beheaded the western Yar leaving its former headwaters hanging above Brightstone Bay (SZ 445798) and forming the famous chines. These deeply incised valleys are similar to the "Bunnies" of the mainland*.

The minor drainage of the New Forest can be seen to be of some complexity. The exact stages in its development will be further considered below.

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* The southern end of this beheaded Yar Valley is only at 10 ft. (3 m.) above present sea level at its lowest point and so only a small rise in sea level would sever West Wight from the rest of the Island. This process was presumably responsible for the destruction of the chalk ridge west of the Needles in the Late Pleistocene.

Chapter II. The Gravel.

Previous workers in the New Forest (principally Green, 1946, and Everard, 1954a) concentrated on the terrace surfaces to the exclusion of the gravel deposits which underlie these surfaces. As many of the structures and features of the sedimentology of the gravels reoccur on several of the terraces examined, no attempt has been made to discuss these features terrace by terrace. The main feature which distinguishes one terrace from another is the height of the terrace surface so in this chapter first the deposits of the terraces will be described and then the terraces themselves.

a) Introduction

The gravel covers the terraces everywhere in the area where the terrace surfaces were examined except perhaps on the 25 ft. (8 m.) stage of the western Yar where no clear exposures of gravel could be seen. (However, even here fields on the terrace surface had stones on the surface and a stony soil so gravel was probably present below the surface.) Everard (1954a) states that the 25 ft. (8 m.) terrace surfaces around Marchwood (SU 384100) and Southampton Common (SU 415145) are cut partly in the solid and partly on the gravel, while White (1917) describes a terrace at Cliff End, Highcliffe (SZ 202931) where an old cliff in the Avon's 25 ft. (8 m.) stage is partly cut in the solid Bracklesham Sand and partly in gravel. It has not been possible to verify Everard's observations due to the lack of exposures in the areas concerned while at Cliff End the exposure described by White is now obscured by a sea wall and fill so the relationship of the gravel to the Tertiary deposits cannot be made out.

b) Gravel thickness

The thickness of the gravel is fairly uniform on the terraces at around 15 to 20 ft. (4.6 m. to 6.1 m.) although some irregularities occur in the top of the Tertiaries at Hall's Pit (SU 450019) in the

60 ft. (18 m.) terrace, and variations in the thickness of the gravel therefore occur. As much as 30 ft. (9.14 m.) of gravel is present in some parts of Hall's Pit. (An exact measurement of gravel thickness is difficult at Hall's Pit because of the lack of clear exposure of the underlying Tertiaries.) Codrington (1870) suggests that the gravel at Hordle (SZ 269920) in the 60 ft. (18 m.) terrace was "18 to 20 yards thick" (i.e. 16.5 m. to 18.3 m. thick) in 1789. He states that the cliff is retreating at the rate of a yard (.914 m.) per year so that these great thicknesses of gravel were in situ only 60 to 80 yards (54.9 m. to 73.15 m.) from the present (i.e. 1870) coastline. Codrington also describes exposures around half a mile (804 m.) inland of these cliff exposures which are only 3 ft. (91.44 cm.) thick. This tremendous thickening of the gravel may be due to the presence of a buried channel in the 60 ft. (18 m.) stage and this possibility will be discussed further below (see section, Fig. 18). Certainly the only comparable thicknesses of gravel in the area at present are those which fill the Devensian buried channel off Spithead. Whitaker (1910) describes a 90 ft. (27.43 m.) thickness of gravel and sand in the well boring for Noman Fort (SZ 639938) and although these sediments are stated to be "recent marine deposits" and some of the thickness may be post-Pleistocene, the bulk of these gravels must be a buried channel fill, probably of late Pleistocene age.

In addition to the irregularities of the base of the gravel causing the deposits to thicken as at Hall's Pit, in some areas (also in Hall's Pit and in Pennington East Pit) the gravel thins over the underlying Tertiaries. At Hall's Pit a "projection" into the base of the gravel seems to take the form of an eyot-like feature orientated in a parallel direction to the flow of the stream which deposited the gravels as shown by the current bedding. The gravel was up to 20 ft. (6 m.) thick on either side of this projection of stoneless sand but no gravel could be seen on the "eyot" itself. A small thickness of gravel on the "eyot" may have been removed by quarrying as the sand of the eyot was being exploited by the gravel diggers and the relationship of the gravel on either side of the "eyot" was obscured by back-filling in the pit but enough of the exposure was still visible to show that considerable thicknesses of gravel had been replaced by Tertiary sand for a narrow area of the pit (see Fig. 15).

At Pennington (SZ 311936) in the 25 ft. (8 m.) terrace, 20 ft. (6 m.) of horizontally bedded gravel in the west pit is replaced in the east pit (100 yards - 91.4 m. - to the east) by only 10 ft. to 15 ft. (3 m. to 4.6 m.) of very sandy gravel. According to the quarrymen, the gravel thins away to nothing on the north side of the east pit (although this proved impossible to verify due to back-filling of the pit with rubbish). However, 200 yards (182.8 m.) further to the north a face left beside an old grassed over pit reveals a 15 ft. (4.6 m.) thickness of gravel. It seems possible that a similar "eyot" occurs in this pit as well as at Blackfield but the details of it are unfortunately even more obscure.

c) Gravel composition and particle shape

at the outset of this part of the present study it was hoped that examination of the composition of the gravels of the terraces of south Hampshire would provide some evidence of their origin and perhaps assist in suggesting an environment of deposition. Reference to the tables of composition (Table 1) shows that there is little change in gravel composition from terrace to terrace. Except for a rise in exotic material in the 100 ft. (30 m.) terrace at Highcliffe (probably associated with a diversion to the east of the Avon), no significant trends in the amount of erratic material present could be found. Almost all the gravel samples show over 80% of flint with quartz as the next most numerous material. The quartz is most abundant in the $\frac{1}{4}$ inch (6.25 mm.) or 1/8 inch (3350 micron) fraction. (Bury, 1923, states that quartz is most abundant in the ½ inch (12.5 mm.) fraction in the Stour gravels to the west of the Avon.) The majority of quartz in the finer fractions to the east may reflect the increase of finer material from the Avon (Green, 1965 unpub.). Whatever size fraction the quartz occurs in, it is always very well-rounded and so is certainly derived from the Tertiaries to the west as described in Chapter I. The other minor constituents of the gravel are an assortment of Lower Greensand chert and sandstone (the latter often very bleached and weathered), small fragments of sarsen, occasional very well-rounded fragments of volcanic rock and pebbles of sandstone and siltstone of lower Palaeozoic aspect. The well-rounded constituents all have their origin (as far as south Hampshire is concerned) in the Tertiary pebble beds although some of the sarsen and greensand may have been rounded in the Pleistocene by the constant battering of the harder flints. The pebbles derived from the Tertiaries show a markedly greater degree of roundness than the mostly Pleistocene eroded flint because the Tertiary marine conditions provided a far better rounding environment than the fluvial conditions of the Pleistocene in whose deposits they now rest*.

Apart from these "erratic" materials the main constituent of the gravel is flint. The amount of flint from the Lower Tertiaries to the west has been stated (above) to be only a very small proportion of the total amount of flint in the Pleistocene gravels, so the major initial source for the flint must have been the chalk outcrop. The Lower Chalk

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* Bury, 1923, described pebbles of granite and porphyry as well as the "erratic" types described above in his investigation of the Stour gravels. Bury also states that the quartz percentage in the gravels west of the Avon is as much as 25% for the gravels of the Solent and 10% for the gravels of the Stour. These percentages drop markedly to the east of the Avon probably due to the "dilution" of the quartz by the Avon flint.

and Upper Chalk of the Isle of Wight and all three divisions of the chalk on the mainland are flinty to a greater or lesser degree and vast amounts of flint must have been released into the rivers of the area during the greatly accelerated erosion of the Pleistocene.

At some localities in the area under discussion the flint is fresh, having only recently (relative to some of the polycyclic material present in the gravels) been eroded from the chalk. At Cadland (SU 475005) in the 25 ft. (8 m.) terrace, massive cobbles of flint up to 12 inches (30 cm.) by 4 inches (10 cm.) occur both in the gravel and also in otherwise stoneless sandy lenses within the gravel. These cobbles preserve their white chalky patina almost undamaged and have been transported only a short distance, perhaps by floating ice in the case of the cobbles in the sandy lenses. In addition to the small amount of fresh flint in the gravels there are also present a few blue/grey flints which appear to have been favoured by Palaeolithic man for working into hand axes. Almost all of the worked flints found during this work have been of this blue/grey flint, and the Acheulian implement from Hall's Pit (SZ 450019) was of this material (see Plate 32).

Apart from these minor examples, however, almost all the flint in the south Hampshire gravels is red or reddish-brown and iron stained. Some horizons even have iron concretion layers in them in a discontinuous fashion. Codrington (1870) thought that this staining of the gravel could be used to separate an upper (less stained or bleached) gravel from a lower (red or very oxidised) gravel. While the top of the gravels is often bleached, there is no uniformity in the depth of bleaching, as would occur if the colour change was a depositional feature, so no differentiation on these grounds can be made. At Stone Point the gravel underlying the organic deposits is characteristically far more oxidised than the 25 ft. (8 m.) terrace gravel which overlies them. However, these two gravels can be divided on strict stratigraphical grounds, so the colour is of no significance.

In Hall's Pit in the summer of 1969 the western face of the pit was cut back to reveal two continuous bands of black staining on the stones, one at a depth of 12 ft. (3.6 m.) and the other at a depth of 6 ft. (1.8 m.) from the surface. Both these bands of staining were around 6 inches (15 cm.) thick and occurred as coatings on individual stones and sand grains. Samples from these horizons were taken and the coatings when analysed in the laboratory were found to be manganese dioxide. The manganese dioxide did not act as a cement to the gravel but individual sand grains were stuck to the stones by it.

These manganese horizons were continuous over a distance of 300 ft. (91.4 m.) and continued into the face of the pit for up to 3 ft. (91.4 cm.) as shown by the irregularities of the face cut by dragline used in the pit. The occurrence of manganese dioxide in gravels is often evidence of fluvial deposition (Woodward, 1909, cites several examples of manganese in the gravels and even brickearths of the Thames) as it is concentrated by fluviatile vegetation. It seems unlikely that water plants could grow in a stream spreading gravel of the calibre of much of the material in Hall's Pit so the manganese may be due to a primary precipitation (as suggested by Woodward) or to precipitation from groundwater with the two horizons in the face at Hall's Pit representing a permafrost table or some other post-depositional surface.

The constituents of the gravel, the individual pebbles, show no well rounded examples, with the exception of the "Tertiary" pebbles described above, which are mainly confined to the smaller size grades. Even in their preferred size grades these well rounded pebbles are in a minority and the overwhelming majority of the pebbles are angular flints with only slightly rounded edges and fresh fracture scars. The very well rounded flint cobbles which occasionally occur in the gravels are most probably derived from the Eocene of the north of the Hampshire Basin (Green, 1965, unpub.).

Despite the fact that many of the pebbles in each terrace may have been through several different episodes of erosion through the Pleistocene it is only these "Tertiary" pebbles that are well rounded. Each terrace was built in part by cannibalisation of its immediate predecessor but the individual pebble was never moving through the system long enough for it to be well rounded in the Pleistocene, especially not in a fluvial environment*.

d) <u>Boulders in the gravel</u>

In a few localities from Milford (SZ 288915) eastward large boulders of sarsen occur in the gravels of the 60 ft. (18 m.) and 25 ft. (8 m.) terraces. The origin of these hard quartzites is obscure but they may represent the last remnants of an eroded Tertiary formation or perhaps just silcreted remnants of one of the pure Eocene sands such as occur in the Bagshot or Barton beds. These sarsens characteristically occur as very large boulders in the gravel although pebbles of many sizes down to the smallest gravel fraction (0.07 ins., over 2 mm.) occur. Although these boulders can be found at all levels in the gravel (Codrington, 1870, and Bury, 1933, cite examples of boulders of unstated size 8 ft. (2.5 m.) above the top of the Eocene gravel boundary), it seems that the largest of them occur at its base. Bury (1933) suggests that the boulders may be in situ where they formed on top of the Eocene. This seems unlikely as the very large sarsens described below from Pennington (SZ 308930) were resting on the Headon beds clay which is quite unlike the coarse quartz sandstone of the sarsens so could hardly have provided the materials for their concretion. Also the surface below the gravel at Pennington is not a buried Eocene surface but the bench of the 25 ft. (8 m.) terrace which was cut in the Upper Pleistocene.

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* The period any particle spends in traction and is hence subject to wear is very small compared with the length of time a particle spends in storage in a contemporary deposit - Leopold, Wolman & Miller (1964).

At Milford-on-Sea (SZ 288915) well rounded 12 to 18 inch (30-45 cm.) boulders of sarsen occur throughout the gravel of the 25 ft. (8 m.) terrace. Photographs in Everard, 1952 (unpub.) show some of these boulders which appear to be considerably larger than any at present visible in the cliffs. In Pennington west pit (SZ 308930) conspicuously water-worn (i.e. covered with chatter marks and percussion scars) but angular sarsens can be seen beside the pit. The very large size of these blocks (up to 5 ft. by 2 ft. by 2 ft. - 150 cm. x 60 cm. x 60 cm.) and their original position (one is in place in the bottom of the gravels while the others were dug from this position according to the quarrymen) would seem to suggest that Bury (1933) was correct in attributing their formation to concretion on top of the Eocene and in suggesting that they are in situ. However, as mentioned above, the local Headon clay and the quartzite of the sarsens are totally different and as the blocks are covered on all visible surfaces with marks indicative of transport in a gravel moving environment the blocks cannot be in situ. It is unlikely that with the shallow stream gradients which must have been present at the time of the deposition of the 25 ft. (8 m.) terrace, the blocks of sarsen could have been moved by fluvial action alone, whatever the increase in discharge due to accelerated run-off, and it is most likely that the blocks of sarsen were transported to their present position by drift ice in some form*. Some of the smaller boulders figured by Everard are however sufficiently rounded to have been at least partially formed by fluvial action although this would not take long, as many of the sarsens are poorly cemented.

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* J.B. Bird, 1967, found that the largest boulders in the channels of the Yukon and Mackenzie Rivers of Canada were pressed into the river bed by ice to form a boulder layer. The presence of large sarsens at the base of the gravel at Pennington may indicate the operation of a similar process in action at the time of the deposition of the 25 ft. (8 m.) terrace gravels.

e) Sediment blocks in the gravel

At Barton Cliff (SZ 239929) stabilising operations during the summers of 1968 and 1969 resulted in a clean profile cut into the 100 ft. (30 m.) terrace. Several examples of blocks of silt and blocks of sand were examined (see Plate 13). In a north-south section cut to allow earth moving machinery on to the under-cliff a large block of coarse, ferruginous sand lies in the gravel. The extent of this sandy block is difficult to ascertain as only one dimension is revealed in the section but this one face alone is 5 ft. by 3 ft. (1.52 m. x 91.4 cm.) in size so the block must be quite a large one overall. The origin of this block is difficult to decide but, in view of the fact that it is entirely surrounded by gravel, it must have been incorporated in the gravel in a partly consolidated condition although at present it is completely unconsolidated. This block of sand may have been incorporated in the gravel in a frozen state and quickly buried out of the reach of erosion. The block is not a block of the local Tertiary rocks incorporated in the gravel, because it contains flakes of flint (up to about 10% of the block, and easily recognisable by their whiteness in contrast to the ferruginous staining of the quartz grains which make up the other 90% of the block) which none of the local Tertiaries does. Also the Tertiaries are rarely iron-stained while the Pleistocene deposits commonly are, so it is probable that this block of sand is an eroded piece of an earlier Pleistocene deposit incorporated in the gravels of the 100 ft. (30 m.) stage.

Near to this block of sand are other inclusions in the gravel. These blocks are composed of more silty sand than the previously described one and one of them rests at an angle of 25° to the horizontal in the gravel. This block was also revealed by the cliff works in 1968-9 (see Plate 14) but by 1972 was obscured by vegetation and silt washed from above. The block is around 2 ft. (60.8 cm.) thick and extends up to 10 ft. (3.0 m.) into the gravel. The grain-size analysis of samples taken from this block show a marked affinity with the grain-size distribution in samples of the brickearth (compare histogram No. 36 on figure 8 with the others on this graph) and the block and the others around it may be blocks of almost contemporaneous material incorporated in a frozen state in the gravel. Further force is given to this suggestion by the presence of a fine seam, perhaps 1 inch (2.5 cm.) thick, of gravel which lies below this silt block and appears to have been forced into the underlying Upper Barton sands by the weight of the block at the time of deposition*.

As well as the large block of silt described above, the section at Barton contains numerous smaller inclusions of various shapes from blocky to lobate. Some of these silt blocks were so curved that it was originally thought that they were formed by cryoturbation; but examination of the gravel surrounding the blocks gives no evidence of any disturbance, so the variety of shapes may be due to differential erosion of the block in its frozen state by moving flint gravel at the time of its incorporation in the gravel.

Further inclusions of aggregates occur in the gravel at Cadland (SU 473003) where the bottom 9 inches (22.5 cm.) to 12 inches (30 cm.) of the gravel of the 25 ft. (8 m.) terrace are composed of rolled balls of clay/silt up to 6 inches (15 cm.) in diameter. These balls rest in a thin bed of sandy silt, little thicker than their diameter. These balls may have been eroded from the clay of the Upper Headon Beds which outcrops

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* Wymer, 1968, describes several blocks of chalky coombe rock which were incorporated in the Taplow terrace of the Thames near Iver, while Shotton, 1968, describes blocks of silt similar to those at Barton incorporated in the bottom of the Avon No.2 terrace at Brandon. This terrace was formed in the aggradation which marked the onset of the late Devensian glaciation. Czudek and Demek, 1970, while not principally concerned with fluvial erosion, incidentally provide evidence for how silt blocks could be incorporated into fluvial gravels. They suggest that thermo-abrasion niches under-cut the banks of streams causing them to collapse. If this occurs during bankful, as it well may, the fallen blocks of silt shown in Czudek and Demek's diagram, p.106, would soon be buried in gravel.

at sea level about 2 miles (3.2 km.) to the south-west at present.

Whatever the origin of these balls they must indicate very limited transport as such soft pebbles would soon be destroyed in a gravel moving environment. These clay balls at Cadland probably owe their preservation to the rapid erosion and deposition which occurred in the braiding streams of the Pleistocene. (Further discussion of the environmental implications of these clay balls will be undertaken below, Chap. IVb.)

f) Current bedding

Previous writers on the terraces of south Hampshire, notably Everard (1954a) and Green (1946), paid little attention to the composition of the gravels and likewise almost disregarded the structures within the gravels. Everard (1954a) states that the bedding of the gravel is horizontal in all in situ sections, while Green (1946, 1947) makes no mention of structures in the gravel at all. In fact, although much of the gravel is horizontally bedded (see Plates 9 and 10), there are considerable current bedded structures visible in many exposures. Current bedding is especially noticeable in sand lenses within the gravel. At Milford (SZ 285915), where the cliff section in the 25 ft. (8 m.) stage has half of its thickness in sand at some points, fine gravel is mixed with the sand and provides well marked lines of pebbles to point out the structures.

Measurements were made of the current bedding directions wherever they could be found. The directions obtained were plotted on the map (figure 6). The directions were measured by means of a simple compass/clinometer and only sites where it was certain that a true direction of the current bedding was being determined, i.e. only faces with two dimensions visible, were measured. Uni-dimensional faces were ignored as it was found impossible to avoid just measuring the trend of the face of the quarry rather than the current structures. From these measurements twelve current bedding directions were obtained, three on the 100 ft. (30 m.) terrace, four on the 60 ft. (18 m.) terrace and five on the 25 ft. (8 m.)

terrace. All of these directions fell between 220° and 340° north, all thus indicating a broad easterly flow for the water depositing the gravel. All the angles of the individual current bedded laminae were below 25° with the determinations in sand lenses dipping at a slightly greater angle than those in gravel (15° average against 11° average). These low angles of dip for the current beds are probably due to the fact that the beds were deposited by fluvial action in shallow water as the level of the stream fell from bankfull.

At Hall's Pit (SU 450020) the current bedding is accompanied by imbrication structures with the pebbles pointing in the opposite direction to the current bedding i.e. upstream as opposed to the downstream trend of the current bedding. Rust (1972) suggests that upstream imbrication is typical of a braided stream as far as "platy" pebbles are concerned. The angular flints typical of the south Hampshire gravels presumably behave as "platy" pebbles rather than Rust's other class which is "roller" shaped pebbles. Most of the flints in south Hampshire are far too angular to be considered as "rollers" in any way. Hall's Pit is the only site where definite imbrication structures can be seen. At Barton (SZ 239930) and Highcliffe (SZ 215931) erected stones can be seen in the gravel but these have no coherent imbrication direction and are probably due to frost heaving.

g) Channels in the gravel

Previous writers, especially Green (1946), regarded the gravels of south Hampshire as a veneer spread across benches cut into the Tertiaries. As has been shown above, the gravel is by no means the uniform thickness described by Green or Everard (1954a). The gravel also contains finer material channelled into its top at several places. At Hordle Cliff (SZ 263922) in the 60 ft. (18 m.) stage, a sand filled channel 8 ft. (2.43 m.) deep and apparently 500 ft. (152 m.) wide is cut into the gravel. The channel is cut entirely in the gravel and is separated from the

Tertiaries below the gravel by 2 ft. (60 cm.) of gravel. The channel's sandy fill feathers out evenly on each side of the centre of the channel forming a symmetrical open profile. A similar wide, shallow, channel occurs in the 25 ft. (8 m.) stage at Hengistbury Head (SZ 180905) where a 3 ft. (91.4 cm.) deep, apparently 300 ft. (91.4 m.) wide channel filled with coarse sand is set in the gravel. As at Hordle this sandy channel fill is separated from the local Tertiaries (in this case the Bracklesham sands) by about 6 inches (15 cm.) of gravel. Both the above described channels are overlain by the brickearth which appears to truncate the gravels and sandy channel fill indifferently. It is possible that the sandy channel fills are an interim deposit intermediate in type between the extreme flow conditions indicated by the gravels and the quieter conditions signified by the brickearths.

Also at Hengistbury Head the 60 ft. (18 m.) terrace is cut by a channel similar to those already described. In this case, however, the channel, which is a large one up to 20 ft. (6 m.) deep and apparently 900 ft. (274 m.) wide, and filled with sand, has a further fine gravelly channel let into the top of the sandy fill. This gravel - sandy channel fill - gravel succession probably represents a sequence of braided channel deposits or a change in the flow regime of the Avon or Stour which presumably deposited these gravels. The other channels described at Hordle, however, cannot be referred to any present stream and may represent former braided courses of the Solent River. Because of their position at the top of vertical cliffs of Eocene sediments it is impossible to examine the channels and their fills closely to see if there is any particle imbrication or other directional structures. It is probable that the marine erosion which has cut the sections through the gravel has cut sections at an oblique angle to the trend of the channels so that they in fact do not trend north-south as it appears from superficial observation.

Chapter III. The Brickearth.

a) Introduction

The brickearth of south Hampshire is widespread on the terraces of the area and especially thick on the 100 ft. (30 m.) and 60 ft. (18 m.) terraces as shown by the long coastal section at Highcliffe (SZ 215931) and Hordle (SZ 269921). The geological survey maps of the area show only limited areas of brickearth but, as Kay (1939) and Everard (1952 unpub.) have both pointed out, this deposit is more widespread than indicated on the survey maps and indeed probably accompanies the gravel everywhere it outcrops at a greater or lesser thickness.

b) Thickness

At Barton (SZ 239930) the brickearth has a maximum thickness of over 8 ft. (2.5 m.) and it is also well developed below Hordle House (SZ 269920) where a maximum thickness of 6 ft. (1.8 m.) occurs. The 25 ft. (8 m.) terrace is almost devoid of brickearth. At Milford (SZ 282916) only about 1 ft. (30 cm.) of fine sand mixed with stones can be seen while further east near Stone Point (SZ 458985) about 18 inches (45 cm.) of brickearth can be seen on top of the gravel. On the 25 ft. (8 m.) terrace at Sowley Pond pit (SZ 375965) the brickearth is only 1 ft. (30 cm.) thick and totally absent from the western face of the pit. However, around Sowley Pond even though the brickearth is thin it completely covers the gravel because the soil revealed in ploughed fields shows a characteristic loamy texture which always occurs over brickearth.

At Highcliffe (SZ 215931) the brickearth of the 100 ft. (30 m.) stage thins to only 1 ft. (30 cm.). The section here may be partly disturbed, however, and the top of the gravel contains far more fine sand than is usual, so some periglacial or organic mixing of the brickearth and the top of the gravel must have occurred. The brickearth also thins into the minor valleys of Chewton and Becton bunnies but again this is due to disturbance, probably by man. In inland exposures as at Pennington and Hall's Pit no brickearth can be seen. Whether this is due to an original lack of brickearth or to subsequent removal is uncertain, although the latter is most likely as the method of gravel extraction used in these pits requires the removal of most of the over-burden of the gravel before exploitation of the gravel can begin. Gravel digging has also hidden the thickness of the brickearth at East End (SZ 366976) in the 60 ft. (18 m.) stage where no thickness of brickearth can be seen at all in this very overgrown pit. Again the gravel is very loamy at this locality, probably indicating the thorough mixing of the gravel and brickearth by the people who originally dug the pit.

As can be seen from the above quoted examples, the brickearth seems to be of different thicknesses on different terraces but, as far as can be seen from the exposures at present, the thickness of the brickearth on any one terrace is more uniform.

c) Structures

The brickearth is structureless, unlike either such deposits as the fluvial loams of the Thames terraces (such as those in the Barnfield Pit, Swanscombe, see photograph in Wymer, 1968) or the loess of continental Europe (Zeuner, 1959). However, recent alluvium may be structureless in the same way as the brickearth is, but it tends to be inter-bedded with the channel deposits (either sand or gravel) of the stream. In contrast the brickearth always has a planar boundary with the underlying gravel with no suggestion of channeling of the brickearth into the gravel or any inter-fingering of one deposit into the other.

d) Grainsize

To attempt to determine the exact origin of the brickearth, samples were taken at several localities along the cliff section from Highcliffe to Milford where the best exposures occur. These samples, together with a further sample from Downend (SZ 535879) on the Isle of Wight and others from Selsey and the Thanet brickearth of Kent, were subjected to grain-size analysis by the pipette method (for the exact procedure followed, see appendix A) and the results plotted as histograms and cumulative curves (see also Figs. 8 and 9). (The brickearth at Downend* is distinguished by being the highest brickearth in south Hampshire or the Isle of Wight, as it outcrops between 330 ft. (100.6 m.) and 340 ft. (103.7 m.) and in fact may rest partially on the chalk. The exact field relations of this deposit are obscure due to the digging of the deposit for brick clay.)

It was found that the brickearths of the coastal section comprised up to 50% sand (i.e. grains over 64 microns) and only small percentages of silt but with a second peak of clay size (under 2 microns) particles. Examination of the histograms published in Zeuner of the Ebbsfleet (Kent) loess (1959, p.165) and of samples of the Thanet brickearth show that these deposits are up to 80% silt with only very small amounts of sand present. Samples taken from the Selsey brickearth had an intermediate amount of silt between the extremes of the Thanet and south Hampshire examples. (This may reflect the increase in true loess size particles as more easterly and hence more continental deposits are sampled.) Whatever the origin of the south Hampshire brickearth, it almost certainly contains some loess-derived material as it is unlikely that thick loess sheets could be deposited as

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* The samples from Downend proved to be different from either Selsey, Thanet or the Hampshire examples. This deposit proved to be composed of 50% clay and only 15% sand. In view of the altitude of its outcrop this brickearth is probably of early Pleistocene deposition and it seems likely that the clay fraction has been enlarged by the weathering the deposit has undergone since it was deposited.

close to south Hampshire as Normandy (see Journaux, Helluin, Lautridou and Pellerin in Péwé, 1969), the Channel Isles (see Part II) or Thanet (Weir, Catt & Madgett, 1971) without some particles being blown into deposits being formed by other processes. Indeed, Coombe and Frost (1956) describe loess type particles in the soils of the Lizard Peninsula in Cornwall so it is possible that loess deposition extended further west than the New Forest area.

A section of the thickest part of the brickearth at Barton (SZ 239930) (on the 100 ft. (30 m.) terrace) was sampled at 40 cm. (1 ft. 4 ins.) intervals down to its maximum thickness of 8 ft. (2 m. 50 cm.). It was found that throughout its depth the brickearth was composed of fine sand and coarse silt with very little fine silt, and a second peak of clay. The brickearth was most sandy in its middle portion at a depth of120 cm. (4 ft. 6 ins.) where the sand percentage was over 50%. Kay (1939), working on an area to the east of Southampton Water, describes a section near Hound (SU 474088) on the 100 ft. (30 m.) terrace which also becomes more sandy at a depth of 3 ft. (91.4 cm.). In Kay's example the percentage of sand increases to 73% at this depth. Why the brickearth should exhibit this coarsening is uncertain.*

The brickearth contains within it a small number of fine gravel particles with a maximum size of about 1 inch (25 mm.) long axis. These flints are always angular rather than rounded in shape but in addition are usually flat and are perhaps best described as discoid or blade-like in shape, but without the rounding that the use of these terms may imply. All

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* Allen, 1965, describes coarsening of fine grained materials in a flood basin environment and suggests that this is due to "crevasse splay" deposition where a sequence of overbank deposits is interrupted by coarser material "bled" direct from the stream channel by crevassing of the stream's banks. If, as will be suggested below, the brickearth of south Hampshire is primarily on overbank deposit, such crevasse splaying could occur but whether fluvial conditions in south Hampshire were ever such as to allow the formation of the levées necessary for this type of deposition is unknown.

samples of brickearth collected had at least one of these flint fragments within them. The top few inches of each brickearth section had more stones in them than the rest of the section but this is clearly due to ploughing. At Taddiford Farm (SZ 262927) ploughing downslope across both brickearth and gravel outcrops has resulted in a thorough mixing of the two deposits for the top 1 ft. (30 cm.) of any section but below this level the brickearth is undisturbed by human agency.

It seems most unlikely that the occasional stones in the brickearth were incorporated by way of periglacial disturbance. There is no evidence for periglacial churning of the brickearth and the stones do not form the lines, stripes or festoons typical of periglacial action. It is probable that the stony content of the brickearth is an original feature with the stones incorporated in the sandy matrix during deposition. This seems to rule out an aeolian origin for the deposition of the brickearth if not for some of its constituent particles. The lowest few inches, like the top ploughed layer, are similarly stony. This is probably due to the disturbance of the top of the gravel by the process depositing the brickearth. These bottom of the brickearth stones are arranged in lines similar but on a much smaller scale to the lines of pebbles in recent alluvium and were probably formed during transition conditions between the gravel forming environment and the brickearth episode.

e) Origin

From the above description it can be seen that the brickearth is a problematic deposit. Previous authors have assigned it to varied processes of origin ranging from solifluction and aeolian deposition to fluvial deposition. Everard (1952, unpub.), bearing in mind the non-calcareous nature of the brickearth, suggested that it might be a reworked head with its calcareous constituents leached out. This is unlikely as true head is very gravelly. White (1915) describes the head of the Portsmouth district as typically being a "stony loam" which is unlike the loam with small stones which is what the brickearth actually is. Everard concludes that, despite its uniform appearance, the brickearth is of several ages and the reworking of the original head was in part aeolian and in part fluvial. (It is difficult to reconcile Everard's idea of a marine origin for the gravels of the area with an aeolian-fluvial origin for the brickearth.)

That the deposit as a whole is not aeolian can be demonstrated by reference to its sandy character and the presence of flint chips within it, although as stated above some aeolian particles may be present in the brickearth. It seems most likely that the brickearth is in fact of fluvial origin and that White (1917) was correct when he stated that the brickearth "may be a flood loam of little later date than the underlying gravel". Whether in fact the brickearth and the gravel have closely similar ages is uncertain but the fact that the brickearth almost invariably overlies the gravel and does not seem to overlie the non-gravel areas seems to suggest that only a short period of time can have elapsed between the deposition of the two deposits. If a long period had elapsed between the deposition of the two deposits it would be unlikely that the same palaeotopography would persist so that brickearth would be deposited just on the gravel and nowhere else.

The fact that the brickearth everywhere overlies the gravel but not the solid Tertiaries is also an argument against the brickearth having an aeolian origin as fall out from wind deposition would cover the whole landscape. It is clear too from the granulometric data that the brickearth is not a loess. Opinions vary as to the exact size parameters to be adopted for loess (Weir, Catt & Madgett, 1971, state that the loess grade is between 50 microns and 2 microns with the majority of particles between 50 microns and 20 microns; Zeuner, 1959, states that typical loess is from 1 micron to 7 microns*, while Smalley, 1971, also regards loess as being from 50 microns to 20 microns), but it is generally agreed that it is composed almost entirely of silt. The south Hampshire brickearth is, however, almost entirely deficient in this size grade.

The fact that the granulometry of the Hampshire brickearth is unlike that of the true loess of Europe does not preclude the possibility of it having an aeolian origin or at least having some aeolian particles in it, but it does prevent the deposit being regarded as a loess in the true sense (Smalley, 1971). The field relations of the deposit, however, and the presence of flints within it rule out an aeolian origin. Similarly the lack of festoons and other features of periglacial sorting rule out the possibility of any solifluction origin for the brickearth. The best explanation for the origin of the brickearth is then the one advanced by White (1917) (see above). Such fluvial brickearths are widespread in the Thames valley (see Pocock, 1902, Kennard, 1944 and West, 1969), in a similar position, overlying fluvial gravel, to those of south Hampshire. The brickearths of the Thames are regarded by the authors cited above as alluvium analogous to that of the present river. While the origin of these deposits is indeed fluvial it is questionable whether their environment of deposition was similar to conditions at present (see below, Chapter IVc, for discussion of Kennard, 1944, on this point), and it is possible that while the process of deposition of the Hampshire brickearth was similar to processes acting at present, the magnitude of the process was several times greater than any similar depositional processes of recent times.

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* He actually does say this in both Zeuner 1945 and 1959, but also states that the parameters for loess are 0.1 and 0.01 millimetres, i.e. 100 microns to 10 microns, which are much more realistic than 1 micron to 7 microns which is almost all clay. However, it is possible (but improbable) that some European loesses are predominantly around 7 microns.

Chapter IV. The Environmental Significance of the Gravels and Brickearth

a) The depositional environment - fluvial or marine?

As stated above the gravels and brickearths of south Hampshire have been attributed by various authors to either marine or fluvial deposition. The two main hypotheses are exemplified by the work of Everard as an advocate of marine deposition and White as an advocate of fluvial deposition of these deposits. The views of both these workers have been stated already above, but by way of clarification both their positions will be restated here.

Everard takes the view that the gravels are of marine origin and were deposited in a large bay or estuary which extended at its maximum as far west as the present mouth of the Avon. Everard (1954b, p.42) states:- "... for much of the period considered, marine conditions of an estuarine character are believed to have predominated in the area but fluviatile phases indicative of a marked withdrawal of the sea occurred at the 300 ft. (91.5 m.) and buried channel stages. In each of these a river system not unlike Reid's Solent River was probably in existence.".

In his suggestion that an inlet of the sea covered south Hampshire for much of the Pleistocene, Everard explains that the gravel of the terraces was formed as marine beaches by erosion, at each stage, of the pre-existing gravels. The gravel in these beaches is stated to be angular (rather than rounded as would be expected of a beach deposit) because it had its origin in the rivers flowing into the Solent Bay. The gravel constituents retain their fluvial angularity because of the lack of reworking by wave action caused by the limited fetch available in the Solent Bay which could not provide waves large enough for the rounding of flint pebbles to take place. The amount of fetch available is, however, thought to be enough to generate waves sufficiently large to erode the cliffs of gravel to provide material to construct the next beach in the lowering altitudinal sequence. Everard's main reason for suggesting a marine origin for the gravels is, however, the slope of the surfaces of the terraces, which he believes is too shallow to allow any origin except a marine one for the terraces.

Everard's suggestion of the deposition of the gravels in a Solent Bay needs to be examined more closely. With the Wight to Purbeck ridge intact as it must have been through much of the Pleistocene (see Chapter VI), only a very limited fetch can have been available for wave generation. The only directions through which any degree of fetch would be available would be from the east, south-east or north-east as the chalk ridge would have allowed only a very limited fetch from the west or south. This limitation on waves generated by the westerlies would also limit the longshore drift postulated by Everard for the dispersal of the gravels introduced to his Solent Bay by stream action. Longshore drift from the east would tend to pile up the stream introduced gravels about the mouths of the streams rather than spread it across the terraces*.

The longshore drift is at present weak, even with the large expanse of Christchurch Bay open to the west, so it is not unreasonable to suppose that such action must have been far weaker in the Pleistocene when this bay did not exist. The lack of fetch would also inhibit the cliff erosion considered necessary by Everard for the provision of gravel from which new terraces could be built. Even at present it is only the cliffs of Christchurch Bay which are fully open to the west which are eroded to any extent. East of Hurst Narrows only the section between Lepe (SZ 433985) and Cadland (SU 470003) has any cliffs and these are due to the coast's facing due east

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* At present longshore drift occurs predominantly from west to east in the Solent and such structures as Hurst Spit and Calshot Spit owe their origin to it. This movement of gravel is, however, quite weak and the easterly fetch generates waves which are weaker still and according to Bird (1964) can only form the recurves on the ends of the two spits mentioned above.

at this point and so have quite a long fetch over Spithead and up the Channel over which easterlies may generate waves. To the west of the Beaulieu River no cliffs at all occur because the greatest fetch possible with this due south facing coast is the 3 miles (4.83 km.) across to the Isle of Wight.

If Everard's map (1954b, p.52) is examined (see also Figs. 1 and 5), it will be seen that he envisages strandlines for his various stages parallel to the shores of the present Southampton Water and Solent. It seems impossible to reconcile the narrowness and lack of fetch in these inlets with the necessity of the generation of waves large enough to cause the erosion and longshore drift envisaged by Everard.

The narrow inlets shown by Everard (1954b) also present problems in the cutting of the benches on which the gravel terraces rest. The wide expanse of the 150 ft. (45.7 m.) and 100 ft. (30 m.) stages at Beaulieu Heath (SZ 355999) and Lady Cross Walk (SU 350010) up to 2 miles (3.21 km.) wide at its widest is unlikely to have been cut by a stable sea level*. Wide benches such as those at Beaulieu Heath require a rising sea level for their cutting, but from what is known of the rate of Pleistocene sea level rises (see Fairbridge, 1961) these are unacceptably rapid from the point of view of wide bench cutting**. Even the fact that the benches are cut across soft Tertiary sediments and the possibility that some of the lower terraces may be composite and occupied more than once cannot account for the wide

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* King, 1963, suggests that the maximum width of bench which can be cut under a stable sea level is 4000 ft. - 1220 m.

** Several authors (Godwin, Suggate & Willis, 1958; Curry, 1961; Oakley, 1964) cite very low sea levels for dates in the late Devensian. Figures of 100 m. (328 ft.) below present sea level at a date of only 15,000 years before the present are typical of the low sea levels cited for the late Devensian (or Wisconsin in Curry). As present sea level was reached around 6,000 years B.P. (Godwin, 1956) only 9,000 years are available for a rise in sea level from around -328 ft. (100 m.) up to the present. This rate of sea level rise is far too fast to allow the cutting of any widespread benches.

terraces visible in the landscape of south Hampshire.

From the above remarks it may be concluded that the gravels were not deposited by marine action. From the character of the gravels themselves it is probable that they were in fact laid down by a river and thus are exclusively fluvial in origin. While Everard (1954b) suggests that some of the gravel was introduced into his Solent Bay by stream action and then reworked by marine processes it seems much more likely from examination of the structures in the gravel, the angularity of its constituents, and the improbability of the marine cutting of the benches, that all the gravels were in fact of fluvial origin with no marine influence being present.

While Everard and others such as Codrington (1870) postulate a marine origin for the gravels, others such as Palmer and Cooke (1923) suggest a composite origin with a marine bench being covered by a veneer of fluvial gravel. The chief objection to this hypothesis is the one raised above, namely that there would be insufficient fetch in any Solent Bay to allow the generation of waves large enough to cut a bench similar to those seen in the landscape at present. It is in fact far more likely that the fluvial gravels described by Palmer and Cooke rest on a fluvially cut bench without the intervention of any marine influence*.

Having suggested that the marine hypothesis for the origin of the south Hampshire gravels is mistaken the only origin possible for these

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* Everard, 1954b, also makes use of this hypothesis to explain the gravel distribution. He suggests that the gravels were in part spread over marine surfaces by extending "consequents" flowing into the Solent Bay as the sea withdrew. The consequents would be expected to flow down the maximum slope of the marine bench exposed by the falling sea level, in this case the north-south slope, and thus parallel to the Beaulieu and Lymington Rivers. Examination of the current bedded structures (see Chapter II) shows that the gravels were all deposited by currents with a strong easterly component and no north-south elements at all. In addition the terraces visible in the landscape closely follow the line of the postulated Solent River rather than the courses of the north-south streams.

deposits is a fluvial one as suggested by White (1917). Suggestions that the gravels may be partly solifluction deposits - Everard, 1954b; Palmer and Cooke, 1923 - can be discounted on the grounds that only minor solifluction structures can be seen in the gravels, for instance at Highcliffe (SZ 215931) and Hall's Pit (SU 450019) (see Plate 27) and no evidence can be seen for the wholesale movement of the gravel which solifluction would entail.

A restatement of White's beliefs on the origin of the gravels contains the basis for further investigation of these deposits. White (1917, p.48) stated: "... the local plateau gravels (i.e. of the area of the Bournemouth sheet of the Geological Survey) contain no deposits that could reasonably be regarded as of marine origin".

In the Memoir to sheet 331 (Portsmouth and Lymington), White states (White, 1915, p.49): "... the structure and deposition of the gravels imply that the greater part of the district was overrun by shifting channels fed by a volume of water greatly exceeding that carried by the local streams at the present day.".

These two quotations from White's work provide a clear statement of his position on the origin of the "plateau" gravels. White also makes the point (White, 1917, p.49) that the calibre of the material of the plateau gravels is in sharp contrast to the calibre of the material being moved by present day streams in the area and he suggests that this is due to the gravels being formed in a more severe climate than that of the area at present.

As the work of White suggests the evidence for the fluvial origin of the gravels is largely contained within the gravels themselves, in their structures and their arrangement as terraces. The slope of the terraces is ambiguous when their origin is being considered as the work of Everard (1954b) shows and examination of this alone may give rise to suggestion of a marine origin (see below).

The thickness of the gravel of any one terrace is a guide to the environment of origin of the gravels. As noted above (Chapter II) the gravels of the New Forest area thicken and thin at random (as in Hall's Pit). This thickening of the gravel with no discernible pattern is not typical of a sequence of marine deposits. The deposits of a transgressive sea would tend to be of uniform thickness or perhaps thicken to seawards. The rapid thickening and thinning is much more characteristic of the deposits of a series of braiding stream channels rather than the smooth sheet of gravel which would be associated with a marine transgression.

The particles which make up the gravel are also more typical of fluvial deposits than marine, as Everard (1954b) points out. It is more likely, however, that the gravel was deposited in the fluvial environment which it typifies than the rather unusual marine environment used by Everard to explain the presence of angular gravel in a marine sequence. Everard's main evidence of a marine origin for the gravels was contained in the flatness of the "horizontal" segments of the terraces between the Avon and Southampton Water. This extreme flatness is very unlike the longitudinal profile normally to be expected from a stream depositing large quantities of coarse gravel so the postulation of an unusual environment for the deposition of the south Hampshire gravels is not unreasonable. However, the very gentle slopes of the "horizontal" segments of south Hampshire are not unparalleled. The 100 ft. (30 m.) terrace of the Thames from the mouth of the Lea to Swanscombe has an extremely low gradient (under 6 inches per mile, 1 in 1560) (Zeuner, 1959) while the Caversham channel of the Thames has an "imperceptible" gradient (Thomas, 1961) yet is filled with 20 ft. (6.0 m.) of coarse gravel. Thomas regards this gravel as primarily outwash but this example indicates that it is not necessary for steep gradients to be present for coarse gravel transport to occur.

The current bedded structures while only few in number show a consistent easterly component (see Chapter II and Figure 6) typical of deposition in a stream flowing from the west. The variations around due east seen in the current bedding determinations can be explained by the different directions through which a braiding (or even a meandering) stream will flow, especially in a dynamic episode such as that represented by the gravels. These current bedded directions are inconsistent with the gravels being deposited by marine action. The probability of a braiding environment is added to by the presence of channels in the gravel at several points in the sequence (see Chapter II). These channels also suggest that the gravels are not of marine origin as it is not typical of marine deposition to cut channels of the size of those at Barton (SZ 23990) for example, in beach deposits.

From the above evidence it must be concluded that the gravels and terraces of south Hampshire are of fluvial origin and were deposited by a Solent River closely similar to the one envisaged by Reid (1902b). Although the gravels are basically fluvial some marine influence may have occurred in the Solent's estuary. The position of the head of the estuary at any particular stage is undetermined although Reid (1902b) places the mouth of the river as far east as Beachy Head and associates the Black Rock raised beach with the Solent deposits. West and Sparks (1960) suggest a brackish water environment for the Ipswichian interglacial deposit (actually only the lower part of this deposit was examined by West and Sparks) at Stone Point on the grounds that the deposit is rich in the inter-tidal gastropods Hydrobia ventrosa (Montagu) and Hydrobia ulvae (Pennant). It seems most likely that the position of the mouth of the Solent (like that of the Thames, Zeuner 1959) fluctuated in its position during the Middle and Upper Pleistocene. At the low sea level stages of the Devensian (Fairbridge, 1961; Curry, 1961) when the sea level may have been at least 100 m. (328 ft.) below the present, the mouth of the Solent must have been far to the east and Reid's suggestion of a mouth of the river off Beachy Head may be correct. However, at this low sea level stage, any association with the Black Rock beach which reaches around 40 ft. (12.2 m.) O.D. (White, 1924; Smith, 1936) is unlikely.

b) The climatic environment

Although it has been suggested that the gravels of south Hampshire are of fluvial origin the problem remains of their broader environment of deposition. The height of the gravels above present sea level at the long established interglacial sea level heights would seem to indicate that the gravels were deposited during interglacial conditions. However the coarse gravels which make up the terraces are totally different from any deposits being formed in the rivers of the area at present as White (1917) pointed out. White suggested that this increase in the calibre of the load of the Solent River compared with the calibre of present stream loads was due to a great change in climate.

Other workers in the area make little or no reference to the climate during the period of deposition of the gravels. Everard, beyond a passing reference to solifluction as a process by which the gravels may have been spread across the terrace surfaces, makes no observations as to the climate during the deposition of the gravel and variation in climate has no place in his explanation of the Pleistocene of south Hampshire. Tremlett (1965) suggests a cold climate for the time of the deposition of his 35 ft. (10.7 m.) terrace on the Beaulieu River because of the great width of this terrace which indicates a greater rate of run-off and larger streams than at present.

The fact that the gravels are so much coarser than the present loads of the streams in the area alone would suggest a significant change in stream regime from the present to that of the Pleistocene. By extension the type of change in stream regime necessary for greatly increased run-off could only be achieved by a climatic change, either an increase in precipitation or a change in the permeability of the soil and its vegetation cover so that far more of the precipitation that falls is utilised immediately as run-off and not stored in plants or as ground water.

The evidence for precipitation rates in the Pleistocene is controversial. Several authors (Zeuner, 1959; Frye, 1961; Kerney, 1963) suggest that precipitation in the extra-glacial areas during glacial periods was greater than the precipitation in the same areas at present. Kerney and Zeuner cite the existence of widespread deposits such as the coombe rock and the head as evidence that solifluction under a climate wetter than the present occurred as such solifluction would need considerable amounts of precipitation to be efficient. Tricart (1970) contends that the precipitation during glacial episodes was little different from that at present because the planetary wind circulation patterns were unchanged. Williams (in Pewe, 1969) states that the climate of southern England was drier in the Pleistocene than at present because, given the temperatures he cites from palaeotemperature studies and the present amount of rainfall, Dartmoor should have been glaciated and no evidence has been found on Dartmoor for the existence of ice caps.

The same effect, in streams, however, as an increase in precipitation, would be caused by a decrease in temperature so that vegetation cover was destroyed. The surface of the ground would then be frozen for much of the year and a markedly seasonal fluvial regime would be set up with a spring flood of extreme dimensions releasing the whole year's precipitation in a few weeks at the break-up of the winter ice. Several writers have stressed that the lack of vegetation more than any other single factor will increase run-off. Some illuminating figures are quoted by Quinn (1957) from the work of Bennett (1939) who states that when the vegetation cover of an area is completely stripped the increase in run-off and erosion is little short of catastrophic. Bennett's figures were for a 12 degree slope under equal rainfall (36.4 inches, 92.45 cm. per annum) and the same soil type. Under these conditions the following figures were observed:-

Cover	Run-off in % of rain	Denudation in tons/acre
Woods	0.12	0.0
Grass	6.50	0.04
Barren	48.80	69.00

Similarly, Orme and Bailey (1971) describe an experiment in Monroe Canyon, California where a small catchment in the San Gabriel Mountains which was de-forested by lightning fires was used experimentally to examine the run-off under different vegetation types. The area in question was formerly covered with chaparrel scrub on its steep slopes and forests of sycamore, laurel and alder in the valley bottom. The regeneration of the forest following the fires was made selective by the use of herbicides so some ground was bare, some in grass only and some in the natural sage-chaparrel. The processes operating in the valley were observed over eleven years, 1960-1971. It was found, as in the example cited by Quinn (1957), that bare ground was eroded at catastrophic rates while ground covered even with an open scrub of chaparrel was less susceptible. Orme and Bailey contend that the extreme erosion suffered by the slopes of Monroe Canyon was in part due to the steep slope of the valley sides and to several extreme storms which occurred during the period of the experiment, as well as the vegetation changes in the valley. However, the nearby Volfe Canyon (a tributary of the Monroe Canyon) suffered the same weather conditions and has the same steep slopes but was not subject to vegetation disturbance and showed very little erosion even in the fiercest of the storms. While the mountains of California with their steep slopes are hardly analogous with the low relief of the New Forest the example described above shows the effect of the disturbance of the vegetation cover on stream run-off.

Examination of the extreme effects of vegetation break-down on fluvial regimes seems to show that an increase in precipitation is unnecessary to increase stream run-off if the climate is cool or cooling. As these conditions of cool or cooling climate are fulfilled for part of the Pleistocene, and in view of the dispute among various authorities whether there was an increase in rainfall or not during this time, it seems wisest, in the absence of definite data on Pleistocene precipitation, to explain the great increases in run-off necessary to move the coarse gravel as being due to the effects of a cooling climate rather than increased precipitation.

It is well known at present that in high latitudes extreme rates of run-off occur for part of the year and that large amounts of sediment are moved in these episodes. Tricart (1970) describes the massive discharges of the Lena in Siberia which has a peak discharge of 13,900 cub/m. per sec. (490,878 cub.ft./sec), while Bird (1967) describes the spring and summer break-up of the Mecham River on Cornwallis Island in the Canadian arctic as having a maximum discharge of 45 x 10^6 cub.m./day (15,891 x 10^6 cub.ft./day) on July 2nd which levelled off to 0.1 x 10^6 cub.m./day (353.15 x 10^6 cub.ft./day) by July 20th. After these massive peaks the rest of the flow season before the rivers freeze over in the autumn is taken up with very quiet flow moving only sand in contrast to the "coarse deposits" (Tricart) moved earlier in the season.

An environment similar to that of the high arctic at present with a cold climate causing extreme run-off conditions and massive transport of coarse debris (partially supplied to the streams by periglacial erosion of the valley sides in the winter according to Tricart, 1969) seems the only possible environment for the deposition of the gravels of south Hampshire. True interglacial conditions such as the present are clearly inadequate for the deposition of gravel spreads and under the natural vegetation conditions of Pleistocene interglacials with much of the land surface being covered by closed canopy forest, run-off and erosion would be less than at present*.

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* Walker and West, 1970, cite an example of certain areas in Kent where sedimentation of organic silts showed a marked increase in pollen zone VIIb, the sub-boreal, which coincided with the first forest clearances by Neolithic/Bronze age farmers. The increase in open habitats is shown by the marked increase in Gramineae and Compositae pollen at this stage.

/That

Although the climate at the time of the deposition of the gravel was cold it was not a full glacial climate as, during the coldest part of glaciation, sea level would be very low and so stream action would only take place in areas now buried or flooded such as the Solent buried channel (Everard, 1954a)*. The actual stage during which the gravels were deposited must fill a place between the full interglacial warm climate and the full glacial cold climate. The exact stage at which the gravels were deposited will be discussed below in Chapter IVc where an attempt will also be made to reconcile the problem posed by the seemingly mutually exclusive deposition of cold climate gravels at a high, hence warm, interglacial sea level.

Whatever the nature of this intermediate phase between the two climatic extremes, the climate must have been too cold for closed canopy forest to grow. The evidence for a cold climate during the time that the gravels were deposited is meagre in the gravels themselves. There are few periglacial structures of any kind and only one example of a series of periglacial structures actually within the gravel has been found. These

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(* cont. from previous page)

That this increase in the deposition of silt was caused by the destruction of the forest cover of the area and not by an increase in rainfall is shown by Godwin (1956) who considers that zone VIIb of the post-glacial is marked by a decrease in precipitation rather than an increase, so the increase in sedimentation occurred in spite of a slight decrease in rainfall.

* The low glacial sea levels of the Pleistocene are well documented. While the Pleistocene was marked by a general progressive fall in sea level (Zeuner, 1959), superimposed on this general fall were the eustatic oscillations shown by Zeuner, 1959, and Fairbridge, 1961. The lowest sea levels of the Pleistocene may have been very low indeed. Mitchell and Orme (1966) suggest a sea level of -45 m. (-146 ft.) for the Wolstonian glacial maximum, while the deep buried channels of the Devensian are well known and may indicate sea levels as much as 60 ft. (18.3 m.) below the present (Everard, 1954a). Studies in other areas suggest even lower sea levels occurred in the late Devensian with Curry (1961) suggesting a level of -390 ft. (-118.9 m.) for the Tazewell - a contemporary of the late Devensian - stage of the Wisconsin of North America.

structures occur in a sand lens 3 ft. (1 m.) below the surface of the 60 ft. (18 m.) terrace at Hall's Pit. The structures, which are minor "flame type" involutions, may be sealed between two layers of gravel (see Plate 27), thus indicating conditions cold enough for periglacial activity during the deposition of the terrace gravel - or at least during a break in deposition between periods of terrace formation. The gravels overlying the sand lens may in fact also be disturbed so merely placing the periglacial disturbance in a post 60 ft. (18 m.) terrace episode. The actual relationship of the structures in the overlying gravel to those in the sand lens is not clear.

Certain structures in the gravel such as the included silt blocks at Barton and the "clay" balls of Cadland may be indicative of a cold climate (see above, Chapter II). Under present day conditions, even without large amounts of flint gravel washing against them, blocks of alluvium are soon destroyed in fluvial environments so some agent of consolidation must be invoked to hold these silt blocks together long enough for them to be buried. As such blocks are described by Shotton (1968) from cold environments in the Devensian and by Czudek and Demek (1970) from recent cold environments it is reasonable to assume that the blocks in the south Hampshire gravel have their origin in a frozen state also*.

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* Hamelin and Cook, 1967, suggest that, at the spring break-up of the ice cover of streams in the Canadian arctic, much of the energy of the stream is utilised in lateral under-cutting of its banks. The valley floor is frozen and presents more resistance to erosion than the thawed active layer on top of the frozen ground. This under-cutting tends to loosen blocks of the sandy alluvium deposited at the end of the previous year's period of flow and incorporate them in the flood gravels. Czudek and Demek's (1970) thermo-erosion niches may serve a similar purpose in causing fine grained blocks to be released into the gravel.

As mentioned above the presence of large sarsens in the gravels is also indicative of cold conditions during the deposition of the gravel because floating ice is virtually the only agent which could be responsible for their occurrence in the gravel*.

These small pieces of evidence alone do not add up to a convincing case for confirming that the gravels of south Hampshire were deposited in a cold climate. However the over-riding factor in determining the environment of deposition is the massive discharges necessary to move the coarse gravel found in the terraces. The only type of fluvial regime which can provide such discharges is the cool or cold climate one. When this is realised all the other minor pieces of evidence contribute to confirm that the climate when the terrace gravels were deposited was a cold if not periglacial one.

The type of flow which occurred while the gravels were being deposited is problematic. White's (1915) "shifting channels" seem to suggest a braiding regime and this is generally thought to be the sort of flow which occurred during cold episodes in the Pleistocene (Zeuner, 1959). Doeglas (1962) states that braiding requires a low flow regime with periodic extreme maxima while meandering is typical of uniform flow regimes. Dury (1958), however, regards meandering as typical of the episodes of great discharge which formed his valley meanders and recently has attributed at least one period of such valley meandering to a cold but warming period at the end of the Devensian (on the Severn, Dury, Sinker & Pannet, 1972).

Orme and Bailey (1971) state that at bank full, which was also valley bottom full, on Monroe canyon, the stream was almost a debris chute and that

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* Bird, 1967, states that boulders eroded from the river banks in winter by frost action fall on to the ice covering the river and are frozen in and thus carried away when the spring break-up occurs. Similarly boulders on the stream bed may be frozen into the ice in the autumn and then carried away in the spring melt.

braiding only occurred as the water level sank from bank (or valley) full to a lower level. This seems to be typical of streams in periglacial areas at present where, at the spring break-up, the whole valley floor may be covered by a sheet of moving water washing gravel along with it (Hamelin & Cook, 1967; Tricart, 1970). Braiding then only becomes important as the flood level subsides. It seems likely that in south Hampshire the largest streams, the Solent, Avon and Test/Itchen, probably had a braiding course at all stages of their flow regime as the discharges necessary to cover a valley bottom as wide as that of the Solent's 100 ft. (30 m.) stage are so large as to be extremely improbable. The main gravels would be deposited in braiding channels in the spring break-up, each year causing the erosion and reworking of a portion of the previous year's deposits. The sand filling the channels in the gravel as at Hengistbury Head can be referred to stages as the river level fell after the initial spring bank full level.

The minor valleys such as the valleys of the Beaulieu and Lymington rivers, however, probably had their whole floors flooded and behaved like Dury's valleys but without valley meanders forming. The streams in these valleys today are certainly misfits due to climatic change in the way envisaged by Dury (1958) (see Plate 8)*.

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* It is possible that the straight or slightly sinuous courses, with steep valley sides, of the lower Beaulieu and Lymington Rivers are due to their originating in a cold climate. The form of these valleys is similar to valleys described by Tricart (1970) as being typical of valleys formed under a periglacial climate at present. The meandering valleys described by Dury, such as the Warwick Itchen or the Sussex Arun are far older streams than the very recently developed Lymington and Beaulieu Rivers and part of the development of their valley form must have occurred in a warm climate. The meandering of these valleys then may be merely a trimming process while the minor streams of south Hampshire probably had their entire origin in cold conditions and so their valley form reflects far more closely the shape of the periglacial valleys described by Tricart.

If the gravels of south Hampshire are referred to cold climate fluvial deposition it follows that the brickearth of the area is also most probably a fluvial deposit, and as it is of little different age to the gravels (see Chapter III) it too must have been deposited in a cold climate. Bird (1967) describes the great expanses of alluvium left on the valley floors of streams in the Canadian arctic by over-bank flow during the spring break-up while Tricart (1970) states that river rises of 10 m. (32.8 ft.) are not uncommon in the spring on streams in Siberia so the spreading of this sandy material across the flood plain of the Solent River is easily explained. Bird (1967) states that these fine deposits mantle the channel gravels of the streams and, because they are unvegetated, are further distributed by wind*.

In this chapter it has been demonstrated that the gravels and brickearth of south Hampshire are of fluvial rather than marine origin and were deposited in a cold rather than warm interglacial climate. The main factor controlling the deposition of the gravels is thought to have been the climate acting through the vegetation to cause widespread open habitats and extreme run-off and stream discharge. The bearing of this fact on the deposition sequence during interglacials will now be considered.

c) The fluvial depositional sequence during interglacials

The climate during the deposition of the River Solent gravels was a cold one. Nevertheless the terraces appear to relate to sea levels which

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* Bird states that only moderate winds (around force 4) are necessary to cause dust clouds 200 m. (656 ft.) high, in summer in northern Canada so the further distribution of these essentially fluvial sands by wind is most likely. The reworking of the south Hampshire brickearths by wind presents some problems, however, because of the coarse nature of much of the sand of which this area is composed. It is difficult to envisage this coarse material being blown far by even quite powerful winds so it seems likely that the primary origin of the south Hampshire brickearth was as a fluvial deposit.

are thought to be indicative of interglacial conditions. For this reason it seems necessary to refer the periods of gravel deposition to a transitional phase between full glacial and full interglacial conditions. Theoretically this transitional phase might be either before an interglacial maximum (equivalent perhaps to part of the Late Glacial of the Devensian) or after it in the climatic decline into the succeeding glacial epoch.

In view of what is known about the transition from the end of the Devensian to the Flandrian a late glacial age for gravel spreads does not seem likely. In using the Late Glacial of the Devensian as a model of conditions at the end of any glacial period it must be remembered that this particular period of glacial to interglacial transition may be unlike the Anglian to Hoxnian or Wolstonian to Ipswichian transition. At the end of the Devensian the sea level rise from the minimum of the last glacial stage was not complete until pollen zone VIIa (the Atlantic) by which time the climate was at the stage of climatic optimum (Godwin, Suggate & Willis, 1958). Deposits of this Flandrian transgression and the aggradation which accompanied it anywhere near O.D. consist of peat and silt (Everard, 1954a) and no fluvial gravel spread can be dated to the post-glacial. Cool conditions do seem to have persisted into the early part of the sequence at Selsey (West & Sparks, 1960) but by the time brackish influences occur at this site the climate was fully temperate. At Swanscombe the lowest part of the sequence also shows cool conditions (from the molluscan evidence - Kerney, 1971) but here too these are soon replaced by fully temperate conditions.

From these examples it can be seen that gravel spreads do not appear to be characteristic of glacial to interglacial transitions and although some gravel may be deposited in these episodes as at Swanscombe (Kerney, 1971), gravel terraces are not characteristic of the early part of interglacials. The deposition of thick gravel spreads in full interglacial conditions has been shown (above) to be unlikely so the only phase of high sea level during which gravels could have been deposited is the transition from interglacial to glacial conditions.

The sequence which can be envisaged is as follows. Towards the end of an interglacial climatic deterioration sets in and causes a general destruction of forest cover and the spread of open conditions. This in turn accelerates run-off and increases erosion. Under such conditions soil profiles are quickly swept away and gravel transport in streams commences as run-off from bare ground and an increase in stream load provides the "ingredients" for this to occur. Under these conditions the streams begin to form braided channels although, in the absence of negative base level change, lateral erosion is paramount and over several reaches aggradation may occur. The widening of stream channels under the influence of increased run-off is well documented - see particularly Dury, 1958. Orme and Bailey (1971) describe a stream in Monroe Canyon, California, which was surveyed in 1942 and again in 1958 and showed no change in channel configuration. In 1958 prior to the vegetation changes (see above, Chapter IVb) the channel was 1 to 2 m. wide (3 ft. 3 ins. to 6 ft. 6 ins.) and .5 m. (1 ft. 7 ins.) deep in its surveyed region. After deforestation and erosion re-survey took place in 1969. Although complete re-survey was impossible due to the disappearance of reference points in the extreme erosion of the channel, spectacular changes had occurred. The channel was now 28-32 m. (91 ft. 9 ins. - 105 ft.) wide and 3 m. (9 ft. 9 ins.) deep and had a well marked "trench" shaped cross section. From this example it can be shown that while some deepening and aggradation of the stream channel occurred at certain points the main action of the stream was to greatly widen its channel. Shotton (1968) provides a further example of channel widening under increased run-off from the Warwick Avon. At the top of Avon terrace no. 4 a great overstep of gravel occurs, up to 1400 ft. wide (426.7 m.) and 15 ft. (4.5 m.) thick, across the outcrop of earlier Ipswichian deposits. This gravel, which contains a cold fauna, is interpreted by Shotton as representing an early Devensian cold period prior to the maximum of the early Devensian glaciation which Shotton believes is represented by the abrupt downcutting to Avon terrace no. 3.

During this initial period of erosion most of the fine-grained sediments (peat, silt etc.) left by the previous interglacial are eroded away and much of the gravel is deposited directly on to the local solid geology rather than on to the deposits of the previous interglacial stage. This period is replaced by one of powerful downcutting with the streams abandoning lateral planation for deep incision of their channels in response to the fall in base level caused by the eustatic fall in sea level (Rust, 1972, suggests that even in braided rivers one branch of the braiding pattern is dominant; it is possible that as downcutting commences it takes place along the line of this major branch). The excavation by this main branch of the braiding stream continues until the new (glacial) base level is reached.

As the area of lateral planation and gravel deposition in braiding channels is abandoned overbank flow deposits the finer material carried by the stream as brickearth. In some episodes the fall in base level may be sufficiently fast so as to allow only a thin layer of brickearth to be deposited before the former floodplain is abandoned and left as a terrace never to be washed by the stream again. It is difficult to account for the brickearth except in terms of overbank flow. This deposit is almost certainly fluvial - see above, Chapter III - although it may have some included aeolian material in it, but it is quite unlike any alluvial material being deposited in the area at present in that there is little evidence - beyond one exposure at Barton - of any gravel interfingering or channeling the brickearth. This sequence of fine deposits inter-digitating with coarse is characteristic of recent floodplains (see Allen, 1965) in temperate areas but little is known of such deposits in cold climates. Czudek and Demek, 1970, show photographs of Siberian rivers with vast thicknesses of brickearth type material overlying gravels in a similar fashion (allowing for differences of scale) to those of south Hampshire. The explanation of the brickearth of south Hampshire is made doubly difficult by the fact that no geomorphologist has observed stream action under cooling conditions and a falling base level so differences in both process and magnitude compared with stream action even in present high latitudes may occur. However, as the brickearth is almost certainly fluvial it is difficult to escape the conclusion that it is an overbank deposit of some kind.

As the river level falls so does the temperature as the cause of the fall in base level is the fall in temperature which is also causing the eustatic fall in sea level. This fall in level may not be continuous as the submerged terraces described by Everard (1954a) show, but eventually a glacial minimum sea level is reached. At maximum glaciation it seems likely that stream flow is greatly reduced due to the increase of water being stored as land ice and, possibly, to the decrease in precipitation*.

As the climate begins to warm up into an interstadial or interglacial run-off again increases to a maximum and gravel transport occurs but under conditions of unstable base-level associated with the ends of glacial periods no individual base-level is held for long enough for a substantial gravel terrace to be formed. Further, by the time sea level has risen to

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* Many of the buried channels of British streams are narrower in their deepest parts than the wide, immediately sub-surface, channels. Beckinsale and Richardson (1964), Hawkins (1962) and Shotton (1968) all describe sections in which a buried channel much narrower than the previous lateral planation stage occurs. Whether this is a function of decreased precipitation causing a reduction in stream width, or due to the transference of stream energy to downcutting rather than lateral effects is uncertain. The narrowness of the buried channels may reflect a combination of these two factors.

such a level so as to have deposits easily examinable (by their being close to present sea level) the climate has become far too warm for gravel deposition. By the time this stage is reached fluvial deposition is similar to the present with only fine sediments being deposited.

The above described sequence is to some extent synthetic in that in any area examined only some of the described stages may be present. In addition as already stated the sequence of depositional environments for any particular interglacial may vary so certain interglacials may have a widespread gravel deposition phase at their beginning while others may not, or at least have a phase of gravel deposition far below present sea level so their deposits are difficult to examine. It is probable that much of the gravel deposition at the glacial/interglacial transition goes to fill the buried channels of the previous glaciation. The thick gravel in the buried channel off Spithead has already been mentioned (Chapter II), but the base of the infills of the Severn (Beckinsale & Richardson, 1964), the Bristol Avon (Hawkins, 1962) and Thames (Woodward, 1909), are all gravelly and these gravels may represent the cold but warming conditions of the end of the last glaciation.

Suggestions by Sparks and West (1972) that a considerable fall in base level can occur without any downcutting by streams due to their shallow gradient when near to base level do not seem to be applicable to south Hampshire. These authors suggest that if a gently sloping sea bed is present off-shore, with a fall in base level streams would merely extend across this area and would not incise their courses until well into a glaciation when sea level had fallen considerably. This explanation may be applicable to East Anglia where Sparks and West have principally worked but off Hampshire the submarine slope east of the Isle of Wight is steep and any fall in base level would cause downcutting to begin rapidly.

Further evidence that the main episode of gravel deposition is in the climatic deterioration at the end of an interglacial is contained in the position of the faunal and archaeological remains associated with the gravels. Specifically, the position of the fossils (usually mammalian bones) and artifacts may show the sequence of climate under which the gravels were deposited. As mammalian remains can be referred to a particular climate (albeit only tentatively in the case of extinct species) so in situ or only slightly rolled implements also point to certain climatic conclusions.

It has been well known for a considerable time that implements in a sharp condition are mostly found at the base of Pleistocene gravel spreads. Abbott (in the discussion to Reid, 1893) suggests that the implements found in south Hampshire usually occur in the bottom of the gravel (actually "within two or three feet of the base") and Reid in this paper (1893) describes finding a Levallois flake at the base of the 25 ft. (8 m.) terrace gravels below Nelson's Place, Cadland. Palmer and Cooke (1923) suggest that most of the sharp implements from the Portsmouth district are in the base of the gravel or resting on one of the local solid formations, while Bury (1923) describes palaeoliths from the base of the gravel at Southampton Common (SU 415145) and Bitterne (SU 448132). Calkin and Green (1949) state that most implements rest on the Tertiary clay below the gravel in the Bournemouth area while Wymer (1968) in his exhaustive gazetteer of Thames valley Lower Palaeolithic sites mentions many localities on all the terraces of the lower Thames where sharp implements lie at the base of the gravel, either directly on the solid geology or in the lowest levels of the gravel. By contrast, implements recovered from higher levels in the gravel are always much rolled.

Wymer contends that this distribution of implements with the sharpest at the bottom of the gravel spreads and the most rolled within the gravel is a result of the terraces being constructed of "the sweepings of ancient land surfaces" in which any implements left beside an interglacial stream are soon buried by gravel as climatic deterioration sets in. The more rolled implements are those which have either been re-excavated from under their gravel cover by the braiding channels of the river later in the phase of climatic deterioration, or implements which by chance have not been incorporated into the gravels until this later stage.

The sites which contain sharp implements such as the famous pit in the Boyn Hill terrace of the Thames at Furze Platt, Maidenhead (Wymer, p.221) often have an appearance of the coarse gravel of the terrace having been deposited in a "great rush" over the implements and the chalk which here forms the solid geology, and on which the implements lie. This flood of gravel was laid down without damaging or even greatly disturbing the implements. Wymer states that the situation at Furze Platt is rare and the more usual pattern for the end of an interglacial is for all the soil and fine material (together with the implements) to be swept away by the extreme conditions of gravel transport.

Many of the mammalian remains found below the gravels are of warm species such as Palaeoloxodon antiquus (Falconer and Cautley) and Hippopotamus amphibius (Linne). Franks (1960) shows that the faunal remains found in association with an Ipswichian pollen spectrum and macroscopic plant remains such as Corylus nuts, Acer fruits and Trapa natans (Linne) fruits at Trafalgar Square, London, are beneath the deposits of the Upper Floodplain terrace of the Thames (in this case sands capped with gravel rather than gravel alone). Similarly at Selsey, the Ipswichian deposits containing Dicerorhinus hemitoechus, Hippopotamus, Megaceros sp.(?) and Dama dama (clearly a warm fauna) lie directly below West and Sparks's (1960) raised beach which appears to be related to the 25 ft. (8 m.) terrace of the Solent.

In contrast the cold mammalian species usually occur in brickearth overlying the terrace gravels. The Crayford brickearth contains a typical "cold" fauna comprising Mammuthus primigenius (Blumenbach), Coelodonta antiquitatis (Blumenbach) and Equus przewalski. The brickearth in which these specimens occur lies on a gravel which in turn rests on the chalk. This gravel may be of Upper Floodplain terrace age (Kennard, 1944)*.

From this evidence it can be shown that certain brickearths are cool climate fluvial deposits. It does not necessarily follow from this that all brickearths are thus of cool climate origin but it does indicate that these fine grained sediments may form under such conditions. It is also possible for brickearth resting on gravel to represent a warm episode as in the case of the Lower Loam of Barnfield pit, Swanscombe, which is similar to brickearth in its description and is regarded by Kerney (1971) as of full temperate origin. However the large spreads of brickearth in the London area (mostly now quarried away) and in south Hampshire seem to represent cool climate fluvial deposition, probably formed by overbank flow during episodes of increased stream action due to increased run-off.

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* Kennard, who describes this Crayford deposit and its fauna, regards it as a warm assemblage and quotes Falconer as regarding the mammoth as a temperate species. Kennard states that no (warm-blooded) mammal would choose to live in a tundra environment like that usually envisaged for the mammoth and even states that a mammoth living in the tundra would starve to death because of the poor grazing provided by tundra plants. This rather unusual opinion of Kennard's can be refuted by reference to Farrand (1961) who gives a summary of the distribution of frozen mammoth remains in Siberia and describes a pollen analysis of the stomach contents of the famous Berezovka mammoth. The tree pollen in this specimen's stomach is from only a few species and these are the arctic types Salix polaris, Pinus sp., Larix sp., Abies sp. and Betula nana. The herbaceous pollen on the other hand fills a long list (Farrand, p.731) and consists of an assemblage of "boreal, meadow and tundra plants". Farrand also states that the frozen mammoth carcases found were all of robust individuals, not the dwarfed and thin examples which would be expected if the mammoth had been forced to live in an unfavourable habitat by being unable to compete with more successful species. Heintz (1958) gives a ^{14}C date for the Berezovka mammoth of around 39,000 years B.P. This further indicates the mammoth's preference for living in a sub-arctic or tundra environment as this date in the Middle Weichsel (Devensian) is close to the apogee of mammoth development (Kurten, 1968) and shows that many of the frozen mammoths of Siberia were not the remnants of a warmer climate population pushed to extinction in an unfavourable environment at the end of the Weichselian.

Chapter V. The Stratigraphy and Environmental Significance of Pleistocene Deposits at Stone Point*.

a) Introduction

On the Hampshire coast at Stone, Pleistocene deposits comprising gravel, sand, clay and peat outcrop on the foreshore and in the cliff behind it.

Organic horizons were first described at Stone by Reid (1893). He recognised their Pleistocene age and identified a flora indicative of mild climatic conditions. The stratigraphy of the Pleistocene deposits was considered briefly by Palmer and Cooke (1923); they recognised the gravels of a 15 ft. (4.6 m.) terrace at Stone overlying the organic deposits, but they considered the latter to pre-date not only the 15 ft. terrace but also an earlier 50 ft. (15.2 m.) terrace. The organic horizons were re-examined by West and Sparks (1960), who placed them, on the basis of pollen evidence, in zone f of the Ipswichian interglacial (Ip IIb). At the time of the latter investigation the site was largely covered by recent inter-tidal sediments and no detailed stratigraphical study was possible. The present account provides a re-appraisal of the stratigraphy of the site and describes organic sediments, including several horizons of _Phragmites_ peat, at levels slightly above O.D. and therefore higher than the material discussed by West and Sparks. During the present investigation the Pleistocene stratigraphy at Stone was studied in numerous excavations and auger holes on the foreshore. Forty three sections were measured and many additional unmeasured trial pits and auger holes were located between the main excavations. The distribution of the more critical sections is indicated in Figures 12-14.

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* This chapter is the text of a paper by Brown et al., 1975, Proceedings of the Geologists' Association, in the press.

b) Stratigraphy*

Figure 14 indicates the main relief and outcrop features at Stone. The cliff which falls 5.0-5.5 m. (16-17 ft.) to the beach from a level of about 7.5 m. (25 ft.), exposes a thin (< 1.0 m.) layer of brickearth resting on coarse gravel, termed in this account the Upper Gravel. At most times the lower part of the cliff is covered in talus, but short-lived sometimes extensive exposures can occasionally be observed. The upper part of the inter-tidal zone slopes seaward at an angle of about 8° for a distance of about 15 m. (50 ft.). Near the foot of the cliff this slope is covered by a modern beach of shingle and sand. At the seaward margin of the slope, Pleistocene deposits were exposed during the period of investigation (1971-73). The lower part of the inter-tidal zone slopes seaward more gently ($< 1.5^{\circ}$) and is everywhere covered by a thin layer of recent inter-tidal sediments. At low tides a broad area of this inter-tidal flat is exposed.

On the area of foreshore investigated the organic beds are separated into two outcrops occupying depressions in underlying gravel and sand, termed here the Lower Gravel. Between the two organic outcrops the Lower Gravel comes to the surface. Eastward and westward the Pleistocene deposits were found (pits 24 and 48-51) to pass beneath increasing thicknesses of present-day beach material and boundaries have not been traced. The general form of the deposits may be inferred however and is discussed below. Seaward the Pleistocene beds have been traced out on to the inter-tidal flat (pits 1, 2 and 11-15) and appear to pass beyond the low tide mark**.

Stratigraphically the lowest member of the Pleistocene succession is everywhere the Lower Gravel. In composition (Table Ia) and general appearance the Lower Gravel is similar to terrace gravels of the former River

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* By the present author and C.P. Green.

** Detailed studies have been concentrated around the more westerly of the two organic outcrops (Fig.12).

Solent. The flints of which it is largely composed, while obviously abraded, are mainly angular. The bulk of the deposit seems to be gravel; beds of sand are present but no structures were observed. The full extent of the Lower Gravel is unknown; it is not, however, present at Lepe Coastguard house, 0.6 km. (650 yds.) west of Stone, nor at Cadland, 2.0 km. (1½ miles) north-east of Stone. At both these sites the gravel of a 7.6 m. terrace rests directly on the Tertiaries and its base is at approximately the same level as the base of the Upper Gravel at Stone. The Lower Gravel appears therefore to occupy a depression cut in the Tertiaries to below present sea level. Where the Lower Gravel comes to the surface, pits (22-27) dug through the modern beach encountered up to 2.4 m. (8 ft.) of gravel beneath the beach shingle without reaching a base. Where the Lower Gravel and the organic beds outcrop on the foreshore, they are usually separated by a thin ($<$0.25 m.) (10 inch) bed of pebbly clay (examined in pits 40-43). In the underlying Lower Gravel parts of a profile resembling the bleached E_g,B_s (iron pan) and C horizons of a podzol were observed.

The organic beds rest on a generally flat surface which slopes very gently seaward. The full thickness of the surviving organic deposits has been established at 16 points and nowhere exceeds 2.2 m. (7 ft.). The complete stratigraphy of the organic deposits cannot be described from a single section. The topmost horizons are preserved on the south-western side of the exposure where lower horizons, which are present further down the beach, are absent. The estuarine silty clays and freshwater detritus mud described by West and Sparks are not encountered beneath the deposits described here and probably lie to seaward.

The organic deposits consist of distinct peat horizons and lenses between 2 and 24 cm. (1 and 10 inches) thick containing abundant remains of _Phragmites_, which alternate with homogeneous dark grey (5Y 3.5/1) estuarine clay. The outcrop of four peat horizons (A-D) could be traced on the beach and into pit sections, and a further horizon (E) was recognised at depth. Peats C and D merge together in places and are noticeably variable in thickness. The dip of the peat horizons is irregular in detail but is generally inward from the edge of the organic deposit at angles between 1° and 6°. The peat horizons are highly compressed and have laminae which, except in peat A, are separated by thin layers of clay.

The estuarine clays are in general not obviously organic, but lenses of organic clay occur in the thick clay horizon in the upper part of the succession between peats A and B. This clay yielded molluscan remains, abundant plant macro-fossils and a tibia of Dama dama Linn. The uppermost clays in pits 44 and 45 show signs of weathering.

The Upper Gravel, like the Lower Gravel, resembles terrace gravels of the former River Solent, both in composition (Table 1a) and structure. Coarse gravel is largely predominant but a few beds of fine gravel and sand are present. Obscure imbrication and horizontal stratification are common in the gravel and cross bedding occurs in some of the finer material. Cross bedding at Stone indicates a current direction from approximately 280°N. An easterly trend is, understandably, typical in the current bedding of most of the gravel terraces of the former Solent. The Upper Gravel forms part of a 7.6 m. (25 ft.) terrace, extensively preserved between Calshot and Lymington. At Cadland, cliffs in the gravel of this terrace show, in addition to the features displayed at Stone, cut and fill structures, and numerous pebble-size mud clasts in the gravel.

West and Sparks (1960) suggest that the organic deposits at Stone pass like those at Selsey beneath the gravels which form the cliff. Examination of the upper part of the beach shows that this is not now the case. In pits 32, 33, 37 and 40-42 no sign of the organic beds was seen at the appropriate level. The organic beds are likely, however, to have passed beneath the Upper Gravel when the cliff, which is suffering erosion at the present time, stood further to seaward. Reid (1893) states that the clay 'distinctly underlies' the gravel. Figure13, section A indicates a steep margin to the organic deposits at their north-western limit and section B shows that the underlying pebbly clay and Lower Gravel can be traced into the cliff, up to a level of about 2.0 m. (6 ft. 7 ins.) O.D., where the Lower Gravel is directly overlain by the Upper Gravel, without any intervening organic bed. The base of the Upper Gravel is evidently a level above which organic horizons are unlikely to have survived; therefore little or none of the organic succession is lost as a result of present-day erosion, and there is small likelihood that organic horizons higher than those described in this account exist at Stone.

When the lower part of the cliff has been exposed, the junction between the Lower and Upper Gravels has been traced to the east of pit 33, at about the same level, over a distance of 85 m. (266 ft.). However, the cliff exposure to the west of pit 33 and sections through the upper part of the beach show that the junction of the Upper Gravel with the underlying deposits is uneven. Moreover patches of gravel, thought to be the Upper Gravel, have been found on the inter-tidal flat, resting directly on the organic clay (pits 11-15).

c) Flora*

(i) Collection and preparation.

Pollen samples were collected from the faces of pits 44 (peat A), 45 (peats B-D) and 34 (peats B-E). Peat horizons were sampled separately except in pit 34. The correlation of peat horizons between pits was possible both stratigraphically and on the basis of pollen evidence.

Pollen is abundant in most samples, whether from peat or clay. Grains are usually well preserved although squashed and badly folded grains made identification difficult in some instances.

Bulk samples were collected for both molluscan and plant macrofossil analysis from pits 44 and 45 and from exposures on the foreshore (Figure 14).

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* By R.C. Brown.

Plant remains were taken from the samples after the extraction of the molluscs. One sample (pit 35) was taken from a surface exposure of clay, rich in plant remains, between peats A and B, specifically to examine the plant macrofossils.

(ii) Palaeoecology.

The pollen spectra are similar to those described by West and Sparks (1960) from lower in the succession at Stone and from the upper horizons at Selsey, and placed by them in zone f of the Ipswichian interglacial (Ip IIb). Much of their interpretation can be extended to the present results. The differences are in the occurrence of *Carpinus*, possibly placing the deposits nearer the top of zone f (Sparks & West, 1970), and in the higher frequency of pollen of *Acer* and Chenopodiaceae.

The proportion of tree pollen varies from 46 to 62 per cent, except in the weathered horizons in pits 44 and 45. Higher frequencies here (54 to 75 per cent) are interpreted below. According to Pennington (1970) 46 to 62 per cent AP does not indicate a closed forest cover, although in the present case allowance must be made for over-representation of NAP from plant communities in the immediate inter-tidal zone. Nevertheless arboreal macrofossils are locally abundant and suggest proximity to the former forest community.

There is little change of individual pollen frequencies in the profiles and it is unlikely that changes of regional vegetation occurred. Only in the weathered clay at the top of pit 45 is any marked change apparent. Here *Pinus* and *Alnus* values rise and *Quercus* shows a marked decrease. This may reflect differences between marine and freshwater environments (cf. West & Sparks, 1960). However, *Quercus* grains show signs of decay in this horizon and pollen is much less frequent. It seems more likely therefore that the low *Quercus* values reflect selective oxidation of this species. Selective oxidation may also have affected NAP in this horizon and may explain the higher AP frequencies mentioned above. All the results obtained from this weathered horizon are disregarded in the present palaeoecological interpretation.

Quercus forms a consistently high percentage of the tree pollen (47-79 per cent) and points to a regional vegetation dominated by oak. The presence throughout the deposits of small quantities of *Acer* pollen (3-24 per cent), which is normally under-represented in pollen rain, suggests that the forest included a fairly high proportion of *Acer* trees. Conversely, small amounts of *Pinus* pollen (2-27 per cent) suggest that few *Pinus* trees were present.

The amount of *Alnus* pollen increases slightly in peat A. This either reflects an increasing regional importance of *Alnus*, or is associated with the change to fresher water conditions indicated by this peat. The pollen of *Betula*, *Ulmus* and *Carpinus* are sporadically present throughout the succession, and trees of these genera were probably present in the forest.

Pollen of *Carya*, *Tsuga*, *Celtis* and *Sciadopytis*, and a number of distinctive well preserved, but unidentified grains are probably derived from nearby Tertiary beds. Grains of *Carya* in zone b at Selsey are considered by West and Sparks to be derived. *Picea* and type 'A' cf. *Taxus* pollen may also be derived. Grains of *Picea* were in general the least well preserved.

Pollen from the herbaceous group constitutes from 12 to 35 per cent of total and is chiefly made up from pollen of Gramineae (7-50 per cent) and to a lesser extent of Chenopodiaceae (3-54 per cent). Grass pollen was probably contributed to the spectrum from both the local reed community and from the regional oak forest.

Alternations of freshwater and marine conditions are faintly apparent in the pollen succession. Pollen of Gramineae and, as West and Sparks found at lower levels, of Sparganium are more frequent in the freshwater deposits. Nevertheless the highest frequency of Chenopodiaceae pollen (54 per cent) is in peat A.

Plant macrofossils support the pollen evidence. Remains of *Quercus robur* are common in the deposits, especially in the clay between peats A and B, where they include wood (some with bark attached), buds, cupules and fruit (see Plate 18). These were presumably derived from forest at the edge of the marsh, since no tree remains are rooted in the deposits. Fragments of Acer fruits (without wings) are also quite frequent. The other remains derived from the terrestrial vegetation include a fragment of Pteridium aquilinum with sori and spores present.

Apart from terrestrial plant remains, the clays chiefly contain the remains of saltmarsh species, confirming molluscan evidence of the intertidal nature of the sediments. Aster tripolium, one or more species of Atriplex, Glaux maritima and Scirpus maritimus are present. In the peats, on the other hand, salt marsh and freshwater species are equally frequent except in peat A which contains almost exclusively freshwater species. Such mixtures would result from periodic flooding of reed communities which is also suggested by the presence of clay and molluscs in these peats. Freshwater species include Carex cf riparia, Carex cf rostrata, Hydrocotyle vulgaris, Lemna sp., Lycopus europaeus, Menyanthes trifoliata, Ranunculus sceleratus and Sparganium sp.

d) Mollusca*

(i) Preparation and identification.

Shells were separated from the bulk samples previously mentioned. Samples of 1 kg. (air dry weight) were heated to 100°C in an oven for several hours and then soaked in 10% NaOH for varying lengths of time. They were subsequently wet sieved, with a strong jet of water, through a 250µ sieve.

The molluscan remains at Stone are sporadically distributed, often fragmentary and frequently cannot be determined to specific level with certainty. Shells of Hydrobia ventrosa were commonly recovered intact. Specimens of Hydrobia ulvae were sometimes complete but generally rather

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* By D.D. Gilbertson.

abraded. The counts of Phytia myosotis are based on apical fragments, though fragments of lip and columella occur. Intact specimens of Scrobicularia plana can be found on the foreshore, but none was recovered intact in the samples. This species was recognised on the basis of hinge fragments which are variously preserved. Like Ostracods and Foraminifera it is rare in the deposits examined.

(ii) Palaeoecology.

Both the composition and the sporadic distribution of the molluscan fauna are of interest. The fauna resembles that found in the lower horizons of the Stone deposit by West and Sparks (1960). These authors' arguments and conclusions can be applied to the material described here.

All four species of mollusc recorded are diagnostic of brackish water. The dominant species, Hydrobia ventrosa and the less common Phytia myosotis are more frequent today in the upper parts of the inter-tidal zone, whereas Hydrobia ulvae and Scrobicularia are generally more abundant in the more saline conditions of the lower part. In the inter-tidal environment considerable mixing of faunas can be expected due to the action of tides and storms. Additionally the behaviour of molluscs has to be considered. Hydrobia ulvae, for example, is known to float in and out on tides, as well as crawl short distances and burrow (Chatfield, 1972). Where substantial numbers of molluscs occur in the present deposits and in the sediments described by West and Sparks (1960), the faunas indicate that the clays were collecting in the upper parts of a salt marsh. When shells, particularly the Hydrobids, do occur at a particular horizon, they are found in thousands, exactly as they can sometimes be seen on modern tidal flats. The largest numbers lie between peats A and B and below peat D. They appear patchily elsewhere, and their distribution probably reflects the presence of shallow ridges and hollows on the mud surface on which they lived. The occasional occurrence of inter-tidal species in the Phragmites peats can probably be explained by deposition during exceptionally high tides or storms.

The general absence of freshwater and terrestrial species in what must have been fresh or only weakly saline environments is particularly interesting. Sediments collecting in brackish conditions nearly always contain some marsh and/or terrestrial species where there is some fluvial influence. Such shells are re-deposited after falling into a stream from vegetation, or being eroded from a stream bed or bank (cf. Selsey, West & Sparks, 1960, Table 4; Wretton, Sparks & West, 1970, p.24). The total absence of land and freshwater shells suggests that the site upon which the Stone interglacial beds were deposited was not significantly influenced by freshwater streams while the sediments were collecting.

e) Discussion*

The Pleistocene deposits at Stone have previously attracted less attention than those at Selsey and have been described less thoroughly (Reid, 1892, 1893; West & Sparks, 1960). They have been thought, moreover, merely to confirm certain features of a more complete record at Selsey. In the present account it is shown that the Stone deposits differ in several important respects from those at Selsey.

At Selsey the Pleistocene succession can be interpreted as a fairly typical Ipswichian one. During periods of low sea level associated with glaciation prior to the Ipswichian valleys and channels were eroded to levels below the present sea level. Aggradation of these valleys and channels occurred as the climate improved and the sea level rose during the Ipswichian.

At Selsey, West and Sparks (1960) describe continuous freshwater sedimentation (their Bed 1), from at least as low as -4.0 m. (13 ft.) O.D. to at least as high as -1.0 m. (3 ft.) O.D., representing Ipswichian pollen zones b-c (late Wolstonian-early Ipswichian transition). They recognise a fall of water level during zone c, to explain the erosion of the surface

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* By C.P. Green and the present author.

of Bed 1. Water level cannot have fallen below -4.0 m. (13 ft.) O.D., if as West and Sparks believe, sedimentation is continuous at that level between Bed 1 (zones b-c) and Bed 2 (zone d onward). Above this level Bed 2 spreads unconformably across the eroded surface of Bed 1. Thereafter sedimentation continued without interruption into zone f, to a level of at least -1.0 m. (3 ft.) O.D.. At -1.76 m. (5 ft. 6 ins.) O.D., within zone f, evidence of brackish conditions comes in but sedimentation is continuous.

West and Sparks regard the Selsey deposits as having been laid down in a lake or slow moving river. The generally clayey and silty sediments are certainly consistent with sedimentation in a quiescent environment (although erratic boulders in Bed 1 are problematic). It is also evident that the onset of brackish conditions during zone f was gradual; e.g. by progressive upstream migration of high tide levels; or by the increasingly frequent invasion of a freshwater lake by high tides.

At Stone the situation is different. There is no evidence of continuous sedimentation in the early part of the Ipswichian. The zone f sediments are everywhere deposited unconformably over inorganic gravel and sand (the Lower Gravel). The latter represents an aggradation from below present sea level to at least 2.0 m. (6 ft. 6 ins.) above it, and at least 4.0 m. (13 ft.) above the level at which brackish conditions commence in the Ipswichian deposits (i.e. at least 4.0 m. (13 ft.) above the lowest organic sediments described at Stone). Moreover the Lower Gravel had accumulated and was already somewhat dissected prior to the deposition of the organic beds in zone f of the Ipswichian. The Lower Gravel might be regarded as the equivalent of Bed 1 at Selsey. For several reasons it is, however, unlikely that the Lower Gravel at Stone represents evidence of fluvial or estuarine aggradation in the earlier part of the Ipswichian. Firstly such aggradation related to a sea level below O.D. (cf. Selsey), whereas the Lower Gravel occurs at levels up to 2.0 m. (6 ft. 6 ins.) O.D.. Secondly, the Lower Gravel does not resemble a flood plain deposit of interglacial origin laid down by a river of very low gradient such as the former Solent or its tributaries seem likely to have been. Nor does it resemble sub-tidal estuarine sediments, although it is overlain by inter-tidal mud. There is no sign in the Lower Gravel at Stone of the erratics found in Bed 1 at Selsey. The Lower Gravel is generally very similar to the Upper Gravel and both suggest torrential conditions of deposition, probably in braiding fluvial channels.

The Lower Gravel represents evidence of fluvial aggradation commencing below present sea level and rising above it, during a period prior to the rise of sea level in the Ipswichian. It is difficult to be more precise about the age of the Lower Gravel. Neither the base level of the surface on which the Lower Gravel rests, nor the level at which aggradation culminated are known. The present authors consider that the Lower Gravel is most likely to represent aggradation during a cool interstadial within the Wolstonian.

Other evidence of low sea levels has been recognised in south Hampshire. Buried channels are described by Everard (1954) in the Solent but the gravels occupying them are probably Devensian. Codrington (1870) described gravels, now eroded away by the sea, at Hordle (19 km. (12 miles) south-west of Stone) filling a channel cut in the Tertiaries down approximately to present sea level. The surface of these gravels formed a terrace at about 18.0 m. (60 ft.) O.D.. The gravels were unlikely therefore to have accumulated during or since the Ipswichian interglacial. They might have been of Wolstonian age and equivalent to the Lower Gravel at Stone, but this cannot be demonstrated and the possibility of there having been other periods of low sea level remains. Kellaway (1973) suggests for example that the erratics in Bed 1 at Selsey may be of pre-Cromerian age.

We conclude therefore that the brackish and freshwater sediments at Stone are not underlain by earlier Ipswichian deposits, but by a pre-zone f land surface. It seems possible that a podzolic soil had developed upon this surface prior to the deposition of the organic beds. The surface was not flat, and although the origin of the local relief is unknown there is no evidence that the rise bounding the organic deposits on the north-east and north-west was the margin of a pre-existing channel or lake. Stone was not then a flood plain site or lacustrine site like Selsey. The Stone site seems to have been a gently inclined valley side slope or coastal plain of low relief, perhaps overlooking the estuary of the contemporary Solent river. This interpretation of the terrain, as one somewhat removed from direct fluvial influences, is strongly supported by the distinctive character of the molluscan fauna at Stone. On the basis of the molluscan evidence West and Sparks described the Ipswichian site as an 'open foreshore'. The fauna, of exclusively brackish species, suggests that no freshwater streams drained through this area of coastal salt marsh. A suitable analogy for the coastal terrain in Ipswichian times can be seen today just west of Stone at Thorn's Beach and Pylewell. Here a coastal plain, in this case the gently sloping surface of the 4.6 m. (15 ft.) terrace of the former Solent, descends to present high water mark where it is covered with inter-tidal sediments.

At Stone the accumulation of inter-tidal muds and the development of salt marsh occurred during zone f of the Ipswichian as rising sea level caused marine conditions to encroach across the low lying terrain and created a suitable inter-tidal topography. The rise of sea level was apparently interrupted on several occasions. The pauses or perhaps slight falls of sea level are indicated at Stone by the development of Phragmites peat. Phragmites is tolerant of slightly saline conditions and occurs at the back of many south coast salt marshes today. In peats B, C and D remains of salt marsh plants and mollusca, and the presence of fine laminae of clay, suggest that the reed swamps were subject to periodic inundation by the sea. In peat A the absence of most of these features (molluscan remains are still found) suggests that a more marked fall of sea level may have occurred at this time. The continuing overall rise in sea level is indicated, however, by inter-tidal clays overlying peat A.

The organic Ipswichian sediments were originally overlain by the Upper Gravel (of the 7.6 m. (25 ft.) terrace). West and Sparks following Everard (1954) suggest that this is a raised beach deposit and probably equivalent to the raised beach overlying the Ipswichian deposits at Selsey. There are, however, important contrasts between the gravels at Stone and Selsey, as West and Sparks recognise. The Stone gravel resembles terrace gravels of the former Solent, which are undoubtedly of fluvial origin. The flints in the Upper Gravel, though water-worn, are mainly angular. Well rolled material is rare, whereas at Selsey the pebbles are mainly rounded. At Stone and in the presumed equivalent of the Upper Gravel nearby, no erratic blocks have been seen. In the Pleistocene sands and gravels of the West Sussex coastal plain, of which the Selsey raised beach is part, Hodgson (1964) describes erratics as common and widespread.

Everard (1954), and subsequently West and Sparks argue that the gravel at Stone is of terrestrial origin, but has been soliflucted and then re-sorted by marine action. There is, however, ample evidence at or near Stone that the gravel in its present form is of fluvial origin. Particle shape and orientation, the distribution of the deposit as a broad terrace composed largely of gravel and the character of the poorly developed sedimentary structures are all consistent with deposition in a braiding river. In almost all respects the sediments in question are quite unlike either the present day beach deposits of the Solent coastline, or the raised beach deposits in West Sussex.

Thus, the Ipswichian organic deposits at Stone are overlain by a fluvial gravel indicative of deteriorating climatic conditions. A similar climatic succession is indicated at several other Ipswichian sites: Wretton (West & Sparks, 1970); Stutton (Sparks & West, 1963); Ipswich (West, 1957);

Trafalgar Square (Franks, 1960). The Upper Gravel at Stone rests unconformably on the underlying sediments (cf. Wretton) and the base of the gravel is uneven. Weathering effects are apparent in the upper part of the underlying clays but it is not clear whether these effects relate to a pre-existing land surface or whether they have arisen since the deposition of the Upper Gravel. It is not possible therefore to determine the level to which the Ipswichian inter-tidal sediments may originally have accumulated.

Chapter VI. The Climatic and Chronological Succession in South Hampshire.

a) Surfaces over 150 ft. (46 m.)

From the above considerations the climatic status and stratigraphic position of the Pleistocene deposits of south Hampshire can be determined. The basis of this chronology must be mainly altitudinal. The earliest Pleistocene deposits of the area are those of the high levels described by Everard (1954b). As stated above these gravels were not examined due to the fragmentary nature of their outcrop and their great age.

b) 100 ft. (30 m.) terrace

The earliest major level in the sequence is the wide flat ranging from 130 ft. (39.6 m.) down to around 90 ft. (27.4 m.) well represented in the Beaulieu Heath - Lady Cross Walk level. On altitudinal evidence this level may be equated with the Swanscombe deposits but only the upper levels at Swanscombe are represented in south Hampshire as these gravels must be referred to the end of the Hoxnian interglacial as the climate cooled. No deposits clearly of early Hoxnian age can be seen. This terrace has extensive brickearths resting on it which must be referred to a period of overbank deposition (as described above) as the sea level fell with the approach of the first stage of the Wolstonian glaciation.

The number of exposures of the bench below the Hoxnian gravel is small - only the cliff section from Highcliffe to Barton has an extensive section across the bench. While it is, therefore, unwise to state firmly that no deposits of Hoxnian interglacial age occur in the New Forest, the evidence of the Highcliffe exposures seems to show that the gravels of the Hoxnian terrace were all deposited in the late Hoxnian - early Wolstonian transition. Green's (1946) description of the 100 ft. (30 m.) terraces in the New Forest as "Boyn Hill" also suggests a Hoxnian date although his suggestion of an "Upper Taplow" (a presumably post-Hoxnian) age for a terrace between 100 ft.

(30 m.) and 50 ft. (15 m.) shows that he did not notice a marked break in the gravel surface which occurs at 85-90 ft. (26-27.6 m.) O.D. which splits his "Upper Taplow" terrace into two.

c) 60 ft. (18 m.) terrace

Following the formation of the 100 ft. (30 m.) terrace downcutting to at least around present O.D. occurred before aggradation up to 60 ft. (18 m.) and the formation of the 60 ft. (18 m.) terrace surface occurred. There is clear evidence of this downcutting in the former Hordle channel. In the lower Thames similar post-Hoxnian downcutting has been recorded in the Swanscombe area (Burchell, 1936b) while Wymer (1968) suggests that the gravel which underlies the Crayford brickearth also dates from this episode.

The downcutting from around 90 ft. (27.5 m.) to present O.D. in post-Hoxnian times seems likely to have been prompted by a cold period and renewed aggradation up to 60 ft. (18 m.) seems equally likely to indicate an amelioration of the climate. The presence of a wide terrace surface above the Hordle channel points to an episode of lateral planation (as described in Chapter IV.c) under cooling conditions so it is possible that the 60 ft. (18 m.) terrace is the product of an interstadial if not an interglacial.

The events of post-60 ft. (18 m.) times are somewhat obscure in south Hampshire. As this episode is pre-Ipswichian and post-Hoxnian it is reasonable to date it as Wolstonian although how it relates to known Wolstonian sequences elsewhere is uncertain. No deposits definitely of Wolstonian age are known in south Hampshire. The last deposit of the 60 ft. (18 m.) terrace, the brickearth of Hordle cliff, can perhaps be dated to an early phase of this glaciation but other deposits of this age are unknown. It is possible that the gravel below the organic horizon at Stone (Chapter V) may have been dissected during this period but no real evidence can be advanced for this suggestion.

d) 25 ft. (8 m.) terrace

The presence of the interglacial site at Stone indicates a date for the 25 ft. (8 m.) terrace. The gravels overlying the peat and silt must postdate zone Ip IIb of the Ipswichian, and the presence of Carpinus at the top of the pollen diagram described by Brown et al. (1975) suggests that zone Ip III had begun before gravel began to be deposited. As at many other Ipswichian sites (see Part III) there is ample evidence for a full interglacial climate at Stone. The unconformity between the estuarine deposits of the organic horizon and the coarse gravels of the terrace proper clearly relates to the deterioration in climate leading to the Devensian. The exact stage within the Ipswichian at which this climatic decline began, however, is unknown as the powerful force which deposited the gravel of the terrace also removed the top of the organic deposits.

Green (1946) does not refer to any terrace below 50 ft. (15 m.) and he regards this terrace as the last formed by the Solent River. Everard (1954b) describes the two lowest terraces of the Solent as the 35 ft. (10.7 m.) and 15 ft. (4.6 m.) terraces. There is little clear evidence that the low terrace reaches above 30 ft. (9 m.) but, given the difficulties in measuring the terrace heights in the New Forest, the 35 ft. (10.7 m.) and 25 ft. (8 m.) terraces are probably the same feature.

Whether the 15 ft. (4.6 m.) terrace also belongs in the 25 ft. (8 m.) stage is open to question. In a few places west of Southampton Water gravels at around 15 ft. (4.6 m.) can be seen (see fig. 1). It is possible that these gravels are part of the 25 ft. (8 m.) terrace and were formed as the sea level fell in the early Devensian or they may be attributable to an early Devensian interstadial.

e) Post-Ipswichian events

As the Solent River system persisted into the Devensian the minor drainage of the New Forest is essentially a product of the last glacial period. As has been established above (Chapter IVb) the valley forms of many of these minor streams are similar to those described by various authorities for valley forms in Arctic areas, which gives additional weight to the suggestion that these valleys formed under cold conditions.

The episode of capture of the south-west to north-east stream component by a north to south component must also be placed in the Devensian. As all the minor stream systems below around 30 ft. (9.1 m.) must be Devensian it follows that the age of the captures must be Devensian too as all of the "elbows of capture" in the area lie below this height. Tremlett (1965) who pointed out the capture by the lower Beaulieu and Lymington Rivers of an original south-west to north-east stream states that these lower, capturing reaches have no 60 ft. (18 m.) terrace because these north to south reaches were not cut until a lower base level was established. He suggests that a north - south "consequent" established itself on a land surface abandoned by the 60 ft. (18 m.) sea and cut headwards to erode the present Beaulieu River valley. The capturing streams probably began by flowing down the main slope of the terrace, in this case the transverse slope, when the levels which appear at present as the terrace surfaces of the Solent River were abandoned by that stream. This abandonment would occur when the base level began to fall during the onset of glaciation and the braiding channels of the Solent transferred their energy into downcutting to the buried channel.

As the lower Beaulieu and Lymington Rivers have no 60 ft. (18 m.) terrace the drainage of the 100 ft. (30 m.) terrace in "60 ft." times must have been carried by the south-west to north-east stream later dismembered by the Lymington and Beaulieu river captures. This original stream is much older than the north - south streams which cut it apart. The remnants of its course which can be seen above Brockenhurst, where its elbow of capture lies, flow in a very wide open valley the form of which is in distinct contrast to the relatively deeper and narrower troughs of the lower reaches of the Lymington River (see Plates 4-6 and cross-profiles of the Lymington River, Fig. 10).

The capturing north - south streams were initiated on the 60 ft. (18 m.) terrace of the Solent River. Tremlett (1965) suggests that the lower Beaulieu River valley contains a 35 ft. (10.7 m.) terrace and a 15 ft. (4.5 m.) terrace. There is a suggestion of terraces at these heights on the west bank of the river below Beaulieu but the terrace bluffs are masked by a continuous slope down from the 60 ft. (18 m.) terrace of the Solent River, which is here cut by the Beaulieu river (see Plate 7).

A marked flattening at around 25 ft. (8 m.) does occur on both the Beaulieu and Lymington Rivers near the mouths of these streams. At Lymington, while much of the town is built on the 60 ft. (18 m.) and 100 ft. (30 m.) terraces of the Solent, Lymington High Street descends a steep bluff from around 60 ft. (18 m.) to a flat at around 25 ft. (8 m.) which is part of the 25 ft. (8 m.) terrace of the Lymington River. This terrace, while well marked at Lymington, cannot be traced far up the Lymington River. At Boldre Bridge (SZ 320985), around 2 miles (3.2 km.) upstream of Lymington, no trace of this terrace remains (see Plates 4 and 5) and the valley sides rise steeply from the valley floor to the surface of the 60 ft. (18 m.) terrace of the Solent.

Tremlett (1965) correlates his 35 ft. (9 m.) terrace with the "late Ipswichian" terrace of the Solent (presumably the 25 ft. (8 m.) terrace) so elements of the minor drainage pattern may have developed in the Ipswichian. However, most of the minor drainage of the New Forest is solely a product of the Devensian glaciation and the captures of the south-west to north-east streams must have taken place during this episode. The formation of the valleys was greatly assisted by the cold climate and accelerated erosion associated with the periglacial conditions occurring at this time.

Chapter VI. Appendix.

The age of the break-up of the Wight-Purbeck ridge

Ever since the existence of a Pleistocene Solent River was first postulated (Fox, 1862) authors have attempted to date the final break-up of the Wight-Purbeck ridge. Even Everard (1954b) who was otherwise unconcerned with the dating of the south Hampshire gravels attempted to find the age of the final destruction of this long chalk barrier.

Reid (1902) states that the breach of the Wight-Purbeck ridge occurred in the Pliocene or lower Pleistocene and he associated it with the diversion of his upper Avon to its present course. According to White (1917), Reid later modified his views and concluded, along with White, that the final breaching of the ridge did not occur until the "close of the Pleistocene period". White further states in the Lymington memoir (1915) that "the ancient River Solent seems to have persisted well into Pleistocene times, and there is reason to think that the capital disintegration of its system, which followed on the effective breaching of the southern uplands, and the interception of the main stream by the sea westwards of the Isle of Wight took place mainly within the period covered by the deposition of the superficial formations". This statement of White's gives the key to the evaluation and dating of the gravels of south Hampshire for, if the great gravel spreads are to be ascribed to fluvial action, only the Solent River can have been responsible for their deposition in the attitudes and positions they now take up.

Green (1946) dated the breach of the chalk ridge more precisely than White by placing it within his "lower Taplow" stage because he believed that this stage ends as a delta at Christchurch. Green places the exact site of the initial breach at the western side of Christchurch-Poole Bay and concludes that the original breach was enlarged by erosion of the chalk towards the east due to the effects of the prevailing westerly winds in the

Channel. He also states, somewhat obscurely, that the Frome's terraces below his First Lower Taplow terrace should increase their gradient to adjust to the new base level caused by the sea breaching the chalk ridge far to the west of the original mouth of the Solent. As Everard has pointed out, however (1954b, p.57), any breach of the Wight-Purbeck ridge in Green's Lower Taplow time would cause no significant fall in the level of the Frome because the River Solent at this stage (from the evidence of the "horizontal segments") must have been flowing only very slightly above base level.

Everard concluded that the final collapse of the chalk ridge must have been even more recent than Green suggested and placed the final break through in the late Pleistocene at the time of the low sea level of the last glaciation. Everard suggests that the agent of the final cutting of the ridge was the effect of sub-aerial erosion coupled with the dissection of streams such as the Western Yar, which probably flowed down the slopes of the ridge between the Needles and Handfast Point. The final flooding of the breach was then caused by the post-glacial (Flandrian) rise in sea level which speedily eroded the line of chalky islands left by the flooding of these minor valleys.

The present author's work in the area confirms the date suggested by Everard for the final breach of the chalk ridge. The minor valleys, which eroded the ridge into a series of blocks which were left as islets when the sea rose, were probably aided in their work of denudation by the increased erosion of slopes possible under cold conditions. The breach can be dated to a phase of the last glaciation by reference to the terraces of the River Solent. So long as the Solent continued to flow above present O.D. terrace remnants were left to indicate its former existence. At present, however, when the breach of its south bank has caused the Solent River to disappear no fluvial terrace can be formed. The youngest terrace in south Hampshire is the 25 ft. (8 m.) terrace which must date from late Ipswichian times (see Chap. V). After the deposition of this terrace, downcutting caused the abandonment of the terrace and the Solent flowed well below present sea level. The 15 ft. (4.6 m.) terrace mentioned by Everard (1954b) probably dates from this phase of downcutting but it may be of early Devensian interstadial age.

During the early Devensian (in post 25 ft. (8 m.) terrace times), the south bank of the Solent must have been attacked by periglacial action and the ridge was further dissected by the tributaries of the Solent as suggested by Everard. The final sea level rise of the Flandrian was probably unable, in one episode of sea level rise, to complete the destruction of the remnants of the chalk barrier. It is probable that the sea level rose near to the present in the mid-Devensian and carried out part of the erosion of the islets of chalk into which the continuous Wight-Purbeck ridge must have by this time have been cut. Continued action by solifluction in late Devensian times then made it possible for the rising Flandrian sea to complete the formation of Christchurch Bay as it appears at present*. The final stage of the Solent River was then in late Devensian times when the sea level was very low (Fairbridge, 1961) and the final drowning of its system must have been greatly aided by the excavation of the buried channel cut at this time. Although submerged the area of the chalk to the west of the Needles still forms a ridge and only a small (by late Devensian standards) fall in sea level would re-establish the continuous south bank of a new Solent River.

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* The erosion of the chalk continues today especially at the Needles and Freshwater Bay, although the chalk of Ballard Down to the west of Poole Bay is also being eroded. In 1896 during a great storm the stack known as "Old Harry's wife" off Handfast Point (SZ 056825) was cut in two by marine action and in 1967 considerable undercutting of the chalk east of Freshwater Bay caused a new stack to be formed.

PART II

Chapter I. The Channel Islands - An Introduction.

a) Solid Geology

The geological basis of the Channel Islands is one of great antiquity. The islands form part of the Armorican province of western Britain and western France (Renouf, in press), and the presence of Eocene limestones (Curry, 1960) to the west and north of Jersey suggests that the islands have been outlying parts of the main continental Armorican outcrop since at least the Eocene.

As in many other ways, so also geologically the islands present differences in their rock types. Guernsey has the oldest rocks (Roach, 1968), a series of gneisses, the oldest being up to 26 x 10^8 years old (Adams, 1967). These gneisses make up the bulk of the island (see map in Roach, 1968), the rest of which is composed of a younger series of gabbros, granodiorites, diorites and granites. The smaller islets to the east of Guernsey are also granodiorite while Sark has in addition some schists.

Unlike Guernsey, Alderney and Jersey are partially composed of sedimentary rocks. In Alderney the western end of the island is composed of an old granodiorite (age 222 x 10^7 years, Adams 1967) but the centre and eastern end are formed from a coarse, southerly dipping sandstone of late Pre-Cambrian age. The reefs and islets north of Alderney are also formed from this sandstone. Jersey similarly has its sediments, in a series of indurated shales and greywackes of Brioverian (late Pre-Cambrian) age, and a molasse conglomerate of possible Ordovician age (personal communication, J.T. Renouf). The western and south-eastern extremities of Jersey are composed of granites and diorites (age 56-58 x 10^7, Adams 1967) while the central north coast of the island is formed from a series of volcanics of unknown, but probably also late Pre-Cambrian, age.

b) Effects of deep weathering

In spite of their great age and seeming hardness, the rocks of the Channel Isles, with the exception of the Rozel conglomerate of Jersey, have contributed readily to the Pleistocene deposits of the islands. This is principally due to the great depth of weathering which they have undergone, which has enabled marine and periglacial action to destroy rock outcrops with relative ease. This deep weathering is well known in many of the hard rock areas of Armorica and in western Ireland (Palmer & Neilson, 1962; Waters, 1964; Orme, 1966; Ollier, 1969; Eden & Green, 1971). Deep weathering has in the past been ascribed to warm and humid action during the Tertiary (Orme, Waters) but this is doubted by Palmer and Neilson.

Examination of raised beaches in the Channel Isles confirms that Tertiary deep weathering was not alone responsible for rotting of the island's rocks. Such raised beaches and rock platforms as those at Le Catioroc (WV 260789) in Guernsey show that weathering continued well into the Upper Pleistocene. While it is possible that the rock platforms may have been cut in previously weathered rock (George, 1973) it is difficult to see how large cobbles could be formed from deep weathered granite which at present has the consistency of sand. It is simpler to assume that these cobbles were formed from fresh granite and then weathered to their present state in situ. From this it follows that weathering was occurring well into the Pleistocene even if it began in the Tertiary. Whether the weathering only occurred during interglacials (Elhaï, 1963; George, 1973) is uncertain but Czeppe (1964) describes exfoliation and corestone formation in sandstone in the modern periglacial climate of Spitzbergen so it is possible that similar weathering could have occurred during periglacial episodes in the Channel Isles.

The degree of susceptibility to deep weathering in the rocks of the islands appears to follow a definite pattern. The Guernsey gneisses are most affected by deep weathering, followed by the older granodiorites, diorites, younger granodiorites and granites which are sometimes almost unweathered. The Jersey volcanics are only deeply weathered where they are shattered as at Les Platons (WV 653554) and the sediments are virtually immune from deep weathering except for some decalcification in the thin limestones in the Jersey shales. Most of the deep weathering on all these rock types is sandy (see Eden & Green, 1971) with little clay visible in any of the profiles examined. This sand and fine gravel has been one of the main constituents of the solifluction deposits and a considerable contributor to the raised beach sands of the islands. The importance of deep weathering for the provision of material to the solifluction deposits can be seen on the outcrop of the Rozel conglomerate in the north-east of Jersey. As mentioned above this rock is almost immune to deep weathering and the solifluction and rubble head deposits associated with it are far thinner than on other rock types. In the valleys leading to Rozel (WV 696545) the valley sides are devoid of any Pleistocene deposits. This is in marked contrast to valleys on the granite or the Brioverian greywacke which, while they are no less steep sided, exhibit up to 5 ft. (1.5 m.) of head in every hollow in their sides.

c) The inclusion of deep weathered material in drift deposits

The typical solifluction deposit of the edges of the island plateaux in Guernsey and Jersey consists of loessic material (distinguishable from in situ loess by its deep red colour) which incorporates abraded and weathered fragments of the underlying deep weathered solid rock. This gravelly sand was formed by the solifluction of the edges of the loess sheets of the flat plateau surface over the slopes cut in deeply weathered solid rock. The movement, and no doubt frost action, caused particles to become detached from the top of the weathered profile and incorporated in the solifluction sheet (Green & Eden, 1973).

On the island's cliffs both at the present coast and inland the deep weathered material forms a subsidiary part of the head, the major part being formed of large blocks of fresh or nearly fresh rock released from the steep slopes (such as at Bonne Nuit in Jersey) to form piles of rock and weathered sandy material at the base of the cliff*.

As described in Part I above the deposits in the Hampshire terrace sequence are largely derived from the erosion of pre-existing terraces. The same is true in the Channel Isles where a head may consist of a mixture of beach pebbles, earlier head and loess as well as newly eroded rock. Most of the raised beaches are similarly derived from the erosion of earlier beaches and heads as well as erosion of fresh rock.

d) Marine planation in the Islands

One of the most prominent features of the Channel Islands' coastline is the wide platform which stretches to seaward of the present coastline. In Jersey the platform is up to 2 miles (2.6 km.) wide to the south-east of the island (and up to 3 miles (3.9 km.) wide if the part covered by Holocene deposits is included), and in Guernsey 1 mile (1.3 km.) wide (or 1½ miles - 1.9 km. - if the "buried" section inland of the present coast is taken into consideration). Similar wide platforms have been described from the Scilly Isles (Mitchell & Orme, 1966), Sussex (Palmer & Cooke, 1923; Hodgson, 1964), Southern Ireland (Orme, 1966) and south-west England (Stevens, 1970). Despite deep weathering and multiple reoccupation by the sea, these platforms have kept their general surface level although they have considerable microrelief. (Some gullies in the platform near the Seymour Tower in Jersey (WV 724457) are 20 ft. (6 m.) deep.)

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* See Watson & Watson, 1970, and Mottershead, 1971, for accounts of similar examples of head formation in the Cotentin and south-west England.

Because of its great width the rock platform appears to be of great antiquity. Being merely a rock platform and lacking deposits except on its inner edge the platform is undatable, although evidence will be presented below to show that there have been at least two periods of reoccupation by the sea.

The platform is cut across all rock types in the islands indifferently. Its widest sections occur on the granites of Jersey and Guernsey while it is at its flattest and most regular when cut across the phyllite band in the Guernsey gneiss at Divette (WV 342754) and across the fine-grained Brioverian sediments at Les Rouaux (WV 656564) in Jersey. An important factor influencing the preservation of the shore platform is the attitude of geological structures. These structures are mostly the joint planes of the igneous and metamorphic rocks but the bedding in the sediments also has some effect. Where these structural planes cut the rock platform at low angles the platform is preserved. In areas where steeply angled structures occur the platform is narrow or absent. Along the south coast of Alderney for example, where the sandstones have a steep southerly dip, no rock platform survives.

The low shore platform is clearly the most extensive in the islands but at higher levels other platforms occur. The highest summits of the islands form a series of descending plateaux now mantled in loess and solifluction deposits*. No in situ deposits of marine origin occur on these surfaces which are at least as wide as the lower rock platforms, and are assumed to be of similar ages to such high level deposits as the highest fragmentary gravel terraces in the New Forest (see Part I). Below 120 ft. (37 m.) a rock platform as wide as the low platform occurs

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* Best developed between 200 ft. (60 m.) and 220 ft. (66 m.), and 160 ft. (48 m.) and 180 ft. (54 m.) but also occurring over 300 ft. (92 m.).

with marine deposits on it and is backed by cliffs at least as well marked as those of the modern coast. In Jersey these cliffs back the east, south and west coast bays. In Guernsey they separate the higher southern parishes of the island from the lowlands of the north and form the ridge which reaches its summit at Câtel Church (WV 310787). The platform at the foot of these cliffs, with its retrimmed 60 ft. (18 m.) continuation, approaches the 2 mile (2.6 km.) width of the low platform.

In spite of the deep weathering which the solid rocks have undergone they have maintained sufficient strength to support many caves around the coasts of the islands. It is in these caves that important parts of the Pleistocene sequence are to be found and these will be discussed more fully below.

Chapter II. The Non-Marine Pleistocene Deposits of the Channel Islands.

The non-marine Pleistocene deposits occupy by far the greatest areal extent of all the Pleistocene deposits in the islands. The two main divisions of these deposits were both formed in a periglacial climate, the head by solifluction and frost shattering and the loess by wind action.

a) The Loess

(i) Distribution

The loess is typically a structureless silt or fine sand (see grain-size analyses, fig. 36). Sections are rare and where they do occur are usually so well vegetated that no bedding can be seen. (Only at St. Martin's Church, WV 324765, in Guernsey can any bedding be seen. Here bands up to 1 inch (2.5 cm.) thick of alternating sand and silt occur. These bands can only be traced for a few yards and it is not clear what significance they have.) However, in spite of this lack of sections the outcrop of the loess is readily apparent on the ground from the characteristic soil formed on its silty grain size.

The main areas of loess are on the upland plateaux of the two largest islands. The smaller islands have almost no loess on them. It is unlikely that loess could be deposited on Guernsey yet not on Sark or Alderney and in fact these islands do have small patches of loess on the widest parts of their summits. The main factor in determining the shape and extent of the loess outcrop is the slope of the land. The two largest islands have extensive areas of nearly horizontal erosion surface broken only by a small number of trench-like valleys with abrupt steep sides. Sark and Alderney have no such large areas with only slight slopes. The loess was presumably deposited over all the islands but on the steeper slopes it was immediately carried away by solifluction so only on nearly level areas was a coherent cover formed. The narrower parts of the interfluves and peninsulas in Jersey and Guernsey behave in the same way as the smaller isles and have no loess cover. (The best example of this is the Jerbourg peninsula in south-east Guernsey.)

The second main characteristic of the loess is that it thins towards the west. In Guernsey road cuttings near St. Martin's Church (WV 324765) show a loess depth of 15 ft. (4.6 m.). At La Villette (WV 309763) one mile (1.3 km.) to the west augering proved 8 ft. (2.4 m.) of loess and at Torteval (WV 261755) 3¾ miles (6 km.) from St. Martin's the coherent cover of loess disappears and only a thick loessic soil remains. In Jersey also the loess thins to the west. Near La Hougue Bie in the east (WV 689504) at least 15 ft. (4.6 m.) of loess occurs. In the centre of the island in St. Lawrence and St. John 8-10 ft. (c. 3 m.) occurs but in the western parishes of St. Brelade and St. Ouen the loess is thin or absent. These western areas which at present have no loess cover clearly had loess deposited over them originally. In La Cotte de St. Brelade many layers of loessic head occur (McBurney & Callow, 1971), although this famous palaeolithic site is up to a mile (1.3 km.) from the nearest in situ loess. Similarly in Guernsey the head sections at Table des Pions (WV 238762) have loess bands up to 1 ft. (30 cm.) thick in them although they too are over a mile (2 km.) from the nearest in situ loess.

On the coastal plain of St. Clements and Grouville in eastern Jersey some exceptional thickness of loess are recorded. Borehole and well records collected by the late Miss Micia Casamir and now in the keeping of the Institute of Geological Sciences, show a maximum thickness of loess of 30 ft. (9 m.) in a well at L'Industrie, St. Clements (WV 675465). This depth (recorded as "sand" in the manuscript) must be exceptional because the limited coastal section at La Motte (WV 674460) shows a loess thickness of only 12 ft. (3.7 m.). Extreme depths for loess on the plateaux of both larger islands have occasionally been recorded. Dunlop (1911) cites a well at Five Oaks, St. Saviour (WV 670501) in which 50 ft. (15 m.) of loess was penetrated before rock was reached. Similarly Warren (1954) cites a well at Les Fosses, Forest (WV 283757) which passed through 53 ft. (16 m.) of "clay" before reaching rock. It is probable that such depths include a considerable thickness of weathered rock in the thickness of loess or that the bore has found a gulley in the top of the solid geology and so recorded an abnormal thickness of loess.

(ii) Organic remains.

The loess has few faunal remains in it. The only mammalian bones found in loess outside caves were some fragments of bone tentatively identified as Bos primigenius which came from the railway cutting at Pontac (WV 689469) in Jersey (Dunlop, 1911). No floral remains have been found in the loess except in La Cotte de St. Brelade and these will be described below (Part III).

Organic remains found in the loess are mainly molluscan. At a few localities* the loess and very loessic head exhibits calcareous concretions which have been identified with the "lössmanchen" of the continental loess. These concretions (which are composed of between 27% and 46% $CaCO_3$ and 34% to 46% fine sand, see Mourant 1934 and Girard 1969) are sometimes fossiliferous. Examples from some Jersey sites were examined by Kennard (see appendix to Mourant, 1935) and pronounced to be a typical loess fauna of:

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* St. Martin's Point (WV 344748), Les Sommeilleuses (WV 298745), Saints Right Battery (WV 322745) and Divette (WV 342754) in Guernsey; Belval (WV 711528), Portelet (WV 600471), La Motte (WV 674460) and Belcroute (WV 607484) in Jersey.

Pupilla muscorum (Linn.)
Succinea arenaria (Bouch. Chant.)
Trochulus hispidus (Linn.)

The Guernsey site of St. Martin's Point has yielded eight species from the loess (Girard, 1966) and this assemblage also points to dry conditions although it is possible that some of the species recorded at this locality are modern and from the soil on this steep slope. The species recorded were:

Helix aspersa (Müller)
Helicella caperata (Montagu)
Helicella virgata (da Costa)
Pupilla muscorum (Linn.)
Lauria cylindracea (da Costa)
Vertigo pygmaea (Drap.)
Cochlicopa lubrica (Müller)
Clausilia bidentata (Ström)

These molluscan assemblages indicate the dry conditions that would be expected during a period of loess formation but, as has been pointed out by Sparks and West (1972), they are a facies fauna and do not indicate any particular age.

(iii) Depositional environment.

It has long been known that the loess in the Channel Islands is of aeolian origin (Derrick, 1892) and a local equivalent of the loess of continental Europe (Elhaï, 1963). The grainsize analyses (figs. are typical of loess and the thickness of loess on east facing slopes (such as those below Grouville Mill (WV 695481) in Jersey) clearly indicate an easterly origin. In addition the great thicknesses of loess on the eastern coastal plain of Jersey (see above) and Guernsey (at Beaucette Quarry, WV 359837) and the rapid thinning of the loess to the west both suggest an easterly source for the wind which deposited the loess.

This deposition from the east fits in well with the theory of loess being of glacial origin produced by winds blowing off the ice sheets during maximum glaciation (Zeuner, 1945). However, many cliff sections in the islands suggest that there was no distinct period of loess deposition during which periglacial activity ceased but that loess deposition occurred throughout the period of formation of the head. The thick section of head with loess bands in it at L'Eree (WV 248784) in Guernsey shows clearly that at some stages loess deposition predominated but the presence of angular fragments even in these loess bands indicates that periglacial activity and loess deposition were contemporaneous rather than mutually exclusive (Plates 49 & 50).

(iv) Age.

The age of the loess is problematic. At the top of most sections of head (as at L'Eree) there is a thin (under 1 ft. - 30 cm.) loess which probably marks the last period of periglacial wind action at the end of the last glaciation and may be referable to one of the late glacial stages* but beyond this there is no evidence for the age of the loess. The coastal plain loess spreads in Jersey rest on the 25 ft. (8 m.) rock platform. If this platform was trimmed to the base of the "fossil cliff" during the last interglacial this loess must be of Devensian age. There is, however, no proof that, even with the high last interglacial sea level, the rock platform was entirely cleared of pre-last interglacial loess, thus some of the loess may be earlier. The survival of head (at Belcroute and Portelet) from pre-last interglacial

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* See Perrin et al. (1973) for similar late loesses in southern England.

times is clear evidence that some of the loess may have survived from the Wolstonian. However, in view of the large amounts of loess in the head which rests on the 25 ft. (8 m.) raised beach it seems likely that much of the loess is Devensian.

b) The Head

(i) Distribution.

The head in the Channel Islands is of two types. At the coast it is the characteristic rubble head of the earliest authors (De La Beche, 1839; Prestwich, 1893) which is a breccia of angular rock fragments in a finer matrix. This deposit is often very thick (up to 100 ft. - 30 m.) but of limited areal extent. The other form of head is a solifluction deposit formed primarily from loess but with an intermixture of rock fragments and pieces of weathered rock from the deep weathered profiles of the solid geology. By contrast with the coastal head this deposit covers large areas but is only of restricted thickness.

The coastal heads were formed by the shattering of rock outcrops by frost and the release of angular blocks to fall under gravity to come to rest on the rock platform or raised beach. The main influence on this process is the steepness of the cliffs which have to maintain a bare rock face to provide continuing amounts of rock to the cone of head at its base. It is probable that in places where deposition continued for a considerable time a profile like that illustrated in West (1968, fig. 8.46) resulted with head resting at a low angle against the cliff. Such a situation can be seen in Jersey 500 yards (460 m.) north-west of Gorey village where a cliff washed by the sea in the Ipswichian but now protected by the dunes of Gorey Common has a thick "wedge" of rubble head resting against it. If the sea were to break through the dunes and trim the base of the head a vertical cliff like those of many of the coastal sections would soon be cut (Elhaï, 1963; Watson & Watson, 1970; Mottershead, 1971).

Most of these coastal heads are undifferentiated, consisting of a rubble of blocks of every size in a matrix of sand or silt. Some sections exhibit loess seams, as at the west side of Moulin Huet in Guernsey (WV 330741), or bedding, such as at Clonque (WA 557072) in Alderney. The thickness of the heads varies from 100 ft. (30 m.) in Bonne Nuit, Jersey (WV 645559) to under 20 ft. (6 m.) at L'Eree, (WV 248785) Guernsey or Gibraltar (WV 709527), Jersey. The determining factor in the thickness of the head is the height of the cliff against which the head is banked. At Bonne Nuit the cliffs rise to 400 ft. (120 m.) at the north-east side of the bay while at L'Eree or Gibraltar the cliffs rise only to 80 ft. (25 m.). This relationship between the height of the cliff and the thickness of head has been described by Watson and Watson (1970) (in the Cotentin) and Mottershead (1971) in Devon. The present author's observations were made independently of these earlier workers and the present account agrees with them that the ratio of height of cliff to thickness of head is consistently around 4 or 5 to 1.

At a few places especially on the outcrop of the Brioverian shales in Jersey the particles in the head exhibit downslope imbrication but this is rare and more usual sections show a complete jumble of blocks. Probably the best example of such a chaotic deposit is the section in Beauport, Jersey (WV 579479) where all calibres of material occur, and even the sandy matrix is angular, derived as it is from the broken granite and its sandy deep weathered fraction.

The loessic head also occasionally reaches the coast as solifluction from east facing slopes such as at Noirmont (Guernsey, WV 361831) or St. Catherines (Jersey, WV 715531), but the main mass of this deposit is inland on the slopes down from the high plateau and from the face of the degraded cliff of the 100 ft. (30 m.) shoreline. The deposit in these areas resembles loess except it has a deeper red colour and has occasional pebbles and rock fragments throughout its thickness. At La Longue Rocque (Guernsey, WV 265772) much of the stony content of the head is composed of these waterworn pebbles which probably came from some ancient strandline now destroyed. (This old beach must have been of some antiquity because the ground surface here is at 180 ft. (55 m.). Mourant (1935) describes such pebbles in "loess" at the Handois Reservoir in Jersey (WV 634538) at a height of over 300 ft. (c. 100 m.) and Dunlop (1896) and Elhai (1963) cite further localities where such pebbles occur. During the mapping of Guernsey it became clear that such concentrations of beach stones in loessic head occur at definite heights: at 160-180 ft. (49-55 m.), at 220 ft. (66 m.) and about 300 ft. (100 m.). These pebbles are almost certainly the last remnants of the high sea levels of the lower Pleistocene which are well known in southern England (Wooldridge & Linton, 1955; Zeuner, 1959) (see fig. 19).

Loessic head with beach pebbles is restricted to areas of the old former strandlines and the more widespread loess head is the typical deep red redeposited loess incorporating weathered remnants of the local solid geology. As noted above the main control over the distribution of the loess is the slope of the land and this must also control the occurrence of the loessic head. A continuous gradation from true loess to coarse head can often be seen. At the Route des Clos Landais (Guernsey, principally in grid square 2677) where the road is in a continuous cutting, a full section is exhibited which shows the transition from in situ loess on the high plateau, through loessic head with broken gneiss particles on the "riser" between the high plateau and the 220 ft. (66 m.) surface, to loessic head with beach pebbles on this surface itself.

Auger holes near La Longue Rocque des Paysans (Guernsey, WV 265772) show a thickness of loessic head of 8 ft. (2.6 m.) but this is probably exceptional and the general thickness is around 3 ft. (1 m.). The loessic head is thickest in Guernsey on the shallow slopes in the parishes of St. Pierre du Bois and St. Saviour where the higher strand-lines cut into the high plateau of the island. An almost complete cover of loessic head occurs on the western end of the bluff below Câtel Church (WV 331788) and on the flat surface of the 100 ft. (30 m.) rock platform near Foote's Lane (WV 317793).

In Jersey the slopes from the island's higher surfaces to the coastal plain are more abrupt so smaller amounts of loessic head occur and the typical exposure consists of a small pocket of head just below the slope break leading in to a large valley such as those east of St. Peter's Church (WV 605515). The sides of the valleys also exhibit pockets of loessic head such as those visible at WV 608504 in the road cutting at Beaumont New Road. The only areas comparable with the large sheets of loessic head which occur in Guernsey are the areas of head on the slopes north of St. Clement's Church (WV 688475) and on the slopes above Grouville Marais (in grid squares 6948 and 6949). Here also the maximum thickness of the head is 7 ft. (2.1 m.) but the more general thickness is 3 ft. (1 m.).

(ii) Organic remains.

The only organic remains found in the head in the islands occurs in caves with the palaeolithic site of La Cotte de St. Brelade in Jersey being by far the most prolific. In Guernsey the only remains so far found were recovered from a cave at La Corbiere (WV 282742) now destroyed (Warren & Mourant, 1936). The fauna at this site consisted only of a vole (Microtus sp.) and Helix nemoralis (Linn.), although when originally discovered in 1825 by F.C. Lukis (see Lukis' manuscripts in Lukis and Island Museum, Guernsey) a larger fauna probably including lemming seems to have been found. Lukis' finds which were in a "calcareous breccia" (no doubt a calcareously cemented head) have been lost since 1825.

Apart from La Cotte de St. Brelade only La Cotte à la Chèvre has produced a head with faunal remains in Jersey. Like the larger cave the fauna in La Cotte à la Chèvre must have been brought into the cave by the palaeolithic hunters whose stone implements form the most durable remains at both these sites. At La Cotte à la Chèvre the cave earth of the occupation layer (a thin loessic head) produced a small fragment of Mammoth tooth and the jaw of a deer (probably reindeer) (Sinel, 1912; Baal, 1917).

In La Cotte de St. Brelade the faunal list is complete only for the upper complex of deposits excavated between 1911 and 1916 (see Sinel & Nicolle, 1911; Nicolle & Sinel, 1912; Marett & Gardner Warton, 1915; Marett & De Gruchy, 1916 and 1917; Burdo, 1960; McBurney & Callow, 1971). The faunal remains, which like those at La Cotte à la Chèvre, represent the food debris of palaeolithic hunters, are contained in a series of more and less loessic heads, some beds of which contain massive boulders which fell from the cave roof perhaps due to their being loosened by frost. The fauna is characteristic of a cool or cold steppe climate and consisted of:[*]

Primates	
Homo neanderthalensis (King)	Neanderthal man
Insectivora	
Sorex araneus (Linné)	Common shrew
Carnivora	
Canis lupus (Linné)	Wolf
Vulpes vulpes (Linné)	Fox
Hyaena spelaea (Goldfuss)	Hyaena

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[*] The most complete faunal list for the lower complex of La Cotte yet compiled.

Rodentia	
Lepus sp.	Hare
Dicrostonyx henseli (Hinton)	Lemming
Dicrostonyx torquatus (Pallas)	Lemming
Microtus ratticeps (Keyserling & Blasius)	Vole
Microtus anglicus (Hinton)	Vole
Spermophilus sp.	Ground squirrel
Perrisodactyla	
Equus sp.	Horse
Coelodonta antiquitatis (Blumenbach)	Woolly rhinoceros
Artiodactyla	
Cervus elaphus (Linné)	Red deer
Megaceros giganteus (Blumenbach)	Giant deer
Capreolus capreolus (Linné)	Roe deer
Rangifer tarandus (Linné)	Reindeer
Bos primigenius (Bojanus)	Giant ox
Proboscidea	
Mammuthus primigenius (Blumenbach)	Mammoth
Mammuthus trogontherii (Pohlig)	Mammoth
Aves	
Anser brachyrhynchus (Baillon)	Pink-footed goose
Branta leucopsis (Bechstein)	Barnacle goose
Branta bernicla (Linné)	Brent goose
Falco tinnunculus (Linné)	Kestrel
Lagopus mutus (Montin)	Ptarmigan
Tetrao sp.	Grouse
Alca impennis (Linné)	Great auk
Gallinula chloropus (Linné)	Moorhen
Cinclus cinclus (Linné)	Dipper
Coleoptera	
cf. Hydrophilus	Hydrophilus beetle

The lower complex of La Cotte, still under excavation by C.B.M. McBurney, has so far produced only a small faunal list as follows (Burdo, 1955, 1956, 1957; McBurney & Callow, 1971):

Primates	
Homo sp.	Man
Carnivora	
Ursus arctos (Linné)	Brown bear
Ursus spelaeus (Rosenmüller & Heinroth)	Cave bear
Rodentia	
species undetermined	
Perrisodactyla	
Equus sp.	Horse
Coelodonta antiquitatis (Blumenbach)	Woolly rhinoceros
Artiodactyla	
Rangifer tarandus (Linné)	Reindeer
Bison sp.	Bison
Proboscidea	
Mammuthus primigenius (Blumenbach)	Mammoth
Aves	
species undetermined	

These few species are enough, however, to show that the climate when the cave was occupied was again cold.

Also in the two cave sites in Jersey there occur many thousands of implements of flint and lesser numbers of implements of quartzite, granite, "greenstone" and quartz. While strictly not organic remains these implements are clear evidence of the presence of man and as such give a guide to the conditions of deposition of the head (see below). Worked flints have also occasionally been found outside the cave sites and almost all of these have been found in the head overlying the 25 ft. (8 m.) raised beach and so are presumably to be equated with the upper complex of La Cotte de St. Brelade (Baal, 1914; Rybot, 1949; a flake was also found by the present author 8 ft. (2.4 m.) above the base of the head at WV 609618 north of Noirmont Point).

(iii) Depositional Environment.

The coastal rubble heads of Britain have long been associated with cold conditions and are thought to have been the counterpart of glacial till in non-glacial areas (De La Beche, 1839; Geikie, 1874). Some recent writers (notably Bowen, 1973) suggest that much of the material described as head is not of periglacial origin but is more properly associated with the interglacials during which the raised beaches were deposited. It is important to decide which type of climate the head was formed under, so that a climatic sequence for the Channel Isles can be built up.

The evidence of the organic remains noted above clearly points to a cold climate for the deposition of the head and the mere presence of man (shown by the occurrence of his stone tools) in Jersey suggests a climate cold enough to have lowered the sea level below the 50 ft. (15 m.) isobath so as to dry the sea floor and allow men to walk across from the continent. However the evidence of the caves is not conclusive as cave deposit might continue to form during interglacial episodes and although man only appears to have been present in Jersey in association with cold climate mammals, further evidence for the cold climate origin of head is needed.

The main reason for ascribing the head to a climate colder than the present is that nowhere in the islands can either of the two types of head which occur be seen to be forming at present. The rubble head of the coast forms vertical cliffs where it is undercut by the sea (as in Beauport, WV 579479, in Jersey). Where the action of the sea is intermittent, as at Les Rouaux (WV 658564), Jersey, or Divette (WV 342754) in Guernsey, the cliff of head still stays vertical aided by a cover of vegetation. Nowhere can cones or heaps of talus be seen at the foot of such cliffs because as soon as such heaps are formed they are destroyed by the sea. For such talus heaps to be preserved, and the formation of head fans to begin, the vegetation which stabilises the cliff faces and the sea which under cuts them must be absent. The climate which enables these conditions to be fulfilled is the onset of cold which occurs at the beginning of a periglacial episode (see Chapter VI below for further discussion of the sequence of climatic events at the end of an interglacial).

Similarly the loessic head on the plateau slopes cannot be shown to be forming at the present. The conditions necessary to cause an increase in slope movement which would be necessary to form such thick layers of loessic head as those which occur in the south-west of Guernsey at present, could only be met by adeterioration in climate and the destruction of vegetation cover. Both these events would occur at the onset of periglacial conditions.

(iv) Age.

If it is accepted that the head is the product of a periglacial climate it then becomes necessary to date the deposit. If the 25 ft. (8 m.) raised beach is regarded as being of Ipswichian age then most of the coastal head in the islands which overlies this beach must be Devensian. As has been stated above it is difficult to subdivide any of the head sections so it is not possible to ascribe the head to any particular phase in the Devensian (but see George, 1973, for an attempt to recognise a consistent stratigraphy in the coastal heads of Guernsey). Similarly, most of the loessic head of the plateau is Devensian if, as stated above, the loess is Devensian. The loess and the head of the plateau are so closely associated that they cannot be of differing ages.

Although most of the head is clearly Devensian some complications do occur. At a small number of sites in Guernsey and Alderney and rather more frequently in Jersey head can be seen to underlie the 25 ft. (8 m.) raised beach as well as to overlie it (see table IV for a list of these sites). These lower heads must be of pre-Ipswichian age and their probable age is Wolstonian although no clear proof of this can be obtained from the sections*.

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* Bowen (1973) suggests that the head below the raised beaches at Portelet (WV 601471) and Belcroute (WV 607482) in Jersey is not of periglacial origin but is a temperate deposit associated with the raised beach. This is clearly not so. The rubble of greywacke fragments below the beach at Belcroute is identical with the rubble which overlies the beach gravel and appears to have had a closely similar origin. The possibility advanced by Bowen that the lower head at Belcroute is an angular facies of the beach gravel is most unlikely. The raised beach gravel is composed of up to 84% granite (from the south-west granite whose contact with the Brioverian sediments occurs 150 yards (138 m.) to the south of the Belcroute section). The heads, both upper and lower, by contrast are entirely composed of greywacke. Similarly at Portelet the lower head, described by Bowen as colluvial loess, is in fact a loessic head with granite blocks up to 6 inches (15 cm.) square in a loessic matrix (see Lawson, 1919) and is very similar to bands of loessic head overlying the raised beach.

Elhaï (1963) also doubts that the lower head in many of the sections enumerated in table 6 is earlier than the 25 ft. (8 m.) raised beach. He suggests that the small number of sections which show such a sequence proves that no distinct episode of deposition is marked by the lower head. He concludes that the upper and lower heads at all the sites he visited are identical and thus of the same age and that the raised beach gravel between the two heads is thus a soliflucted mass within a single head unit. While it is possible that the sections in Bouilly Port (WV 581481) and Portelet could have evolved as Elhaï suggests the long sections in Longis Bay, Alderney (WA 595081) and Belcroute tend to preclude such an idea. At Longis the section is continuous for up to 100 yards (92 m.) and shows no sign of any periglacial disturbance while at Belcroute the great difference in lithology mentioned above also points to the section being in situ. These sections are very important for dating of events around the 25 ft. (8 m.) raised beach and will be further discussed below. (See figs. 23 & 24 and Plate 37.)

It is also significant that the lower cultural complex in La Cotte de St. Brelade is regarded by McBurney and Callow (1971) as Riss (i.e. Wolstonian). This suggestion is based on the evidence of the relationship of the head containing the lower cultural complex to the 25 ft. (8 m.) beach. The way the 25 ft. (8 m.) beach in the cave rests at the foot of a vertical cliff in the "Riss" head deposits, and is itself covered by "Wurm" head (see fig. 25) resembles the way head cliffs are eroded at the present (i.e. in interglacial conditions). The transgressive Ipswichian sea is likely to have eroded vertical cliffs of Wolstonian head just as the Flandrian sea has eroded Devensian head. The evidence from Belcroute and similar sites seems to indicate that total removal of this earlier head did not occur in the Ipswichian and that on the retreat of the Ipswichian sea the formation of Devensian head was greatly aided by the collapse of the vertical faces of these head cliffs. Flandrian trimming of this head may have re-excavated these former cliffs so that some of the vertical cliff sections visible round the islands' coasts may be cut in Wolstonian rather than Devensian head.

It is only the head sections which rest on 25 ft. (8 m.) raised beach gravel that are probably Devensian in age. Even in these cases some doubt may arise because some of the 25 ft. (8 m.) beaches themselves may be pre-Ipswichian (see below). However, in the absence of further evidence the majority of the head may be regarded as Devensian and the product of a periglacial climate. Similarly the loess is also the product of a cold climate and probably contemporaneous with the head.

Chapter III. The Higher Raised Beaches.

a) Introduction

As was stated in the introduction, the Channel Isles contain within the compass of a few small islands an extensive sequence of upper middle and upper Pleistocene marine events untouched by the direct effects of glaciation. The evidence is in two separate forms: (a) the rock cut evidence of rock platforms and caves, and (b) the evidence of deposits - the beach sands and gravels.

As was mentioned above the earliest indications of marine action in the islands are the planation surfaces at 300 ft. (92 m.), 220 ft. (66 m.) and 180 ft. (54 m.) which are especially well defined in western Guernsey (Dunlop, 1896, 1911; Mourant, 1933; Hanson-Lowe, 1938; Elhaî, 1963). These surfaces have no in situ marine deposits on them but at several places they are occupied by solifluction deposits in which beach deposits occur, showing where original beach deposits have been destroyed. As previously noted the age of these surfaces may be similar to those of surfaces at similar heights in southern England (Everard, 1954b; Wooldridge & Linton, 1955).

In discussing the heights of raised beaches in the Channel Isles, the fact that the islands have some of the largest tidal ranges in the world must be considered. The maximum tidal range in Jersey is 42 ft. (12.9 m.) and in Guernsey 36 ft. (11 m.). If such tidal ranges occurred in the Pleistocene (and there is no reason to doubt that they did) raised beach remnants which can be seen in the present landscape may be attributable to a wide range of sea levels merely because of the complications of tidal range. Further problems are introduced by the exposure of much of the islands' coastline to the full force of Atlantic storm waves which may raise shingle ridges well above high water mark.

At La Rue de la Rocque (WV 254786) in Guernsey (one of the few stretches of coast without a sea wall) the shingle barrier at the rear of the beach reaches 10 ft. (3 m.) above high water mark and hence 28-30 ft. (c. 8 m.) above mean sea level and as much as 48-50 ft. (c. 15 m.) above sediments forming near low water mark at present. Despite the above comments measurements of the heights of the raised beaches by Collenette (1916), Mourant (1933) and George (1973) show two clear height envelopes (see fig. 35) for the lower beaches around 25 ft. (8 m.) and 60 ft. (18 m.) O.D.*. The number of fragments of the high beach which occur are too few for such height determinations although the few remnants which occur appear to be at concordant heights around 100 ft. (30 m.).

b) <u>The 100 ft. (30 m.) raised beach</u>

<u>Jersey.</u> The highest in situ marine deposits in the islands occur at around 120 ft. (36 m.) at South Hill, St. Helier (WV 651477) (Dunlop, 1911; Naish, 1919; Mourant, 1933). The South Hill beach is a coarse boulder gravel of granophyre (the local solid rock) and appears to be devoid of foreign stones. The beach reaches a height of 127 ft. (38 m.). Mourant (1933) states that the beach has a lower limit of 103 ft. (31 m.) but this lower part is now obscured by the terracing of the South Hill Gardens. Suggestions that the beach gravel rests on head (Dunlop, 1915) seem to be an error caused by the weathering of the granophyre where it is cut by dykes of "minette" (mica-lamprophyre). The beach gravel itself is only slightly weathered due to the extreme

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* George (1973) recognises a third level at 36 ft. (11 m.) but cites only a very few localities for this stage. In view of the number of times marine transgressions have reached at least 36 ft. this stage probably belongs to one of them and the most likely is the 60 ft. (18 m.) stage.

resistance of the granophyre to rotting.

Only one beach deposit has been found in Jersey at a level between that of South Hill and the 60 ft. (18 m.) beaches. This occurs at WV 686473 in a road cutting 425 yards (384 m.) west of St. Clement's Church. The section is now very overgrown. Dunlop (1911) estimated the height of this beach as 70 ft. (21 m.) above mean sea level but Mourant (1933) suggests this is an error and the true height is 110 ft. (33 m.) O.D. As Mourant later realised (personal comm.) this height too is wrong and the correct height of the base of the deposit is 85 ft. (26 m.). Dunlop states that the beach is 20 ft. (6 m.) thick so its surface height is 105 ft. (31 m.) and it is covered above this by an indeterminate thickness of head. The beach is composed of slightly weathered granite cobbles in a matrix of sand and rests on a bench of very weathered diorite which has, however, preserved the wave cut notch at the inland edge of the platform.

Guernsey. The highest beach deposit in Guernsey caps the hill above Les Rouvets (WV 264781) and is composed of up to 8 ft. (2.4 m.) of medium yellow sand resting on weathered gneiss. The surface height of the beach is 125 ft. (37.5 m.) and despite considerable disturbance of the ground surface by the construction of the German artillery battery 100 ft. (30 m.) from the beach deposit this is probably a true height. This beach deposit can only be found by augering so examination of it is difficult but its height makes it likely that it is comparable in age with the beach at South Hill.

As in Jersey, further localities for the 100 ft. (30 m.) beach occur in Guernsey below 100 ft. (30 m.). At Les Vardes (WV 316825) (see photograph, plate 51) the large granodiorite quarry owned by Ronez Ltd. cuts into a beach gravel at 85 ft. (26 m.). This exposure was discovered by G.F. Mitchell in 1967 (personal comm.) but continued working of the quarry has by now (1974) destroyed most of the deposit although small patches still exist in old German trenches on the hilltop (WV 316824) and in the quarry (WV 317822) north of Maison Le Bas. The deposit consists of a boulder gravel up to 4 ft. (1.2 m.) thick (Plate 52) with most of the constituents of the beach being of the local granodiorite and very weathered, but also present are several flints including cobbles up to 6 inches (15 cm.) in diameter. The beach rests on a bench at 85 ft. (26 m.) O.D. which is cut across deeply weathered granodiorite. The constituents of the beach are similarly deeply weathered and disintegrate at a touch (Girard, 1967).

Other deposits at similar height to Les Vardes occur in several places. At Le Villocq (WV 307798) small patches of beach sand up to 3 ft. (1 m.) thick occur. This deposit is a coarse sand with a few pebbles in it and was seen in building trenches below 3 ft. (1 m.) of loessic head. The beach deposit rests on weathered gneiss and is the last remnant of what once must have been an extensive sheet of beach material resting on the wide flat below the ridge surmounted by Catel Church (section, fig. 24). The whole of this flat is now covered with loessic head except in the Le Villocq area where the sand outcrops just south of the trenches mentioned above. The seaward continuation of this flat near St. Germain (WV 295798) also had a sandy beach deposit on it but this has now been quarried away (George, 1973).

The northern "hougues" of Guernsey have generally accordant summits at around 80-100 ft. (23-30 m.) but only the Les Vardes hougue has a beach gravel on it. At Delancey Park (WV 346810) the summit of the hill reaches 100 ft. (30 m.) but no deposits can be seen except in the north-east corner where a disturbed mass of beach cobbles rests on weathered gabbro in a cutting behind the tennis court. These beach stones are almost certainly soliflucted but they provide evidence that the hill formerly had a cover of beach gravel. Below Vale Mill (WV 354825) beach cobbles occur in head at around 80 ft. (24 m.). The top of this ridge, like the Delancey Park hougue, has no beach gravel on it so these beach stones may be the last remnant of a former beach cover.

At Mont Saint (WV 272790) and La Hougette (WV 260776), overlooking the west coast, small patches of beach gravel occur churned into the deeply weathered solid geology indicating the previous occurrence of beach material. At Pleinmont (WV 248748) a small patch of beach gravel occurs on the hillside 200 yds. (184 m.) above the junction of the coast road with the road from Torteval.

Alderney. In Alderney at WA 596088 in the railway cutting 675 yds. (625 m.) north-west of Whitegates, 4 ft. (1.2 m.) of medium gravel rests on Alderney Sandstone. The gravel is composed of fine grained granite and sandstone with no flint present. The height of the base of the beach is about 74 ft. (22.7 m.) and the pebbles are only slightly weathered, but this beach is assumed to belong to the 100 ft. (30 m.) beach because it is clearly not part of the 60 ft. (18 m.) beach which occurs in the west face of the flooded quarry just to the north of the railway cutting.

The way in which the existing remnants of the 100 ft. (30 m.) sea level seem to occur at two different heights, 70-90 ft. (21.5 - 27.6 m.) and 110-130 ft. (33.8 - 40 m.) indicates the possible existence of two marine episodes. (Marine and fluvial levels elsewhere around 100 ft. (30 m.) show a distinct division into two levels similar to those of the Channel Isles beaches.) The way the beach remnants occur as disjointed fragments on hilltops and as patches on much wider benches at the same height suggests a considerable age for these deposits because of their great dissection in comparison with the lower beaches. There is no internal evidence to provide dates for these beach remnants and they are best dated by reference to the more widespread lower beaches. Discussion of the age of these deposits will be deferred until a later chapter.

c) <u>The 60 ft. (18 m.) raised beach</u>

Jersey. In Jersey this beach is only known from a few sites (see table VI) and wave smoothed notches and caves with a beach deposit are more widespread than deposits alone. At La Cotte à la Chèvre (WV 553566) (Sinel, 1912; Zeuner, 1946) the beach consists of large water worn boulders in marine sand (fig. 26). This site with its palaeolithic industry so closely associated with the raised beach is crucially important in the dating of the 60 ft. (18 m.) beach and will be considered further below.

Several caves in the Grand Becquet area (WV 575563) have 60 ft. (18 m.) beaches as "false roofs" to the caves, which then are empty of deposits down to a modern beach (see fig. 27). At Le Pinacle (WV 545555) a similar cave has had its beach gravel destroyed by an influx of head but the wave notch is still clearly visible. The only permanently visible beach exposure is in the Snow Hill railway cutting at St. Helier (WV 655483) (Dunlop, 1915). This beach has a base at a height of 59 ft. (18 m.) and consists of a fine gravel of granophyre. Associated with this exposure is the patch of beach found during the excavation of the Fort Regent road tunnel 100 yds. (92 m.) south of the Snow Hill section (Renouf & Bishop, 1971) which was also at 59 ft. (18 m.). Other localities for the 60 ft. (18 m.) beach occur at Mont Jubilee (WV 575515) (Renouf, 1970) and Verclut (WV 697476) where temporary sections exposed beach gravels below the abandoned cliffline.

Guernsey. The best exposures of the 18 m. beach occur in Guernsey. The wide flat of the 100 ft. (30 m.) level has been retrimmed on its northern edge by the 60 ft. (18 m.) sea (see section, fig. 24) and several of the northern hougues have large expanses of the 60 ft. (18 m.) beach on their tops and sides. The 60 ft. (18 m.) beach in Guernsey may best be divided into three for descriptive purposes: I, a southern group below the old cliff line of Rocquaine Bay; II, a central group comprising the retrimmed edge of the 100 ft. (30 m.) platform; and III, a northern group taking in the northern extremities of the island and important for details of the relationship with the 25 ft. (8 m.) beach.

The southern group (I) consists of two lunate areas of gravel below Rue des Paysans (WV 260779) and La Pomare (WV 259774) and a small area of gravel and sand at Les Rouvets (WV 265785). The Rue des Paysans deposit is a medium beach gravel mostly of local gneiss but with a few flints resting on weathered gneiss. Its upper limit is at 60 ft. (18 m.) and its lower around 45 ft. (14 m.) although this lower edge may be soliflucted downslope. The deposit at La Pomare is similar in type to that at Les Paysans and a stream section through it shows it to be at least 8 ft. (2.4 m.) thick. This deposit has more angular material and less flint than the Les Paysans deposit. The deposit at Les Rouvets is interesting in that it preserves a complete fossil beach zone (see section, fig. 27). At Les Rouvets House at 60 ft. (18 m.) the beach consists of coarse weathered gravel; 50 yds. (45 m.) to the north-west, in the yard of a vinery, 4 ft. (1.2 m.) of sand, fine at the top but coarser downwards, occurs resting on weathered gneiss. The surface of the ground over the sand is at 50 ft. (15 m.). The gravel at Les Rouvets House represents the storm beach gravel near high water mark while the sand probably is an inter-tidal sediment. Below 50 ft. (15 m.) the beach sand is covered with loessic head (see Collenette, 1893).

The central group (II) of the 60 ft. (18 m.) beach is broadly the re-trimmed edge of the 100 ft. (30 m.) platform and has the best exposures of beach gravels at this height in the Channel Isles. The exposures at King George's Fields (WV 309803) are very flinty, all the other exposures less so. At King George's Fields the beach is at least 3 ft. (1 m.) thick as shown by stream sections while at Pleinheaume (WV 319818) up to 4 ft. (1.2 m.) of well rounded but weathered gravel rests on a weathered bench in a road cutting. All the deposits lie at heights of over 50 ft. (15 m.) O.D. and below 60 ft. (18 m.). The deposit at La Ramee (WV 325798), the most "inland" of the beaches, is the highest at 60 ft. (18 m.) while the deposits at Anneville (WV 321812) and Les Capelles (WV 323813) are mostly below 55 ft.

(16.5 m.) (see Derrick, 1888; De La Mare, 1901). The coarsest gravel also occurs at La Ramee so it is possible that the slight slope and decrease in calibre of particles to the north is an original feature formed in the retreat of the sea from the 60 ft. (18 m.) strandline. The beach at Pleinheaume shows clearly that the 60 ft. (18 m.) deposit is not part of the 100 ft. (30 m.) sea level. This beach gravel is separated from the deposits of Les Vardes by a very steep slope cut in weathered granodiorite and no connection between the two levels can be seen. Similarly (see fig. 25) the 60 ft. (18 m.) beach can be seen to be distinct from the 25 ft. (8 m.) beach at La Passe (WV 315825) where the 18 m. beach occupies the top of the hill into which the lower beach is cut. The lower beach is covered by head which has been soliflucted from this hill.

The northern group (III) contains much of the evidence for the separation of the 60 ft. (18 m.) and 25 ft. (8 m.) beaches. At Chouet in the extreme north-west of the island the large quarry below the German radar tower (WV 332840) shows the separation between the low beach which forms the seaward side of the quarry and the 60 ft. (18 m.) beach which lies on a "shelf" above the quarry side rising from c.48 ft. (14 m.) to c.56 ft. (17 m.) around the south of the quarry. The large flooded quarry to the south of the tower also has a small patch of beach at its summit. At Paradis (WV 358833) in the extreme north-east of the island the 60 ft. (18 m.) beach occupies a typical hilltop location and exposures occur in Noirmont Quarry (WV 361831) and in Paradis Quarry (WV 357832). The beach gravel was also encountered in the excavation of the Dehus Dolmen's foundations (Kendrick, 1928). At Mielette Lane (WV 359833) the beach can be seen in the small quarry to the south side of the lane, outcropping in the higher side of the quarry. The small quarry on the north side of the lane (WV 359834) and a little lower down has the 25 ft. (8 m.) beach exposed below 5 ft. (1.5 m.) of head. On the north side of the Hougue du Paradis at La Lande (WV 357837) the 25 ft. (8 m.) beach can be seen in a quarry below the slope break leading to the 60 ft. (18 m.) beach on the hilltop. None of the outcrops of the 60 ft. (18 m.) beach around Paradis is well exposed and it is difficult to see whether much foreign material is present in the beach, although at WV 359820 small rolled flints can be found in the hedge bank on the edge of the expanse of beach gravel (section, fig. 32).

Alderney. In Alderney only small pockets of 60 ft. (18 m.) beach occur. At Bibette Head (WA 588091) pockets of gravel occupy gullies on the top of the headland at a height of 40 ft. (12.5 m.). These pockets of gravel are associated with the 60 ft. (18 m.) beach because of their weathered state compared with nearby exposures of the 25 ft. (8 m.) beach and because they have no connection with the lower level.

In the quarry north of the railway cutting (WA 596088) mentioned above a small outcrop of 60 ft. (18 m.) beach can be seen in the side of the quarry. As the quarry is flooded this beach exposure cannot be closely examined but it is clearly not associated with the 100 ft. (30 m.) beach in the railway cutting. This beach gravel on the quarry side is probably the one described by De La Mare (1900) and which he stated rises to a height of 58 ft. (17.8 m.).

Chapter IV. The 25 ft. (8 m.) raised beach.

a) Introduction

The most widespread raised beach in the islands is the 25 ft. (8 m.) raised beach. It is exposed widely around the present coasts of the islands just above modern high water mark and in contrast to the higher beaches it is often covered with head and loess. Because of this cover of solifluction deposits it seems far less extensive in outcrop than the 60 ft. (18 m.) beach on its hilltop sites, but in reality the lower beach is present very widely around the coasts of the islands.

Because the 25 ft. (8 m.) beach is so close to the modern beach in its distribution, the grainsize of the deposit and the arrangement of the particles within the two beaches are often closely similar, unlike those of the higher raised beaches which show no relationship to the present coastline. An interesting example of this similarity between the 25 ft. (8 m.) beach and the modern beach can be seen below Fort Tourgis in Alderney (WA 562079) where both the modern and the raised beach become coarser to the north-east towards a projection of granodiorite. The progression from coarse sand to a boulder gravel in the modern beach is exactly matched in the raised beach. Numerous other examples occur on the coasts of all the islands.

b) Jersey

In Jersey the 25 ft. (8 m.) beach is most clearly seen in the south-west and north-east corners of the island and in the bays of the north coast. In the north-east the raised beach occurs as isolated pockets of fine gravel in gullies in the rock platform, as around Belval (WV 709525 and WV 711528), and as a layer of coarse sand in the base of the head, as at Le Sauchet (WV 692549) and Saie (WV 705541). These pockets of beach material are closely similar in grainsize and distribution to the modern beaches nearby.

Along the north coast of Jersey the 25 ft. (8 m.) beach is largely obscured by the massive thickness of the head but at a few points beaches do occur. In Bouley Bay north-northwest of the pier (WV 669549) the beach, which here is composed of cobbles and boulders of rhyolite and andesite up to 2 ft. (60 cm.) in diameter, rests on up to 6 ft. (2 m.) of coarse head which fills gullies in the shore platform and was evidently planed off level with the top of the platform by the marine transgression which deposited the beach gravel.

In Les Rouaux (WV 658564) there are a few very small pockets of beach gravel resting directly on the shore platform and at the inland edge of the platform an excellent wave smoothed notch is preserved in the Brioverian sediments. Close by, below Belle Hougue Point (WV 655564), the 25 ft. (8 m.) beach occurs in a cave and contains a mammalian and molluscan fauna preserved in a stalagmite cement. (Morin, 1919; Zeuner, 1945a; Baden-Powell in Zeuner, 1945a). The marine molluscs were of nine species as follows:

Mytilus cf edulis (Linne)
Patella vulgata (Linne)
Patella cf depressa (Pennant)
Gibbula umbilicata (Montagu)
Astralium rugosum (Linne)
Littorina saxatilis (Olivi)
Littorina littoralis (Linne)
Purpura lapillus (Linne)
Ocenebra erinacea (Linne)

The mammalian material consisted of a series of bone fragments which have been referred by Zeuner (1945a) to a small race of Red Deer - Cervus elaphus jerseyensis (Zeuner) of roe or fallow deer size. The deer bones and the other bones present are all greatly water worn and apart from the deer bones only bones of Epimys rattus (Linne), the black rat, are identifiable. The bones probably came to be in the cave by falling down a fissure from above as there is no sign of human agency in the cave. In 1965 a further deposit of beach material with Cervus elaphus jerseyensis was discovered in a smaller cave beside the site described above (Mourant, 1966). Most of the beach deposit and its contained fossils were removed either by excavation or by weathering but when the present author visited the cave in 1974 a small pocket of conglomerate with a tibia of Cervus elaphus jerseyensis was found in the extreme back of the cave. These fossils from Belle Hougue cave have considerable significance for the chronological and climatic sequence in the islands and this will be further discussed below.

In Giffard Bay (WV 652559) the typical pattern of small patches of beach shingle in the base of the head is repeated, but in Bonne Nuit Bay further to the west (WV 641559) the only beach gravel present consists of a coarse, iron cemented, sandy shingle which is plastered on to the rock platform up to 50 yds. (45 m.) to seaward of the face of the cliff of head at the back of the beach. Mourant (1935) suggests that this "submerged" beach (and others in a similar position in St. Catherine's Bay and at Noirmont Point (see Plate 38) at about 10 ft. (3 m.) O.D. "may be part of the 25 ft. beach but it is possible that (they) represent a separate horizon". As Mourant stated in his earlier description (1933), there is no evidence to date these beaches so there is no reason to suppose that they are not part of the 25 ft. (8 m.) beach.

In the south-west corner of Jersey there are several fine exposures of the 25 ft. (8 m.) beach. Almost without exception these beach gravels are separated from the rock platform by a layer of head (see Chap. II and table IV for details). In Belcroute Bay (WV 607482, see Plate 37) the classic section shows a beach gravel of granite pebbles covered by up to 4 ft. (1.2 m.) of red beach sand which grades up into a fine head of sharp fragments of Brioverian greywacke. Below the marine deposits is up to 4 ft. (1.2 m.) of head which appears to have been truncated by the marine transgression depositing the raised beach (see Dunlop, 1913).

At Portelet (WV 601471) beach sand again overlies the boulder beach which in turn rests on a wave smoothed surface of the lower head (Lawson, 1914).

A further patch of beach gravel rests directly on the rock platform on the north side of the Ile au Guerdain (see section, fig. 31), suggesting that the marine transgression trimmed a shallow sloping surface across the lower head and left a beach profile very similar in angle to that of the present beach.

In Bouilly Port (WV 581481) and Beauport (WV 580479) similar sections of beach gravel resting on head can be seen. In the bay to the south of La Cotte Point (WV 593476) a more unusual section occurs. In this bay, a fine gravel is cemented to the rock platform. This is succeeded by up to 3 ft. (1 m.) of head which is in turn overlain by up to 2 ft. (60 cm.) of coarse beach gravel. (This section is illustrated by McBurney and Callow as their plate IX.) When traced laterally the coarse beach gravels are replaced by a uniform upper head to below the level of the outcrop of the coarse beach gravel. It seems likely that the layer of coarse beach pebbles is a detached block of gravel within the head and it is the lower fine gravel which is in situ. Examination of the modern beach in the same bay shows that the size grades of the fine and coarse beach gravels are up to 30 yds. (28 m.) apart down the beach. If the same grain size relationships occurred during the deposition of the 25 ft. (8 m.) beach the coarse gravel must have been moved 30 yds. (28 m.) during the formation of the head.

About 200 yds. (184 m.) north of Noirmont Point (WV 609467) is a further exposure of the "submerged beach" noted above as occurring in Bonne Nuit Bay. This beach too (see Plate 38) is cemented to the rock platform some distance from the present cliff of head. Many of the pebbles of the beach are rotted (especially the granite) and only a few small flints occur. As at Bonne Nuit there is no evidence to suggest that this beach is not the same age as the 25 ft. (8 m.) beach.

Associated with the present beach in St. Ouen's Bay on the west coast of Jersey is a large area of blown sand (3.2 square miles (8 km.^{2}) in total) which rises on to the island plateau and reaches a height of 259 ft. (79.6 m.).

In the area around St. Peter's Church (WV 595516) a Pleistocene equivalent of this modern dune system occurs. This older deposit can only be examined in temporary sections and auger holes and has no surface expression. The modern blown sand is white in colour, uncemented and full of the shells of the molluscs

Helix aspersa (Müller)
Helicella caperata (Montagu)
Cochlicella acuta (Müller)

and can be seen to overlie the loess. By contrast the older sand is strongly stained with iron oxide so it is cemented to a sandrock, has no molluscan remains and is covered by a loessic soil. A section described by Attenborough, Baal and Sinel (1917) at Tete des Quennevais (c.WV 584505) shows 9 ft. (2.7 m.) of modern dune sand overlying an iron cemented sandrock with Upper Palaeolithic implements on its surface. It is probable that the lower sand in the above section is the same as the one seen by the present author and that the iron cemented sand is of much greater antiquity than the modern uncemented sand. A discussion of the age of this ancient sand will be deferred until Chapter V below (Keen, 1975).

c) Guernsey and the smaller islands to the east.

In Guernsey the best exposures of the 25 ft. (8 m.) beach occur in the north of the island but small pockets of raised beach gravel occur all round the island's coast. In the south-east at Divette (WV 342754) small patches of beach sand up to 2 ft. (62 cm.) thick occur in the base of the head while a section with raised beach overlying head was once present according to Collenette (1916) but this deposit has since been destroyed by the sea. On the south coast at La Bette (WV 314748) a small patch of beach gravel occupies a fissure above the rock platform (see Plate 41) and reaches a height of 33 ft. (10 m.). This beach gravel is entirely of local material and has no flint in it.

On the west coast the beach is well marked at L'Eree (WV 248785) (see De La Beche, 1839) and at this point contains large flints and cobbles of quartzite up to 6 inches (15 cm.) in diameter. All the other headlands of the west coast north of L'Eree have their complements of beach gravel. At Fort Richmond (WV 268749) and Le Catioroc (WV 260790) the beach is very weathered and at the latter locality, in a road cutting only the outer shells of the largest boulders remain with their centres totally rotted away.

At Vazon (WV 284801), Fort Le Crocq (WV 270798) and La Jaonneuse (WV 339842) patches of beach gravel similar to Mourant's "submerged beach" of Jersey occur in the intertidal zone. At these sites the gravel is similar to that of the Jersey localities and like them is well cemented and firmly held on to the rock platform. Again no evidence of the age of these deposits occurs. At Rousse (WV 324833) the whole of the intertidal zone for a hundred yards (91 m.) to seaward of high water mark is underlain by a cemented beach conglomerate rich in flint. This beach lies between 7 ft. (2 m.) and 12 ft. 6 inches (3.6 m.) O.D. (Girard, 1960) and illustrates how far the earlier intertidal zone overlaps with the present one. The beach at Rousse is distinguished by the occurrence of huge (up to 10 ft. (3 m.) square) boulders of granodiorite set into the beach. These blocks were probably placed in their present position by the destruction of offshore rocks and stacks by the raised beach sea. The movement of such large blocks seemingly indicates a climate quite as stormy as at present during the deposition of the raised beach (see below, Chap. VI) (see Plates 44 & 46).

The best examples of the 25 ft. (8 m.) raised beach in Guernsey occur at Mont Cuet (WV 33841) and are exposed in the large quarry below the German tower. The beach gravels here are 5 ft. (2 m.) thick and rise to a height of 33 ft. (10 m.) O.D. (see Plate 45). At their lowest point the beach gravels are at 18 ft. (5 m.) O.D. The raised beach at this point is a uniform gravel consisting mainly of local rock types (granodiorite and granite) but with significant amounts of "foreign" stones including flint, rhyolite, pink sandstone and jasper (see below, and table V). At L'Ancresse (WV 348838) a fine grained beach gravel is also rich in flint (table V) while at Hommet Paradis (WV 362829) a coarse beach gravel is rich in cobbles of greywacke.

The offshore islets and rocks to the east of Guernsey have little in the way of raised beach material on them despite their in some cases sheltered position. Their general shape must have been trimmed by the sea which cut the low shore platform but the extreme susceptibility to weathering of the granodiorite of which they are composed seems to have caused the total disintegration of any cover of beach deposits which these islands may once have possessed. The largest of the small islands, Herm, has no recognisable beach deposit on it. The islets to the north known locally as the "Humps" all have remnants of rock platform on their edges but only Longue Pierre has beach deposits in the form of a small patch of gravel on its south side. Jethou, in the most sheltered position of these smaller islands, has an extensive beach of well-rolled boulders on its south side (Hill, 1887) with many of these boulders being up to 2 ft. (62 cm.) along their long axis. This beach is up to 15 ft. (4.6 m.) thick (the thickest deposit of the 25 ft. (8 m.) beach in the islands) and is mirrored at present by a beach of similar sized boulders which links the rock of Petite Fauconnière to Jethou. This coarse raised beach is probably a remnant of a last interglacial shingle bar which also connected Fauconniere with the main island. Also on Jethou's south coast is a further example of a raised beach interbedded between two heads. In this exposure the lower head fills a gully in the shore platform and the raised beach gravel rests indifferently on rock platform and truncated head with a later head in turn resting on the beach gravel (see fig. 29).

d) Alderney and Burhou

In Alderney the 25 ft. (8 m.) raised beach is confined to the north and east coasts. Good examples of the beach occur below the bedded head at Hannaine (WA 557073) and in patches below the head along the cliff section to the north and west of Hannaine and Fort Clonque (WA 555073). The other main exposures of the beach occur at the eastern end of the island. At Quesnard about 100 yds. (91 m.) south of the lighthouse (WA 604089) is a fine beach of cobbles below head up to 10 ft. (3 m.) thick. This beach rises to 33 ft. (10 m.) O.D. Further to the south near La Petite Folie (WA 606088) the beach occurs at a much lower height, below present high water mark, around 10 ft. (3 m.) O.D. On the south side of Longis Bay, south of the Roman Fort (WA 595081) the beach rests on the rock platform at the northern end of the section but gradually rises to the south until, at the southern end, up to 3 ft. (1 m.) of coarse sandstone head is interposed between the beach cobbles and the rock platform (see fig. 34).

The small island of Burhou 1 mile (1.3 km.) to the north of Alderney, unlike most of the smaller islands in the Channel Isles, has preserved some of its raised beaches. On the western side of the island up to 6 ft. (2 m.) of beach conglomerate occurs forming one of the finest raised beach exposures in the islands (see Plate 39). The pebbles of this beach exposure show a marked imbrication caused by the steepness of the original slope of the beach. Many of the pebbles in this exposure are flint and the raised beaches in Alderney contain the most flint of any of the Channel Isles beaches (see table V).

e) Composition of the 25 ft. (8 m.) raised beach

As has previously been noted foreign stones sometimes occur in the Channel Isles raised beaches. Flint is by far the most common and the raised beaches of Alderney have the most flint in them while Jersey and Guernsey have less (see table V). In addition beaches on north facing coasts have more flint in them than those facing south.

The origin of this flint is difficult to determine. Dunlop, 1913; Collenette, 1916; Sinel, 1923; and Mourant, 1933 all attribute the flint to drift ice. The ice which overrode the Scilly Isles and Fremington (Mitchell & Orme, 1966; Edmonds, 1972; Kidson & Wood, 1974) contained flint, so with westerly winds, calving ice bergs with their flint erratics, would be blown up Channel to the islands from an ice sheet in the western approaches.

An alternative origin for the flint is that it was rolled up the submarine slope from chalk outcrops or pre-existing gravels by the rise in sea level from glacial low sea levels. The possibility that flint gravels may occur below present sea level is suggested by McBurney and Callow (1971) where they show that the industries in La Cotte de St. Brelade changed progressively from being of flint to being of local materials. McBurney and Callow correlate this change in material with the late "Riss" rise in sea level flooding flint rich deposits, so forcing the palaeolithic hunters to resort to non-flint materials obtainable above the rising sea level. There is no other evidence, e.g. a late glacial pollen sequence, to indicate that this material change was due to sea level changes and the increase in the use of non-flint materials may be due to cultural preference.

This rolling of flints from lower levels would also provide a mechanism for the occurrence of Alderney type sandstone and Jersey type jasper, rhyolite and greywacke in Guernsey (see above, and De La Mare, 1895, for localities) and the occurrence of Sark schist in Jersey (Mourant - personal comm.). If large expanses of gravel from the existing areas of the islands were deposited by periglacial action on the Channel floor during low sea levels, the action of the wind and tide during the rise in sea would soon distribute these rock fragments widely.

The location of the beaches richest in flint on north facing coasts suggests that the main influence in depositing the flint came from the north. It is noteworthy that the 25 ft. (8 m.) beach has by far the most flint in it (this may be a subjective judgement because of larger numbers of exposures of this beach). This beach is conventionally dated as Ipswichian (see Mitchell, Penny, Shotton & West, 1973) and so follows the supposed maximum glaciation of western Britain in the Wolstonian during which considerable amounts of flint were introduced into the western approaches by ice (Mitchell, 1960). Pebble counts in the modern beach in Bonne Nuit Bay, Jersey, show that compared with the raised beach in the same bay it has only half as much flint (2.12% against 4.9%). This seems to suggest that the main period of flint introduction was prior to the deposition of the raised beach and that the modern beach which is composed of material from erosion of the raised beach and the (flintless) head contains thus a diluted percentage of the original flint.

The possibility of northerly derivation by ice is strengthened by the occurrence of Devonian crinoidal limestone in the 25 ft. (8 m.) beach at Corbiere, Jersey (c.WV 554481) (Dunlop, 1913) which clearly has a northerly source and is probably not derived from the Channel floor. However, the occurrence of flint in the higher raised beaches up to the exposure of 85 ft. (26 m.) at Les Vardes, Guernsey, makes it clear that flint was being deposited in the area before the Wolstonian. Whether this points to an earlier glaciation introducing flint into the Channel or to a steady amount of flint being deposited in the island beaches by the erosion of submarine outcrops is unknown*.

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* Mitchell and Orme (1966) in the Scilly Isles, distinguish between pre- and post-Wolstonian raised beaches on the grounds of flint and other erratic content. Their Chad Grit raised beach has only small amounts of flint in it and is thought to be pre-glaciation in age while the Porth Seal beach is rich in flint and thought to be post-glaciation (Ipswichian) in age. The authors ascribe the small amounts of flint in the earlier

/beach

Chapter V. The Problem of an Earlier 25 ft. (8 m.) Beach.

It has recently been suggested, principally by Mitchell (Mitchell & Orme, 1966; Mitchell, 1970; Mitchell in discussion to Bowen, 1973; Turner in discussion to Bowen, 1973) that there are two raised beaches recognisable around the shores of the Irish Sea (and by extension therefore around the shores of the Channel) at approximately 25 ft. (8 m.) O.D. The 25 ft. (8 m.) rock platform is clearly older than the beach which rests upon it since sub-aerial deposits separate beach material from the rock platform at several points around the islands (table IV). It is not therefore unreasonable to suppose that beach deposits of two ages may occur. Mitchell and Orme describe two such beaches in superposition in the Scilly Isles and suggest that they may be distinguished on their erratic content (seen above, Part II, Chapter IV).

In the Channel Isles there are no clear distinctions between beaches on grounds of erratic content. It is noticeable that some outcrops are richer in flint than others and that those with the most flint are often the least weathered but other variables may cause beaches of the same age to be more or less weathered (e.g. cover of head, nearness to ground water seepage). The presence of flint in the 25 ft. (8 m.) beach especially is often influenced by the size grade of the pebbles. The coarsest beaches are devoid of flint but beaches with a pebble size of around 2 inches (5 cm.) long axis often show large amounts of flint. Despite these objections there are two sites in Guernsey where an earlier low raised beach

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* cont. from previous page.

beach to "offshore sources" The great increase in flint in the later beach is stated to be due to the deposition of large amounts of flint in the islands by the Wolstonian ice (and its subsequent incorporation in the raised beach.

can be recognised; at Fermain (WV 339762) and at Moulin Huet (WV 331751)*. At Fermain, on the north side of the bay, sheltered by the Gouficher Rock (WV 341763) a section in head and raised beach can be seen. The section rests on a smooth but very weathered platform which is at about 18 ft. (5.5 m.) above mean sea level. Above the platform is 1 ft. (30 cm.) of fine beach gravel which is followed by 3 ft. (1 m.) of coarse angular gravel in a matrix of sandy decomposed gneiss which is clearly a solifluction deposit. This is succeeded by a further 1 ft. 6 inches (45 cm.) of coarse beach cobbles and then 1 ft. 6 inches of coarse sand with angular pebbles near the top which is probably a beach sand grading up into head. The head forms a cliff 15 ft. (4.6 m.) high above the raised beach deposits (see fig. 28).

Such sections showing two raised beaches in superposition are described by Mitchell and Orme (1966) from St. Martin's in the Isles of Scilly and by George (1932) from Gower (Minchin Hole). Bowen (1973) suggests that these Gower sections represent one beach with an angular gravel between two gravels with more rounded pebbles. In the Fermain section the angular gravel between the two beaches shows no sign of being water-worn so a marine regression must have occurred between the two episodes of beach deposition. If such a period of marine regression did occur it would be expected that evidence of it would be found in other sections in the islands but no other section of this kind has been found. If such an event as a double marine transgression had occurred in as recent an episode as the last interglacial it should have left wider traces than just two sections amid very many.

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* In Jersey, Mitchell and Orme (1966) describe a raised beach below the lower head in Belcroute (see above). Repeated searching by the present author has failed to locate the section described by Mitchell and Orme and it is not described in the literature. In addition A.E. Mourant with fifty years' experience of Jersey geology has never seen such a section at Belcroute so it is possible that Mitchell was mistaken in his description. If not the lower of the two raised beaches in Belcroute is probably to be equated with the lower beach at Fermain in Guernsey.

Thus the likeliest explanation of these sections showing two beach gravels in close superposition is that the two beach deposits are of quite different ages and separated by at least a substantial marine regression and probably a full glacial*.

The second locality where this earlier low level beach may occur is in the cave at Moulin Huet (the roof of this "cave" is in fact collapsed and site is in a deep gully rather than a true cave). The cave attracted geological attention early on (Collenette, 1916). In the cave (see section, fig. 33) a remnant of the low shore platform is backed by a fine wave notch and has cemented to it a coarse cobble beach (see Plate 40). Further patches of conglomerate are cemented to the wave notch outside the cave just to the west. The top of the beach reaches 30 ft. (9 m.) above mean sea level. Much higher in the cave at over 45 ft. (13.8 m.) is a further patch of beach in a notch which is less well developed than the lower notch. The two beach gravels are alike in every detail of cementation and condition. The easiest explanation of this arrangement of beach remnants is to assume that the cave was originally filled with gravel to at least the highest point that the gravel reaches at present and that later erosion has brought about the arrangement which can be seen at present. If this is so then the gravel is not a part of the 25 ft. (8 m.) beach of last interglacial age as nowhere can the deposits of this episode be seen to rise above 33 ft. (10 m.)**.

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* A recent re-evaluation of the Minchin Hole site by Bowen and Sutcliffe (1974) suggests that the higher of the two beaches in this cave, at around 40 ft. (12 m.), is the earlier and the lower beach at around 20 ft. (6 m.) is the younger and was formed by the sea entering the cave and retrimming the earlier deposit in the same manner as described for La Cotte de St. Brelade by McBurney and Callow (1971).

** George (1973) offers a radically different explanation of the Moulin Huet sequence to that above. He suggests that the higher deposits (which he says are at 11.7 m. O.D. (38 ft.)) are a different deposit to the lower deposits and earlier, although still part of the Ipswichian beach, in which he includes all deposits in the islands up to 60 ft. (18 m.). As stated above it is unlikely that the sea rose above 33 ft. (10 m.) in the last interglacial so the higher level gravel in Moulin Huet must be pre-last interglacial in the sense that the term is being used in the present work. In view of the similarity between the two gravels there seems to be no grounds for assuming two ages for the deposits in this cave.

Similar caves in Jersey around the north-west of the island have cemented beach gravels in them at around 50 ft. (15 m.). Few of these caves have beach gravels in them at a lower level although at Le Pinacle (WV 545555) and Ile Agois (WV 597557) in Jersey deep gullies contain wave worn notches at both 25 ft. (8 m.) and 60 ft. (18 m.). Mourant (1933) suggests that the 60 ft. (18 m.) level is the earlier and that the 25 ft. (8 m.) sea then cut away the rock floors of these caves to leave the gravel of the higher level hanging as a false roof (see fig. 27). It seems incredible that cave floors of even weathered granite could be destroyed but leave the gravels on them still in situ especially high above the upper limit of last interglacial wave action. It seems more likely that an earlier transgression up to at least 60 ft. (18 m.) from around the present sea level, cut the caves and filled them with sediment which later became cemented. A lower sea level around 25 ft. (8 m.) then eroded the lower parts of the gravel away. The gravel of the 25 ft. sea has in turn been removed by the modern high sea level so only the highest gravel remains.

In just one case at Cane de la Rivere, Jersey (WV 577560), a lower gravel can be seen to rise from around 24 to 40 ft. (7.5 m. to 12.5 m.) above mean sea level. This seems to confirm that a marine aggradation from around the present sea level to over 40 ft. (12.5 m.) occurred at some stage in the Pleistocene. As the archaeological sequences in La Cotte de St. Brelade and La Cotte à la Chèvre occur in caves and in association with raised beach deposits the age of the caves is clearly important in the building of a chronological sequence for the islands. The age of this earlier period of low sea level, the age of the 60 ft. (18 m.) raised beach and the 25 ft. (8 m.) beach are so intimately bound up with the archaeological evidence that they will be considered below in Chapter VI.

Chapter VI. Climatic and Chronological Sequence in the Channel Isles.

a) Higher surfaces

Any chronology of the Channel Isles Pleistocene must use the raised beach succession as a frame around which other deposits may be assembled, as the raised beaches are the deposits which are at present most readily dateable.

As mentioned at the beginning of Chapter III, planation surfaces exist in the landscape up to 400 ft. (123 m.) and some of the lower surfaces (principally those at 220 ft. (66 m.) and 160-180 ft. (48-54 m.)) still have the last remnants of beach deposits on them (see Dunlop, 1913; Elhaï, 1963, for an exhaustive discussion of these remnants). The ages of these surfaces are unknown. Elhaï considers that the initial development of the landscape began in the early Pliocene and that the highest surfaces (at 400 ft. (123 m.) in Jersey and 300 ft. (92 m.) in Guernsey) were retrimmed in the late Pliocene and then tilted, Jersey to the south and Guernsey to the north, about a hinge between the two islands. As Elhaï himself admits the evidence for this planation and tilting is merely that of comparison with areas in the Cotentin and Brittany which have planed and tilted surfaces at a similar height. The lower surfaces below the summits of the main islands and the summit surfaces of Herm and Sark are attributed by Elhaï and Mourant (1933) to the classic Milazzian and Sicilian stages of Deperet (1922).

b) Surfaces and deposits between 125 ft. (37.7 m.) and 85 ft. (26 m.)

The beaches at South Hill and St. Clement's Church are declared by Mourant (1933) and Elhaï (1963) to be Tyrhennian in age on the basis of their heights above sea level. The beaches in Guernsey at Les Vardes and Les Rouvets should also be considered to be Tyrhennian on grounds of height. The widespread level in western Guernsey at about this height is best regarded as a planation surface of the same age as these isolated deposits but stripped of them by later erosion.

The great dissection of these 100 ft. (30 m.) beaches and surfaces, their clear differentiation from the 60 ft. (18 m.) and 25 ft. (8 m.) levels (see above, Chaps. III and IV) and their equation with the Tyrhennian level by various authors make it plain that these beaches are to be dated to the Hoxnian interglacial. Further evidence for this date is suggested by comparison with the deposits of the Slindon - Goodwood raised beach of Sussex (Reid, 1903; Oakley & Curwen, 1937; Dalrymple, 1957). This Sussex beach is also on two levels like the deposits in the Channel Islands (at 80-90 ft. (24-27 m.) in Aldingbourne Park and 125-135 ft. (37-42 m.) at Slindon) and contains flint implements which suggest a Hoxnian date. The handaxes from Slindon are similar in every way to the Acheulian handaxes of Swanscombe and Hoxne both of which are typical sites of the Hoxnian interglacial, so it seems most likely that the Slindon site is of Hoxnian age and that the Channel Isles 100 ft. (30 m.) beaches were formed by the same sea[*].

c) <u>Events postdating the deposition of the 100 ft. (30 m.) beaches</u>

At the end of the Hoxnian interglacial the onset of glaciation caused the lowering of sea level and the abandonment of the fossil cliffs cut during the interglacial. There is no clear evidence in the islands of how far the sea level sank before reaching temporary stability but it is possible that the low shore platform was reoccupied, if not originally cut, at this time[**],[++].

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[*] Kellaway in discussion to Bristow and Cox (1973) and in Mitchell et al. (1973) suggests that the Slindon beach is Cromerian because it contains erratics from the west left by a supposed "Elsterian" (Anglian) ice sheet. A Cromerian date seems unlikely unless the two levels at Slindon are of different dates. As the higher level contains Acheulian implements of typical Hoxnian type it seems most unlikely that this beach is of Cromerian age.

[**] The dating of the shore platform as post-Hoxnian merely states the latest date at which the cutting of this low platform could have begun. Other authors suggest that the platform may have begun its evolution in the Cromerian (Edmonds, 1973) or the Lower Pleistocene (Orme, 1966; Stephens, 1970).

[++] There is no recognisable counterpart in the Channel Isles of the post-100 ft. coombe rock of Slindon with its Acheulian occupation site.

The evidence for a post-Hoxnian - pre-60 ft. (18 m.) sea as low as present sea level is contained in the caves around the coasts of Jersey and Guernsey. Many of these caves (particularly on the outcrop of the north-west granite in Jersey) have cemented beach deposits in them at around 60 ft. (18 m.). Below these deposits (with the single exception of La Cotte à la Chèvre) there is always an open cave cut down to at least present sea level (see fig. 27). It seems improbable that a cave could be cut from below in fresh rock and leave a loosely cemented beach gravel hanging above it. The caves clearly came first and were either cut by the sea rising from a post-Hoxnian (i.e. perhaps early Wolstonian) low sea level or at least retrimmed by this marine transgression, with the original cutting of the caves occurring at some earlier stage in the Pleistocene perhaps in pre-Hoxnian times or perhaps during the marine transgression of the early Hoxnian.

The effect of this marine transgression is most clearly seen in the Moulin Huet cave in Guernsey (fig. 33) where a marked platform occurs with a maximum of 6 ft. (2 m.) of coarse gravel resting on it. In the cave roof at 45 ft. (13.8 m.) above mean sea level further patches of gravel occur which are similar in every detail to that at the lower level and make it most likely that the gravel as it is seen at present is merely the last remnant of the material which originally filled the cave.

Erosion during the Ipswichian interglacial and during the modern high sea level have left the pattern as it appears at present with a few caves preserving a cemented remnant of beach gravel out of reach of Ipswichian (or modern) storm waves*.

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* Several authors (Orme, 1966; Mitchell & Orme, 1966; Mitchell, 1970; Stephens, 1970; Turner in discussion to Bowen 1973 and personal communication) have suggested that the Hoxnian sea level in western Britain rather than occurring at 100 ft. (30 m.) O.D. in fact only reached a level of around 20 ft. (6 m.) O.D. In view of the fact that several of these "low" Hoxnian deposits are interbedded with head and glacial till it seems more likely to the present author that the beach remnants described by the

/above authors

d) The age of the 60 ft. (18 m.) beach and events following it

This beach is of great extent in the islands and is distinct from either the 25 ft. (8 m.) beach or the 100 ft. (30 m.) beach (see above, Chapter III). In view of this separation from these other beaches the 60 ft. (18 m.) is neither Hoxnian nor Ipswichian in age*. If this distinction between the 60 ft. (18 m.) beach and the other beaches is accepted an age in the Wolstonian glaciation seems most likely with the 60 ft. (18 m.) beach being formed in either an interstadial or a hitherto unrecognised interglacial (see below, Part III, Chapter II for a further discussion of this episode). That the period of deposition of the 60 ft. (18 m.) beach was closely followed by a cold period is suggested by the archaeological evidence.

In La Cotte à la Chèvre the massive boulders of the beach deposit are covered by only 6 inches (15 cm.) of weathered beach sand before they are overlaid by the loessic clay with flint implements of the occupation layer (Sinel, 1912; Zeuner, 1946). The lower "Pre-Mousterian" levels at La Cotte de St. Brelade contain implements which are identical in all significant details (C.B.M. McBurney - personal communication) with those of La Cotte à la Chèvre**. These implements occur in association with the

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(cont. from previous page)

above authors should in fact be dated to the phase of low sea level following the Hoxnian as described above. There are great difficulties in associating the Hoxnian with a low sea level in western Britain in view of the fact that all the sites with typical Hoxnian mollusca, artifacts or mammals in fluvial sequences in eastern Britain are at the 100 ft. (30 m.) level (e.g. Swanscombe).

* Elhai (1963) suggests that the 60 ft. (18 m.) beach is a continuous feature with the 25 ft. (8 m.) beach (his haut and bas-normannien). That this is not so is demonstrated in Chapter III.

** Sinel (1912) states that the implements recovered from La Cotte à la Chèvre were clearly of an earlier type than those at La Cotte de St. Brelade. He places these flints in the "pre-Mousterian" (i.e. post-Acheulian) which is the age of the implements from La Cotte de St. Brelade described by Burdo (1960) and McBurney and Callow (1971) even though these lower levels at La Cotte de St. Brelade were not discovered until 25 years after Sinel's death.

butchered remains of such cold climate species as Mammoth and Woolly Rhinoceros. In addition small numbers of pollen grains indicative of a sub-arctic vegetation have also been found in these lower horizons of La Cotte de St. Brelade (McBurney & Callow, 1971).

The flint industries found in the two Jersey caves show some affinities with the Levalloisian industries known in Britain and France (C.B.M. McBurney - personal communication) and although a few handaxes have been found in La Cotte de St. Brelade the general character of the industry is more evolved than any of the Hoxnian Acheulian industries while being far less refined than the Mousterian proper of the upper levels of the site. The closest parallel elsewhere with the industry common to both the Jersey caves is the industry of Baker's Hole, Kent (Burchell, 1936b) which also occupied a position in association with downcutting in a cold climate in this case from the high levels of Swanscombe (Burchell, 1952).

At its maximum the 60 ft. (18 m.) sea level cut into the rock platform of the 100 ft. (30 m.) stage in Guernsey (at La Ramee and King George's Fields) and further eroded the base of the earlier cliffline in Jersey (at Mont Jubilee and Verclut). During the cold period following the deposition of the 60 ft. (18 m.) beach the sea level must have fallen at least 50 ft. (15 m.) below modern sea level to allow palaeolithic man and such beasts as mammoth to have reached Jersey from the continent. The cold climate and solifluction cleared the old shore platforms of their deposits in some areas and replaced the beach deposits with head.

During this post 60 ft. (18 m.) beach episode (the Wolstonian of Britain) the greatest incursion of flint into the Channel Islands area seems to have occurred. The 60 ft. (18 m.) beach has some flint in it (Mourant, 1933; Elhaï, 1963) but it is the 25 ft. (8 m.) beach which has the greatest amount of flint in the islands. Some of the flint tools in La Cotte de St. Brelade were made from much larger flints than any that can be seen in the raised beaches today. McBurney and Callow (1971) suggest that a definite correlation exists between the percentage of flint (against local rock types) used by the inhabitants of La Cotte de St. Brelade and the onset of the Ipswichian interglacial. These authors suggest that the progressive substitution of quartz, dolerite and microgranite for flint in the higher levels of the cave reflects the submergence of flint gravels formed on beaches below the present sea level. It is certain that some of the flint in La Cotte came from beach sources because beach pebbles occur in the occupation levels in the cave but where the beaches were from which the pebbles were selected is unknown.

Whether the flint was introduced into the islands by floating ice or by the erosion of chalk which was brought into the wave zone by the fall in sea level is uncertain. The source of flint was to the north of the islands (see Chap. IV and table V), as are both the suggested origins for the flint. It is noteworthy that Mitchell and Orme (1966) in their description of the Pleistocene of the Scilly Isles state that the ice sheet which overrode part of these islands in the Wolstonian was rich in flint. It is not difficult to envisage icebergs from this great glacier being drifted up Channel to deposit their loads of erratics (of which flint, being among the hardest, has survived differentially) on beaches below present sea level. It would then only remain for the rising Ipswichian sea to redistribute this flint into the beaches which now appear as the 25 ft. (8 m.) beach.

The presence of pebbles of Jersey rock types in the 25 ft. (8 m.) beach at Chouet in Guernsey (see above, Chap.IV) may also indicate some degree of rolling of pebbles up the submarine slope by the transgressive Ipswichian sea but the absence of these Jersey stones in raised beaches on Guernsey's east coast (the nearest coast to Jersey) poses a problem if the foreign stones at Chouet are actually from Jersey. It is possible that these erratics are in fact from the north and were brought by drift ice rather than eroded from gravels soliflucted from the present area of the islands on to the dry sea floor at periods of low sea level.

As the archaeological levels which succeed the 60 ft. (18 m.) beach are themselves succeeded by Ipswichian deposits (in La Cotte de St. Brelade the 25 ft. (8 m.) beach and in La Cotte à la Chèvre a weathering horizon) it seems clear that they are upper Wolstonian in age as is the head which underlies the raised beaches at the sites set out in table IV. The 60 ft. (18 m.) beach is on this evidence of early or middle Wolstonian age.

e) Age and climate of the 25 ft. (8 m.) beach

As described above (Chapter IV) the 25 ft. (8 m.) beach is by far the most extensive in the islands. All authorities (Mourant, 1933; Zeuner, 1946; Elhaï, 1963; McBurney & Callow, 1971) are agreed that this beach was formed in the Ipswichian interglacial* and although it has been suggested that the marine transgression continued to the 60 ft. (18 m.) level (Elhaï, 1963), there is practically no suggestion that the beaches at 25 ft. (8 m.) are anything but Ipswichian in age.

As mentioned above, the 25 ft. (8 m.) beach is the least dissected of all the beaches in the islands which alone might indicate that it is the youngest. Also the beach is the lowest in the altitudinal sequence which (after Zeuner, 1945) should make it the youngest.

As the 25 ft. (8 m.) beach is the youngest in the islands it is the most complete and far more can be deduced of the climate and environmental conditions occurring during the time of the beach's formation than in the earlier periods. What is known of the climate of the 25 ft. (8 m.) beach interglacial in the islands compares so closely with the details of the Ipswichian interglacial in Britain as to leave little doubt on environmental grounds that the 25 ft. (8 m.) beach was formed in this interglacial.

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* Variously described by the authors as the "Last" or "Eemian" Interglacial.

In Jersey, the presence of Astralium rugosum in the Belle Hougue cave suggests a slightly warmer sea than at present for the Ipswichian as this mollusc's present northern limit is the Gironde (Baden-Powell in Zeuner, 1945a). The other species in the Belle Hougue cave all occur in the islands at present so it is possible that Astralium rugosum's tolerance has changed slightly, although the presence of warm indicator species (the plants Acer monspessulanum, Naias minor; and Emys orbicularis, the Pond Tortoise) is a consistent factor at sites of Ipswichian age in Britain.

The other fossils associated with the 25 ft. (8 m.) beach in Jersey are those of Cervus elaphus jerseyensis. This dwarf red deer points to conditions of warmth and some forest cover. The dwarfing of the deer indicates complete separation from the mainland population (cf. the Mediterranean "pony" elephants and dwarf hippos, Zeuner 1945; Kurten 1968) as would be expected with the high sea level. No good pollen bearing deposits of Ipswichian age have been found in the islands but the lower complex in La Cotte de St. Brelade is capped by a sterile series of deposits with organic layers and a weathering horizon in which a very few pollen grains have been found. These pollen grains indicate a cover of mixed oak forest but with areas of swampy alder carr nearby (McBurney & Callow, 1971). It is possible that some of this pollen, tentatively held by the above authors to represent zones f to h/i of the Ipswichian, is redeposited from a lower pollen bearing layer of unknown age found in the lower complex of the cave. However, a mixed oak forest is the vegetation type which would be expected under interglacial conditions in Jersey. The large alder element in the pollen diagram could easily be provided by an Ipswichian equivalent of the marshy area of the Ouaisne pond of today which is only 200 m. from La Cotte. In view of this the layers with the temperate pollen which show evidence of redeposition may merely represent pene-contemporaneous erosion of the interglacial weathered horizon as the sea fell from its maximum level.

Other features of the Ipswichian climate can be deduced from examination of the beach deposits at Rousse in Guernsey and the blown sands of St. Peter's in Jersey. At Rousse the beach lies within the modern shore zone and supports large blocks of granodiorite which are cemented into it (see Plate 44). These blocks have been interpreted (Elhai, 1963) as being due to solifluction, but as the raised beach is cemented around the base of degraded stacks and "tor"-like masses of granodiorite (just as the modern beach is) it seems more logical to explain the large blocks as merely storm-broken boulders which came to rest in the old beach after being broken up by storm waves from the west. This process is constantly occurring on the present beach (see Girard, 1966) and suggests that conditions in the Ipswichian were little different from those of the present where storms were concerned.

Further evidence that the wind directions were similar to those of the present during the Ipswichian is found in Jersey. The area of Pleistocene blown sand in St. Peter's parish (see map, fig. 42) is directly comparable in its downwind elongation to the modern blown sand of the Quennevais dune system. The modern dunes of St. Ouen's Bay were deposited by north-west and south-west winds so the pattern of blown sand deposits appears as two areas of elongation in the north and south of the bay and aligned downwind* (see map, fig. 42). The outcrop of the Ipswichian blown sand occupies an area between the two "horns" of the modern dune system. This perhaps indicates a more due westerly component for the winds in the Ipswichian.

At the end of the interglacial the sea level fell only slowly from its maximum. It seems probable that accelerated erosion, if not full periglacial conditions, had set in while the sea was still, though perhaps only inter-

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* Much of the dune system is dormant and stabilised by vegetation and last appears to have been active in Mediaeval times.

mittently, reaching its highest level. At Belcroute Bay horizontally bedded sands overlying the beach gravel become increasingly stony upwards until, 4 ft. (1.2 m.) above the top of the gravel, the sand is replaced by true head. At Portelet a similar sequence occurs with a passage from beach sand up into fine grained head. Elsewhere, at L'Eree for example, the head rests directly on top of the beach gravel without a break. It seems almost impossible that sea level could fall and leave beach gravels open to sub-aerial weathering for long without some effect being noticeable and as no such effects can be seen it seems to follow that periglacial action was already under way while the sea was still reworking the raised beach. As soon as marine influences were withdrawn the beaches were overwhelmed by solifluction with little or no hiatus.

f) Events post-dating the 25 ft. (8 m.) beach

As described above, the fall in sea level at the end of 25 ft. (8 m.) beach times is closely associated with the onset of cold conditions. If it is accepted that the 25 ft. (8 m.) beach is Ipswichian it must follow that the overlying periglacial deposits are of Devensian age. Except at La Cotte de St. Brelade it is impossible to subdivide the Devensian deposits of the islands. The small fauna they contain (Chapter II) is a facies fauna indicative of cold, open conditions but is not representative of any particular age. In La Cotte the upper cultural levels contain a cold fauna (see Chapter II for a faunal list) and a Mousterian industry, together with the remains of Neanderthal man. Both the human remains and their cultural stage are typical of an early Devensian age before the advent of the advanced Upper Palaeolithic industries and Homo sapiens.

As mentioned above (Chapter II) the head is of periglacial origin but no consistent horizons can be seen within it which can be related to any particular stratigraphic stage. The more loessic bands in the head represent local solifluction streams rather than any wider events. The last event of the Devensian in the islands was the deposition of a thin loess on the top of the thick coastal head. Before this thin layer could be redistributed by solifluction the climate ameliorated and so a coherent layer has remained preserved. The age of this last loess fall is uncertain. Solifluction was active in southern Britain in post-Allerød times (Kerney, Brown & Chandler, 1964; Perrin et al., 1973) so this loess may be dated to the end of zone III times but this dating is necessarily uncertain in the absence of any dating evidence.

It seems clear that in the Devensian, in contrast to the Ipswichian (and the present), the dominant wind direction over the islands was from the north-east. The loess is consistently banked against north and east facing slopes and thins greatly towards the west (see Chapter II) until in the west of the islands no loess occurs. This pattern of a north-easterly derivation is entirely consistent with deposition by a wind blowing off a glacial anticyclone centred over Scandinavia and such a pattern of loess deposition has been described in Germany and Czechoslovakia (Zeuner, 1945), Normandy (Journaux et al. in Pewe, 1965) and southern England (Coombe & Frost, 1956; Weir, Catt & Madgett, 1971).

Part III

Chapter I. The Hoxnian of the English Channel. Some correlations and problems.

a) Introduction

It has been noted in Parts I and II of this thesis that deposits ranging through a considerable part of the Pleistocene are present in both Hampshire and the Channel Isles. No attempt has been made up to this point to date the deposits despite the varying amounts of evidence within them. This is best done by reference to other sites showing similar characteristics, in other areas of Britain.

The types of evidence used in referring features to the Hoxnian can be either organic or geomorphological. Clearly organic deposits, and in some cases archaeological evidence, give the best unambiguous dating information but sites with good organic sequences are rare and it has more often been necessary to fall back on height evidence to indicate the age of deposits. Both in the Channel Isles and Hampshire, in the absence of organic remains height evidence alone must be used. Comparison with sites with organic remains and at a similar height may assist the dating of these sites. Accordingly in this chapter some sites dated by their included fauna and flora and falling into the same height range as the deposits in the areas in question, will be examined and some correlations made.

As some controversy has occurred over the exact height of the sea in the Hoxnian interglacial it is also necessary to consider sites outside the height range of the sites in Hampshire and the Channel Isles which have been described as the 100 ft. (30 m.) terrace or beach in Parts I & II. Some doubt has also been cast on the existence of the Hoxnian as a separate episode, and in dating deposits in the areas under examination in this thesis as Hoxnian some reference will be made to the status of the Hoxnian interglacial.

b) Hoxnian deposits in Hampshire and the Channel Isles

The Hoxnian deposits of the Channel Isles and Hampshire all occur between 80 ft. (26 m.) and 130 ft. (40 m.) O.D. As described in Parts I and II the deposits occur in two groups at 80-100 ft. (26-30 m.) and above 100 ft. (30 m.). In Hampshire two clear terraces can be seen at these heights while in the Channel Isles the beach deposits can also be divided into two groups. In the islands the two groups of deposits are united by the wide bench on which they lie and the fossil cliff which backs them. The deposits contain little organic evidence in either area (just a few rolled handaxes in the 100 ft. (30 m.) terrace at Highcliffe), so the only basis for their correlation is their height above sea level.

c) Some selected Hoxnian sites dated by organic means

I. Slindon, Sussex. This site is important in that it is one of the few sites in Britain of Hoxnian age in which raised beach deposits have any evidence for dating beyond height considerations. At Slindon a similar double level to those in the Channel Isles and further west in Hampshire can be seen (Fowler, 1932; Oakley & Curwen, 1937; Dalrymple, 1957). The higher level reaches 135 ft. (41.7 m.) and the lower (in Aldingbourne Park) 90 ft. (27.6 m.). The lower level contains Clactonian implements and the higher Acheulian handaxes. This suggests that the lower deposit is the earlier although less reliance is now placed on handaxes as "zone fossils" than was the case in the past (see Wymer, 1974).

II. Swanscombe, Kent. This famous site too has two distinct levels in its terrace deposits (see Ovey, 1964 for a summary of the literature on Swanscombe). The lower series reaches 94 ft. (28.9 m.) in the lower middle gravel of Barnfield Pit, while the upper series in the same pit (although cutting through all earlier deposits to bedrock in a channel), reaches 110 ft. (33.8 m.) at the top of the upper loam*. As at Slindon the earliest deposits are the lowest (and Swanscombe has in any case a stratigraphical sequence) and contain a Clactonian industry (Wymer, 1968) while the higher levels contain an Acheulian industry. Mammalian remains of Hoxnian type (Sutcliffe, in Ovey 1964), a pollen diagram similar to the Hoxnian sites of Clacton and Hoxne (Wymer, 1974), and a distinctive Hoxnian molluscan fauna (the vast literature on the Swanscombe mollusca is summarised by Kerney, 1971) also occur at Swanscombe.

III. Nar Valley, Norfolk. This site contains estuarine clays and silts ranging up to 65 ft. (21.5 m.) O.D. (Stevens, 1959) and deposited in 10 ft. (3 m.) of water so the top of this deposit reaches the height range of Swanscombe. (Rose, 1865, states that the clay reaches 80 ft. (24.6 m.) making the maximum height achieved by the sea 90 ft. (27.6 m.) at least.) The Nar clay yields a pollen diagram comparable with that at Hoxne and a molluscan fauna with Hoxnian affinities. Despite the problems of evaluating pollen from marine deposits (set out by Stevens, 1959) the Nar clay is most likely to be Hoxnian with its upper parts representing the top of the marine transgression identified at other sites.

IV. Kirmington, Lincolnshire. At Kirmington a molluscan fauna and pollen bearing silt occurs below till (Watts, 1959; Catt & Penny, 1966) and contains Clactonian flakes (Burchell, 1935). The top of this estuarine deposit reaches 90 ft. (27.6 m.) O.D. and so falls into the height range of the other Hoxnian deposits mentioned. It is possible that the Kirmington estuarine series reached above 90 ft. as the till overlying it is

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* The Dartford Heath gravels reach 136 ft. (42 m.) and are believed by Chandler and Leach (1912) to be associated with the Swanscombe deposits. Hinton and Kennard (1905) and Zeuner (1945) suggest that these gravels rest on a higher bench than any at Swanscombe and so are not part of the Swanscombe sequence but earlier.

formed largely from reworked estuarine material.

V. Speeton, Yorkshire. At Speeton cliff north of Flamborough a shell bed containing temperate mollusca occurs at 90 ft. (27.6 m.) O.D. This deposit is considered to be Hoxnian by Catt and Penny (1966). Although it contains no diagnostic species*, it is overlain by their Basement till which they date as "Saale" (Wolstonian), and so must be Hoxnian or earlier.

VI. Clacton, Essex. The foreshore site at Clacton is in fluvial and estuarine sediments. A typical Hoxnian pollen spectrum has been obtained from the site (Pike & Godwin, 1953; Turner, 1971) and a large mammalian and molluscan fauna has also been collected from these deposits (Warren, 1955). Clacton is also the type site of the Clactonian flake industry (Oakley & Leakey, 1937; Singer et al., 1973). Unlike most of the other Hoxnian marine and estuarine sites the Clacton channel deposits only reach 27 ft. (8.3 m.) O.D. although they contain the same pollen zone Ho II as the lower loam at Swanscombe which lies around 80 ft. (24.6 m.) O.D. (Wymer, 1974). It has been stated by Zeuner (1945) that the Clacton channel deposits were laid down in an "intra - Boyn Hill (sic) erosion stage" which occurred in the hiatus between the lower and upper deposits at Swanscombe and was marked in the Barnfield pit by the weathering of the surface of the lower loam. The presence of the same pollen zone at Clacton and Swanscombe makes this interpretation unlikely and it is now widely thought that the low altitude of the Clacton deposits in relation

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* West (1969b) has described a limited pollen sequence from Speeton which has Ipswichian affinities. Nowhere else is it suggested that the Ipswichian sea level reached as high as 90 ft., so an Ipswichian date seems unlikely for Speeton.

to those of other Hoxnian sites is due to downwarping on the edge of the North Sea basin* (West, 1972).

VII. Other terrace sites. Many places above the tidal limits of the main rivers of southern England have sites where handaxes and interglacial faunas have been found in association with terrace deposits about 100 ft. (30 m.) above the present river (see Wymer, 1968, for a gazetteer of sites in the Thames valley, for example). Many of these sites may be of Hoxnian age. However, most of these records are from work conducted in the last century and little modern palynological information is available to confirm their dating.

VIII. Lake sites. Several pollen spectra have been described from lacustrine sediments. While these sites, e.g. Hoxne (West, 1956); Mark's Tey, Essex (Turner, 1970); Nechells, Birmingham (Duigan, 1956; Kelly, 1964; Shotton & Osbourne, 1965) provide the best preserved pollen record and often well preserved faunal and archaeological remains, they can only be correlated with other sites with organic remains and cannot be correlated with terrace or raised beach deposits on height or geomorphological grounds.

d) The problem of the Hoxnian sea level in western Britain

In south-west England and southern Ireland the Hoxnian is thought to be represented by a raised beach at 15-25 ft. (4.6 - 8 m.) O.D. (Stephens, 1971; Mitchell, 1970 & 1972). The basis of this dating is the relationship of the raised beach to overlying glacial and periglacial deposits. At Fremington and in the Scillies and widely on the Irish coast the raised beach (described by Wright and Muff, 1964, as the "pre-glacial" beach) is said to be overlain by till. This till is generally thought to

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* West and Sparks (1964) consider that the Ipswichian site at Stutton, 15 miles (24 km.) north of Clacton, has been downwarped 30 ft. (9 m.) relative to the (presumably) stable Sussex coast since the Ipswichian. Such downwarping for the older Clacton deposits is therefore not unlikely.

be of Wolstonian (in Ireland, Munsterian) age on the basis of its depth of weathering. At a few sites on the Irish side the deposits over the beach have yielded a sparse pollen assemblage (see Mitchell, 1970) of Gortian (Hoxnian) age.

It is extremely difficult to reconcile a full Hoxnian age for the high raised beaches described above and the river terraces of Thames and Solent with the deposition of beaches as low as those described by Mitchell and Stephens. Both cannot be of full Hoxnian age unless tectonic displacement has occurred and there is no evidence for this. Recent work by Kidson and Wood (1974) and Bowen (1973) has reinterpreted some of these sections where till overlies raised beach at low altitudes and has enabled an alternative scheme of dating to be set up.

Kidson and Wood (1974) conclude from their examination of the Fremington area that there is no evidence for the existence of a raised beach below the Fremington till so if that till is Wolstonian in age the beach exposures near the till sheet must post-date it and so be of Ipswichian age. Bowen, 1973, suggests that many of the sites in southern Ireland which show till overlying raised beach are also showing an Ipswichian beach overlain by Devensian (Midlandian) till on the grounds that such differences in the tills which overlie the beaches are not due to their different ages but due to the tills all being part of the same multi-till sequence.

An alternative explanation of these low beaches buried by till may be that the till is truly of Wolstonian-Munsterian age but the beach is dated to a phase well within that glaciation when the sea level had fallen from the Hoxnian high level under the impact of the build-up of land ice. That the sea level fell to at least around the present in immediately post-Hoxnian times is known firstly from the buried channel below the 60 ft. (18 m.) terrace at Hordle, secondly from the evidence of the aggradation from around modern sea level preserved in the Channel Island caves below the 60 ft. (18 m.) beaches, and thirdly from the occurrence of the cold climate Bridlington Crag (Catt & Penny, 1966) around O.D. below Wolstonian Basement till in Holderness. The pollen described from head above the raised beach in Ireland at such sites as Fenit and Spa (Mitchell, 1970) with its sub-arctic affinities might then represent a phase in the Wolstonian-Munsterian rather than the late Hoxnian-Gortian age suggested by Mitchell.

Examination of the stratigraphy erected by Mitchell, Colhoun, Stephens and Synge (in Mitchell et al., 1973) for Ireland, and by Stephens (in Lewis, 1968) for south-west England shows a lack of Ipswichian raised beaches. In Ireland only one locality has been described (the Shortalstown Marine sand - Colhoun and Mitchell, 1971) as being Ipswichian while in the areas examined by Stephens only weathering is ascribed to the Ipswichian* and all raised beaches are assumed to be Hoxnian.

In view of the fact that the Ipswichian is generally regarded as being the "last" interglacial and that its deposits are widespread elsewhere (see Sparks & West, 1972, chapter 10, for a summary of the Ipswichian) it seems incredible that its deposits should not be recognised in Ireland and south-west England especially when undoubted Ipswichian deposits are widespread in the Channel Isles which are so close to south-west England.

It seems most likely to the present author that the evidence of a sea level around 100 ft. (30 m.) for the Hoxnian from so many sites (see above) cannot be disputed. The low raised beaches in western Britain are

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* It is notable that in Stephens' table 11.1 (1968) the western areas examined by Stephens have no Ipswichian beaches in them, while Somerset, which Stephens did not examine, has a full range of Ipswichian deposits described.

either of Ipswichian age or date from a period well within the Wolstonian glaciation when the sea level had fallen to around the modern sea level. Given either of these dates the low beaches of western Britain cannot be considered to be of Hoxnian age.

e) Correlations between Hoxnian deposits and the areas under examination

As mentioned in the introduction to this chapter, correlation of the Channel Isles and Hampshire deposits around 100 ft. (30 m.) with the Hoxnian deposits of Britain must rest on height evidence alone in the absence of organic material. However, of all the Hoxnian sites described in section c) of this chapter, those which can be firmly associated with base level all show a sea level of around 100 ft. (30 m.) unless they are tectonically affected. This clearly allows a correlation with the 100 ft. terrace of Hampshire and the 100 ft. beach of the Channel Isles.

Only a few of the Hoxnian deposits described above reach above 110 ft. (33.8 m.) while both the 100 ft. terrace and 100 ft. beach in the areas under examination reach over 125 ft. (37.7 m.). The continuity of the two deposits around 100 ft. in the Channel Islands has been demonstrated above but the lack of the higher level at many of the British sites may suggest that the higher beaches and the higher part of the 100 ft. terrace of Hampshire are earlier than Hoxnian. However, the presence of Acheulian handaxes on the surface of the higher part of the 100 ft. beach at Slindon suggests that the sea did reach over 120 ft. (37.7 m.) in the Hoxnian at the maximum of its transgression. As no handaxes are known in Britain before late Anglian times (Wymer, 1974) a pre-Hoxnian age for the higher level at Slindon and hence for the higher levels of Hampshire and the Channel Isles is unlikely.

The movement of sea level in the Channel during the Hoxnian can be summarised thus:- (a) a rise from below 70 ft. (21.5 m.) to around 95 ft. (29 m.) with perhaps a stillstand at this height; (b) a continued rise to around 120 ft. (37.7 m.) O.D. late in the interglacial; (c) a steady (or perhaps slowly falling) sea level during cooling at the beginning of the Wolstonian; (d) a fall to at least present O.D. in early Wolstonian times under the influence of the build-up of glacial ice.

f) The problem of the true age of the Hoxnian

In some recent papers (Page, 1972; Bristow & Cox, 1973; Mitchell et al., 1973) controversy has arisen over the true age of the Hoxnian interglacial. Such proposals as those of Page seem most unlikely (see reply to Page by Shotton, 1973) and should perhaps be regarded as merely a lesson in the limitations of radio-carbon dating. The work of Bristow and Cox, however, if correct, throws the whole of the succession of the British middle and upper Pleistocene into disorder.

On the basis of detailed mapping of parts of the chalky boulder clay of East Anglia (formerly thought to be two separate units of respectively Anglian and Wolstonian age separated by the Hoxnian interglacial) these authors suggest that the Hoxnian in reality belongs to an interglacial which contains both it and the Ipswichian and that the chalky boulder clay is a single till sheet of "Saale" age.

If Bristow and Cox are correct, the status of the Hoxnian is changed. However, other possibilities as to the dating of the single sheet of chalky till and hence of the Hoxnian do exist.

There has always been some doubt about the interglacial character of the Hoxne type site, because it is not overlain by a convincing till. The existence of the Acheulian industry within it, however, suggested a clear correlation with Swanscombe and so with the "Great Interglacial" (Zeuner, 1959). The suggestion of Bristow and Cox that because no till overlies the Hoxne lacustrine deposits the Hoxnian and Ipswichian are closer together in time than was hitherto thought poses many problems.

In the Thames valley massive amounts of erosion occurred between the deposition of the deposits of Swanscombe and the deposition of the Ipswichian Upper Floodplain terrace (West in discussion to Bristow and Cox). In Hampshire, between the undoubted Ipswichian of Stone Point (West & Sparks, 1960) and the assumed Hoxnian of Milford and Highcliffe, downcutting to at least O.D., an aggradation to 60 ft. (18 m.) and further downcutting occurred. Similarly in the Channel Isles two episodes of low sea level and the deposition of the 60 ft. (18 m.) beach separate the assumed Hoxnian level and the Ipswichian 25 ft. (8 m.) beach.

To suggest that the Ipswichian and Hoxnian are not divided by a glaciation may be stratigraphically correct in East Anglia, but this does not prove that they are the product of one interglacial. The Nechells deposit (Duigan, 1956; Kelly, 1964; Shotton & Osbourne, 1965) is overlain by a till of Wolstonian age so glacial conditions occurred in the Midlands, at least, in post-Hoxnian times. The cold oscillation suggested by Bristow and Cox to account for the occurrence of sub-arctic vegetation at the end of the Hoxnian (Ho IV) at Mark's Tey (Turner, 1970) and the beginning of the Ipswichian at Bobbit's Hole (West, 1957) is not sufficient to explain either the full glacial deposits at Nechells or the amount of post-Hoxnian, pre-Ipswichian dissection which occurs at many sites.

The most probable solution to the problem is hinted at by Bristow and Cox themselves in Mitchell et al. 1973, p.12. Here, the authors suggest "that the cold period represented by glacial till in the Midlands is present in East Anglia but not represented there by a till". This situation is not entirely without parallel. In the Devensian the Irish Sea ice and Welsh ice advanced much farther south than the ice in the North Sea so this could have happened in the Wolstonian also (although it is perhaps less likely as the Wolstonian ice limit is much to the south of the Devensian glacial maximum).

If it is accepted that the Hoxnian and Ipswichian are separated by a glaciation which did not produce ice sheets sufficient to cover south Norfolk and the area to the south, Bristow and Cox's suggestion of a "Saale" age for their single chalky boulder clay sheet can be rejected and an Anglian (as used by Mitchell et al. 1973, Table I) age becomes more likely. Then a long period of time becomes available between the Hoxnian and Ipswichian for downcutting in the Thames, the formation of the Coombe rock of Ebbsfleet (Burchell, 1936b), the aggradation to the 60 ft. (18 m.) terraces of the Thames and Solent, and the post-60 ft. (18 m.) cold climate of La Cotte de St. Brelade to occur.

Whatever the age of the chalky boulder clay of East Anglia, the presence on it of the gravels of the 100 ft. (30 m.) "Boyn Hill" terrace at the Hornchurch railway cutting (Wooldridge, 1960) clearly suggests a pre-100 ft. sea level date for a chalky boulder clay glaciation and makes it all the more likely that a long period of time (sufficient to allow for the downcutting described above) separated the Hoxnian and Ipswichian.

Chapter II. The separate existence of a 60 ft. (18 m.) sea level and some correlations.

a) Introduction

In both areas examined on the shores of the Channel a well-defined terrace or beach occurs between the Hoxnian 100 ft. (30 m.) level and the Ipswichian 25 ft. (8 m.) level. These deposits are tentatively dated to a period within the Wolstonian glaciation. However, the existence of a separate level between the Hoxnian and Ipswichian levels has not found wide acceptance. Only Sutcliffe (in Ovey, 1964) has consistently argued for such a separate episode. The main evidence for a separate episode between the Hoxnian and Ipswichian is based on the mammalian fauna evidence from the lower Thames and on morphological evidence. What little pollen evidence there is for sites at about this height suggests an Ipswichian age for them. Zeuner (1945), while considering the 60 ft. (18 m.) level to be distinct from the 25 ft. (8 m.) level, referred them both to his Monastirian and to the "Last" interglacial (i.e. the Ipswichian).

b) Evidence for a 60 ft. (18 m.) beach and terrace in the areas under discussion

As described above a well marked terrace which reaches 60 ft. (18 m.) O.D. and caps an aggradation from at least modern sea level occurs in south Hampshire. No organic remains except a few rolled handaxes are associated with this terrace. In the Channel Islands the 60 ft. (18 m.) beach is also well marked and in Guernsey particularly occupies large areas inland from the present coast. As in Hampshire there are few organic remains associated with this beach except at La Cotte à la Chèvre where a lower Palaeolithic horizon directly overlies the beach deposits. Such a close association of archaeological material with a raised beach is rare and of great significance for dating the beach deposit.

c) Some probable sites for the 60 ft. (18 m.) beach and terrace in Britain

Beaches and terraces at this height are poorly described in the literature and are perhaps less common than Ipswichian or Hoxnian sites.

I. South-west England. Sites at 60 ft. (18 m.) receive a passing mention at several points in the literature on south-west England. Dewey (1935) describes a beach at 60 ft. near Mousehole, Zeuner describes a beach at 55 ft. (14.3 m.) on Plymouth Hoe, and Green (1949b) states that the River Dart has a "50 ft." (15 m.) terrace.

II. Portland. The Portland beach (Baden-Powell, 1930) reaches an altitude of 55 ft. (14.3 m.) and may be a deposit of the 60 ft. (18 m.) stage. Its molluscan fauna shows a somewhat cold affinity and is unlike the warm faunas which characterise the Ipswichian.

III. Gower. Recent work by Sutcliffe and Bowen (1973) has established that the well known site of Minchin Hole in Gower has two raised beaches in it. The lower of these two beaches at Minchin Hole is Ipswichian and reaches about 39 ft. (12 m.) O.D. The higher which also reaches 39 ft. is, however, a low tide deposit of sand so it points to a sea level perhaps 20 ft. (6.1 m.) higher and so could be of similar age to the 60 ft. (18 m.) beaches elsewhere.

IV. Ilford. The main body of evidence for the separate existence of a 60 ft. (18 m.) terrace occurs in a terrace of the Thames at Ilford. On examining the mammalian faunas of a variety of sites in the lower Thames, Sutcliffe (in Ovey, 1964) considers that clear differences in these faunas can be seen. The three terraces described by Sutcliffe exhibit the following faunal characteristics:

The Hoxnian interglacial (primarily Swanscombe).

1. Both Dicerorhinus kirchbergensis (Jäger) and D. hemitoechus (Falconer) were present, the latter being abundant at the end of the interglacial.
2. The fallow deer was a large race, Dama clactoniana (Falconer).

3. The horse was present and became abundant late in the interglacial.

4. Both hippopotamus and hyaena were apparently absent.

The Ilford deposits.

1. D. hemitoechus greatly outnumbers D. kirchbergensis.

2. No fallow deer occurs.

3. The most abundant elephant is an early form of Mammuthus primigenius (Blumenbach) which is considered by Sutcliffe to show affinities with the earlier Mammuthus trogontherii (Pohlig). Neither of these species occurs at Swanscombe or Trafalgar Square. Small numbers of Palaeoloxodon antiquus (Falconer & Cautley) occur, however.

4. Horse is abundant.

5. Hippopotamus is entirely absent.

6. The bear at Ilford is Ursus arctos (Linné) while the bear at Swanscombe is Ursus spelaeus (Rosenmüller & Heinroth).

The Upper Floodplain terrace (principally Trafalgar Square).

1. D. hemitoechus is apparently the only species of rhinoceros present. (This species is typically Ipswichian and occurs at a variety of sites - Zeuner 1945; Sutcliffe 1960; Boylan 1967).

2. The fallow deer present was Dama dama (Linné).

3. The horse was absent (although early on in the interglacial in zones b and c (1G and I Ia) of Selsey horse does occur).

4. Hippopotamus is abundant.

5. Hyaena is abundant.

d) Discussion of the age of the Ilford terrace.

As noted above the Ilford terrace deposits have a different mammalian fauna from either the Hoxnian or Ipswichian terraces in the lower Thames. Whether this difference is a real one and the result of a different faunal pattern, or merely the result of some collecting or preservation bias is open to question. The evaluation of a few hundred bones from only a limited number of sites is a less certain method of dating a site than the stratigraphically more precise approach of pollen analysis and many of the collections from these lower Thames sites were made in the last century in less scientific and systematic ways than would now be considered necessary. Despite these objections certain aspects of the Ilford fauna do seem to be separate from undoubted Ipswichian faunas. Most noteworthy is the absence of hippopotamus. Almost all Ipswichian sites associated with rivers or lakes show an abundance of hippo remains (Stuart, 1974). In the Thames both Brentford (Zeuner, 1945) and Trafalgar Square (Sutcliffe, 1960) have hippo in some numbers so it is remarkable that Ilford, also a river terrace site, should show no sign of this mammal among such a large faunal list.

In contrast to the faunal evidence pollen analyses from the Ilford area (West et al., 1964; West, 1969) show spectra sufficiently similar to those of other Ipswichian sites for them to be zoned in the same way as these other sites. Aveley is considered to show zone f (I IIb) of the Ipswichian while Ilford contains zones b to f (1G to I IIb) of this interglacial. The same zone which is present at Ilford and Aveley (I IIb) also occurs at Trafalgar Square, at Stone, Selsey, Bobbitshole (West, 1957), Wortwell (Sparks & West, 1968) and Wretton (Sparks & West, 1970). At all these sites except Ilford and Aveley the zone I IIb deposits are near O.D. and covered by an aggradation which reaches only 30 ft. (9 m.) at maximum. The terrace which covers the Ilford sites reaches nearly to 50 ft. (15 m.) O.D.

Another factor in separating the Ilford sites (and others at around 60 ft. (18 m.) O.D.) is their seemingly cooler climate. It is well established that the Ipswichian proper had a warm climate, perhaps warmer than the present. Such plant species as Acer monspessulanum, Najas minor, Salvinia natans and Trapa natans (Sparks & West, 1972); beetles such as the scarabs which dominate the dung beetle fauna at Bobbitshole (Coope, 1974); the warm mammals - hippopotamus etc.; warm climate mollusca (Corbicula fluminalis, Belgrandia marginata, Potamiola littoralis in rivers in southern Britain - Sparks & West, 1972) and ostracoda (at Selsey - Whatley & Kaye, 1971) all point to a climate if not warmer than the present at least more continental, for the thermal maximum of the Ipswichian.

The Ilford mammalian fauna is, however, considered by Sutcliffe to represent an assemblage typical of a cool, open steppe (the mammoth, horse, bison and giant ox all suggest open conditions). This is quite out of keeping with the interglacial forest suggested by the pollen diagrams but is more typical of the climate suggested by the cool mollusca at Portland (Baden-Powell, 1931) and the cool climate associated with many sites of Main Monastirian age in Europe (Zeuner, 1959).

The dating by pollen of the Ilford deposits as Ipswichian has led Sutcliffe (Sutcliffe & Bowen, 1974) to suggest that there may be two interglacials with a similar pollen spectrum. The three known interglacials in Britain (Cromerian, Hoxnian and Ipswichian) have diagnostic pollen spectra (West, 1968) but this is no reason why a fourth interglacial with a pollen spectrum like any of the others should not exist if it may be separated from the known interglacials on other grounds. In the mammalian faunas and the height differences, grounds for assigning the Ilford deposits to a separate episode between the Hoxnian and Ipswichian may exist. Kurten (1968) is of the opinion that a separate interglacial is represented by the Ilford deposits and he refers to it as the "Ilfordian". It is probable that the evidence in the lower Thames alone is not yet sufficient to be certain that the "Ilfordian" is a separate interglacial but strong evidence in the areas which are the chief concern of this thesis suggest that deposits at a similar height above O.D. to the Ilford terrace do represent a significant episode within the Wolstonian glaciation which may represent this interglacial.

e) The age of the 60 ft. (18 m.) deposits in the Channel Isles and south Hampshire

As previously described a clear 60 ft. (18 m.) beach and terrace can be recognised in the areas under examination in this thesis. No direct evidence except height above sea level can be used to date this level but consideration of the archaeological evidence from the Jersey caves is of great assistance in dating it. At La Cotte à la Chèvre the 60 ft. (18 m.) beach is overlain by deposits containing an early Mousterian industry. Deposits containing an industry identical in all significant respects also occur as the lower complex of La Cotte de St. Brelade. These deposits in the latter cave are in turn cut into by the 25 ft. (8 m.) beach (see fig. 25). From the thickness of the deposits and the presence of cold climate mammals it seems that a significant cold period occurred between the deposition of the 60 ft. (18 m.) and 25 ft. (8 m.) beaches. This cold period must have been part of the Wolstonian glaciation as it seems to have pre-dated the 25 ft. (8 m.) beach of Ipswichian age*.

In Hampshire the 60 ft. (18 m.) terrace tops an aggradation from around modern sea level in the Hordle Channel. The deposits of a similar aggradation can be seen below several of the 60 ft. (18 m.) beaches in the Channel Island caves. As this rise in sea level seems to be of post-Hoxnian date (it is not associated with the 100 ft. (30 m.) terrace), it is clear that the Wolstonian glaciation is split into two parts separated by the 60 ft. (18 m.) beach and terrace.

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* The Mousterian artefacts of Jersey seem to be similar in many ways to the flint industries of Baker's Hole, Kent (Burchell, 1936b - described as Levallois by him) and High Lodge, Mildenhall (Sieveking, 1968). These industries are both dated as Wolstonian.

If the Ilford deposits are pre-Ipswichian as suggested by Sutcliffe the fact that they occur at a similar level to the 60 ft. (18 m.) beach and terrace of the Channel coasts suggests that they may be of similar age. The considerable width of the bench below the 60 ft. (18 m.) terrace in Hampshire and the platform of the 60 ft. (18 m.) beach in Guernsey suggests an episode of some length for the deposition of these sediments, so a mid-Wolstonian interglacial analogous to Kurten's "Ilfordian" seems probable*.

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* Evidence from deep sea sediment cores (Shackleton and Opdyke, 1973) and solar radiation curves (the "Milankovich" curve - Zeuner, 1959) also point to a warm episode between points on the curves identified as the Ipswichian and Hoxnian interglacials. This episode is perhaps also to be identified with the 60 ft. (18 m.) sea level.

Chapter III. The Ipswichian interglacial and the 25 ft. (8 m.) sea level.

a) Introduction

It is generally considered that the widespread 25 ft. (8 m.) raised beaches and terraces are of Ipswichian age (West, 1968). In several places terraces and raised beaches at this height have been dated by pollen analysis as Ipswichian (e.g. Trafalgar Square, Franks 1960; Selsey, West & Sparks 1960; Stone, West & Sparks 1960, Brown et al. 1975); but in many areas deposits at 25 ft. (8 m.) exist without any datable material in them. Despite the claims of Mitchell and Stephens (see above) that a Hoxnian 25 ft. (8 m.) beach also occurs it is most likely that most of the 25 ft. (8 m.) beaches and terraces are Ipswichian.

b) The 25 ft. (8 m.) beach and terrace in the Channel Isles and South Hampshire

As described above the deposits of the 25 ft. (8 m.) sea are widespread in both Hampshire and the Channel Isles. The Stone Point deposits can easily be correlated with other Ipswichian sites by their pollen content (see above). Both in the Channel Isles and Hampshire the 25 ft. (8 m.) deposits possess certain other attributes, however, which make it possible to draw parallels with other sites of Ipswichian age and perhaps confirm the dating of the sites in the area under examination. It is common for the 25 ft. (8 m.) raised beach in the Channel Isles to be backed by an abandoned cliffline. Other sites also exhibit this feature. In both the Channel Isles and Hampshire sites, Ipswichian deposits occur resting on earlier Pleistocene deposits rather than on a rock-cut bench. This feature, though rare, also occurs in places in Britain and is important for consideration of the age of the rock platform on which the Ipswichian deposits lie. An examination of some non-altitudinal or organic attributes of some 25 ft. (8 m.) deposits will be attempted to find parallels with the Channel Isles and Hampshire sequences.

c) Some sites dated as Ipswichian and associated with aspects of the 25 ft. (8 m.) sea level

Many of the cliffs of the hard rock areas of western Britain are clearly of pre-Ipswichian age (see Orme, 1962, for a summary). Some of these cliffs are still being modified by the present high sea level but many are abandoned and degraded.

I. Sussex coastal plain. The wide flat below the chalk of the South Downs is backed by an ancient cliff line. The cliff reaches its easternmost point at Brighton (Smith, 1936; Hodgson, 1964) where a raised beach occurs at its foot and both cliff and beach are truncated by the modern sea. This cliff extends westwards to Portsdown (Palmer & Cooke, 1923).

II. Holderness. A similar abandoned cliff occurs inland of Holderness and continues southwards into Lincolnshire (Catt & Penny, 1966). Although much modified by glacial erosion, it still preserves beach deposits below it at Sewerby and Hessle. At the former locality a mammalian fauna of Hippopotamus, Hyaena, Straight-tusked Elephant and hemitoechus rhinoceros occurs (Boylan, 1967) and is considered to confirm an Ipswichian date by Catt and Penny (1966).

III. South-west England. In south-west England such abandoned cliffs are rare except inland of modern constructional features such as Braunton Barrows (Stephens in Lewis, 1970) but many of the cliffs being eroded at their bases by the modern sea are composite and have an upper level which was formed during earlier sea level phases (Orme, 1962).

A second feature of the Ipswichian deposits of the Channel coasts is the presence of earlier Pleistocene deposits below the Ipswichian material. A small number of deposits of this type also occur elsewhere.

I. Sewerby, Yorkshire. Although the main beach exposure at this site rests on a bench cut in the chalk, to seaward of the present cliff small pockets of beach gravel rest on a platform cut across Basement till (of

"Saale" i.e. Wolstonian age - Catt & Penny, 1966) which indicates that some sort of surface was cut across the chalk prior to the Wolstonian.

II. West Angle Bay, Pembrokeshire. At this site Bowen (1973) describes a sequence of raised beach resting on till which in turn rests on the rock platform. The beach is dated by Bowen as Ipswichian.

III. Scilly Isles. On St. Martin's, Mitchell and Orme (1966) describe a beach which they regard as Ipswichian resting on a Wolstonian till which in turn rests on a lower raised beach and shore platform.

IV. Selsey, Sussex. At many sites from Selsey west to Porthleven in Cornwall, the rock platform below the 25 ft. (8 m.) beach has resting on it so-called "giant erratics" (Kidson in Gregory & Ravenhill, 1970) which are thought to be the product of a pre-Ipswichian glaciation. Kidson considers that the erratics are similar to those in undoubted till at Fremington and dates them as "Saale" (i.e. Wolstonian) in age. However, similar erratics also occur in the Hoxnian beach at Slindon (Dalrymple, 1957) so either more than one glacial incursion must have taken place or the erratics are the product of a pre-Hoxnian glaciation.

During the course of the present study no evidence of glaciation*

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* Kellaway (1971) has recently attempted to show that in Anglian times glacial ice over-rode Salisbury Plain from the west and that an ice sheet flowed up channel to deposit the "giant" erratics and introduce the erratics to the Channel Isles. As Green has pointed out (1973) there is no need to invoke glaciation to account for the presence of "foreign" stones on Salisbury Plain and in the gravels of the Avon, as these rock types can easily be explained as being derived from Tertiary outliers. Also, in contrast to the situation in the Thames valley where large rises in erratic material in river gravels after a glacial episode occur (Walder, 1967), in the Hampshire basin no such influx of erratics can be seen at any level in the terrace succession.

has been found on the shores of the Channel. As stated above the largest "foreign" stones found in the Channel Isles were around 2 inches (5 cm.) long axis and do not warrant the invocation of glacial ice to account for them. Larger erratics do occur in Hampshire but only east of Milford on Sea and in the area studied only blocks of sarsen have been found. As Reid (1892) points out the overwhelming majority of the Selsey erratics are of local origin (being of Bognor Rock, Bembridge Limestone or Sarsen) and farther travelled crystalline rocks form only a small part of the total of erratics. In the finer grades of the gravels west of Southampton Water no large foreign stone element occurs at any level (see tables). This, with Green's (1973) tables, shows clearly that no part of the Hampshire gravels can be regarded as outwash. However, floating ice is probably the only medium capable of transporting such blocks as the largest Selsey erratics, but the only date which can be placed on this episode is pre-Ipswichian.

If the age of deposition of these erratics could be found a minimum age for the shore platform could be suggested. Most authorities (e.g. Kidson in Gregory & Ravenhill, 1970; Edmonds, 1972) are content to date the primary cutting of the platform as Cromerian or lower Pleistocene and a lower Pleistocene date seems most likely*.

In Britain the end of the Ipswichian is often marked by a series of regression deposits, aeolian sands, slope washes and lagoonal silts, deposited as the sea retreated from its Ipswichian maximum.

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* On the evidence of the depth of downcutting at the base of the pre-60 ft. (18 m.) terrace at Hordle the shore platform could have been partly retrimmed in Wolstonian I times. The cold climate during this glacial period would perhaps cause frost action to assist the sea in breaking up the rock and so allow accelerated trimming of the shore platform.

I. Westward Ho!, Devon. Stephens (in Lewis, 1971) describes a cemented beach deposit within the modern beach. This is regarded by Stephens as Ipswichian and it may be a beach deposited as the sea level fell with the onset of glaciation. The rock platform at 12 ft. (3.6 m.) O.D. described by Kidson (in Gregory & Ravenhill, 1970) as being present in south-west England may also be datable to this episode.

II. Saunton, Devon. Kidson and Wood (1974) describe a thick blown sand overlying the Ipswichian beach at this site.

III. Sewerby, Yorkshire. Up to 25 ft. (8 m.) of blown sand and rainwash overlie the raised beach at this site (Catt & Penny, 1966). Boylan (1967) considers that the absence of Hippopotamus remains in the Sewerby blown sand, in contrast to their abundance in the raised beach gravel, marks a deterioration in the climate when the blown sand was deposited. Despite this climatic deterioration, however, the fall in sea level would not have had to have progressed far for blown sand to have been deposited. Under modern conditions at Sewerby a sandy beach is exposed at half tide so a fall in sea level of only a few feet would allow blown sand to accumulate.

Two sites on the Normandy coast also show regression sediments of late Ipswichian age (West & Sparks, 1960). Between St. Côme-des-Fresnes and Asnelles-Belle-Plage a series of marine deposits give way to fresh-water sediments with a mammalian fauna characteristic of cool steppe (Mammuthus primigenius, Coelodonta antiquitatis, Cervus sp., Equus caballus, Bison priscus, Bos sp. and Canis lupus). The pollen from this site is characteristic of zone i (I IV) of the Ipswichian and this indicates that the marine regression had not retreated far although the climate was quite severe with a forest of pine and much open ground.

d) Some correlations with the Channel Isles and Hampshire

The features of the Ipswichian described above can be matched in Hampshire and the Channel Isles.

The abandoned cliff is widely present in Jersey and Guernsey (see maps, figs. 39 and 40). As described above it is closely associated with the shore platform and was presumably cut at the same time as the initial cutting of the platform.

The presence of pre-Ipswichian Pleistocene material in the Channel Isles has been described in Part II, and at Stone Point in Part I. The presence of this earlier material strongly indicates that the Ipswichian marine transgression advanced over earlier deposits resting on a previously cut surface.

At the end of the Ipswichian the sea level fell slowly at first and a cold climate was well established before the sea had fallen much below O.D. The terrace gravels over the organic horizon at Stone, the blown sands along Guernsey's east coast* and the lagoonal sediments at Hommet Paradis, Guernsey, were formed as the sea fell from its interglacial maximum. Similarly the ancient beach gravels within the modern beach at several points around the coasts of the Channel Isles (see Part II) are also a product of this regression. As the climate increased in severity the sea fell well below the present and the beach deposits in the Channel Isles were covered by a thick blanket of head.

The sea did not attain a level as high as it did in the Ipswichian, again. In mid-Devensian times sea levels as high as -10m (-33 ft.) have been suggested by Donovan (1962). No evidence of such a high sea level in post-Ipswichian times has been found in either area examined in this study. As shown above the final destruction of the Wight-Purbeck ridge did not occur in the Ipswichian and it is probable that a sea level some-

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* The extensive blown sands around St. Peter's Church in Jersey are probably a product of the full interglacial and did not form in the end-Ipswichian regression.

where near the present occurred in mid-Devensian times to help the breaching of the chalk barrier. This marine transgression did not reach present sea level, however.

Chapter IV. A summary of Middle and Upper Pleistocene sea level and climate in the English Channel.

On the shores of the Channel pre-Hoxnian deposits are sparse and only fragments of gravel terrace or bare erosion surface remain. It is most probable that these surfaces were cut during periods of high sea level in the lower Pleistocene but no evidence for dating them is available beyond their height above present sea level. Nothing is known about the climate under which these surfaces and deposits were formed. Some authorities date the earliest phases of the present rock platform to a lower Pleistocene episode but there is no evidence for this beyond the fact that such a prominent feature must have taken a long time to develop. If the cutting of the present day shore platform began in the lower Pleistocene it is probable that its cutting began during a glacial episode. High sea levels are generally believed in for this part of the Pleistocene and a major glaciation would be necessary to lower the sea level sufficiently to allow platform cutting near modern sea level.

As shown above, in early Hoxnian times the sea level rose from at least 70 ft. (22.7 m.) to around 130 ft. (40 m.). In the areas under examination no direct evidence is available to show at what stage the transgression reached its maximum but pollen information elsewhere shows that maximum sea level was achieved late in the interglacial. The onset of cold conditions at the end of the interglacial allowed the coarse gravels of the "100" ft. (30 m.) terrace to form and after some time sea level fell to at least present O.D. and could have retrimmed any pre-existing low shore platform.

The full depth of post-Hoxnian downcutting is unknown. At the close of Wolstonian I times a rise in sea level to 60 ft. (18 m.) O.D. occurred. The name Ilfordian is tentatively suggested for this episode. Whether this period was a true interglacial is uncertain. The existence of a pollen diagram of interglacial type at Ilford suggests an interglacial climate but the cool faunas of other sites suggest a time with a climate cooler than any of the three known interglacials so perhaps the Ilfordian was a long interstadial.

In Wolstonian II times the sea level fell well below present O.D. No definite evidence of the minimum sea level of this time is available but the presence of man in Jersey suggests a fall in sea level to at least 60 ft. (18 m.) below the present*. During the downcutting associated with this low sea level the lower gravel of Stone was probably dissected.

At the end of Wolstonian II times the sea rose to just above its present level. There is no evidence that the Ipswichian aggradation rose above the level it attained in zone I IIb (in the early part of the interglacial). This is in marked contrast to the late (zone III) date for the maximum of the Hoxnian transgression. There is ample evidence that the climate and sea temperature in the Ipswichian were warmer than the present. In other areas increased continentality has also been suggested although the evidence in the Channel Isles suggests that a strong westerly circulation also occurred at times.

As at the end of the Hoxnian the onset of cold conditions did not cause an immediate fall in sea level and cooling was well advanced before the sea level fell much below the present. During the maximum of the Devensian glaciation sea level may have fallen up to 325 ft. (100 m.) below the present although the maximum depth of downcutting known in the areas under examination is only -91 ft. (-27.9 m.). There is no evidence that the sea rose above the present during any of the known interstadials

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* Fairbridge (1961) suggests a minimum sea level of -180 ft. (-54 m.) for the penultimate glaciation.

in the Devensian but the destruction of the Wight-Purbeck ridge argues for at least one period of sea level near to that of the present in this glaciation. In at least one of the periods of the Devensian the climate was more continental than that of the present and an easterly circulation predominated and brought loess to the Channel area.

Appendix A

Method of grainsize analysis followed in analysing fine grained sediments

The sample was separated into smaller samples of 50 gm. Three of these 50 gm. samples were selected for analysis and the rest of each sample was stored. The samples to be analysed were air dried and then placed in litre beakers and made into a solution by the addition of 100 ml. of 5% Calgon ($Na_4P_2O_7$). The samples plus the dispersant were placed in an ultrasonic bath for ten minutes and then removed and made up to 1 litre by the addition of distilled water.

The litre of sample, dispersant and distilled water was placed in a 1 litre settling column and inverted for one minute. Sampling by means of a 20 ml. pipette attached to a simple suction bulb was conducted at the time intervals and depths shown below.

for over 64 mic.	58 sec.	20 cm.
32 mic.	3 mins. 45 sec.	20 cm.
16 mic.	15 mins.	20 cm.
8 mic.	60 mins.	20 cm.
4 mic.	120 mins.	10 cm.
2 mic.	16 hrs. 30 mins.	20 cm.

Before each pipette sample was taken the temperature of solution was taken and for temperatures above or below 20°C a depth correction was applied from the following table.

15°C	17.6 cm.
16°C	18.1 cm.
17°C	18.6 cm.
18°C	19.1 cm.
19°C	19.5 cm.
20°C	20.0 cm.
21°C	20.5 cm.
22°C	21.0 cm.
23°C	21.5 cm.
24°C	22.0 cm.
25°C	22.4 cm.

After the pipette samples were extracted from the solution they were transferred to sampling dishes and dried in an oven until all the moisture was removed. The weight of the sample dishes having previously been noted the combined weight of the dish plus the dried sample was also noted and raised to a percentage by use of the calculation:-

$$\% \text{ sample} = \frac{\text{sample weight} \times 100}{50 \times 50}$$

The percentages calculated were then plotted as a cumulative curve.

The remaining amount of the original 50 gm. sample was washed out of the settling column through a 63 μ (240 mesh) sieve and further washed under running water. This residue was also oven dried and weighed and raised to a percentage by use of the calculation:-

$$\% \text{ of sand fraction} = \frac{\text{fraction weight} \times 100}{50}$$

This method of analysis provides an adequate determination of the grain size distribution of a sediment. Errors may occur at all stages of the analysis but if all samples are subjected to the same treatment a fair comparison can be made and consistent results obtained.

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Figures

Plates

28. Bedded solifluction deposits at Hengistbury Head.

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41. The 25 ft. (8 m.) beach at La Bette, Guernsey.

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43. The 25 ft. (8 m.) beach at Hommet Paradis, Guernsey.

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49. The 25 ft. (8 m.) beach and head at L'Eree, Guernsey.

50. The 25 ft. (8 m.) beach and head at L'Eree, Guernsey.

51. General view of the quarry at Les Vardes, Guernsey.

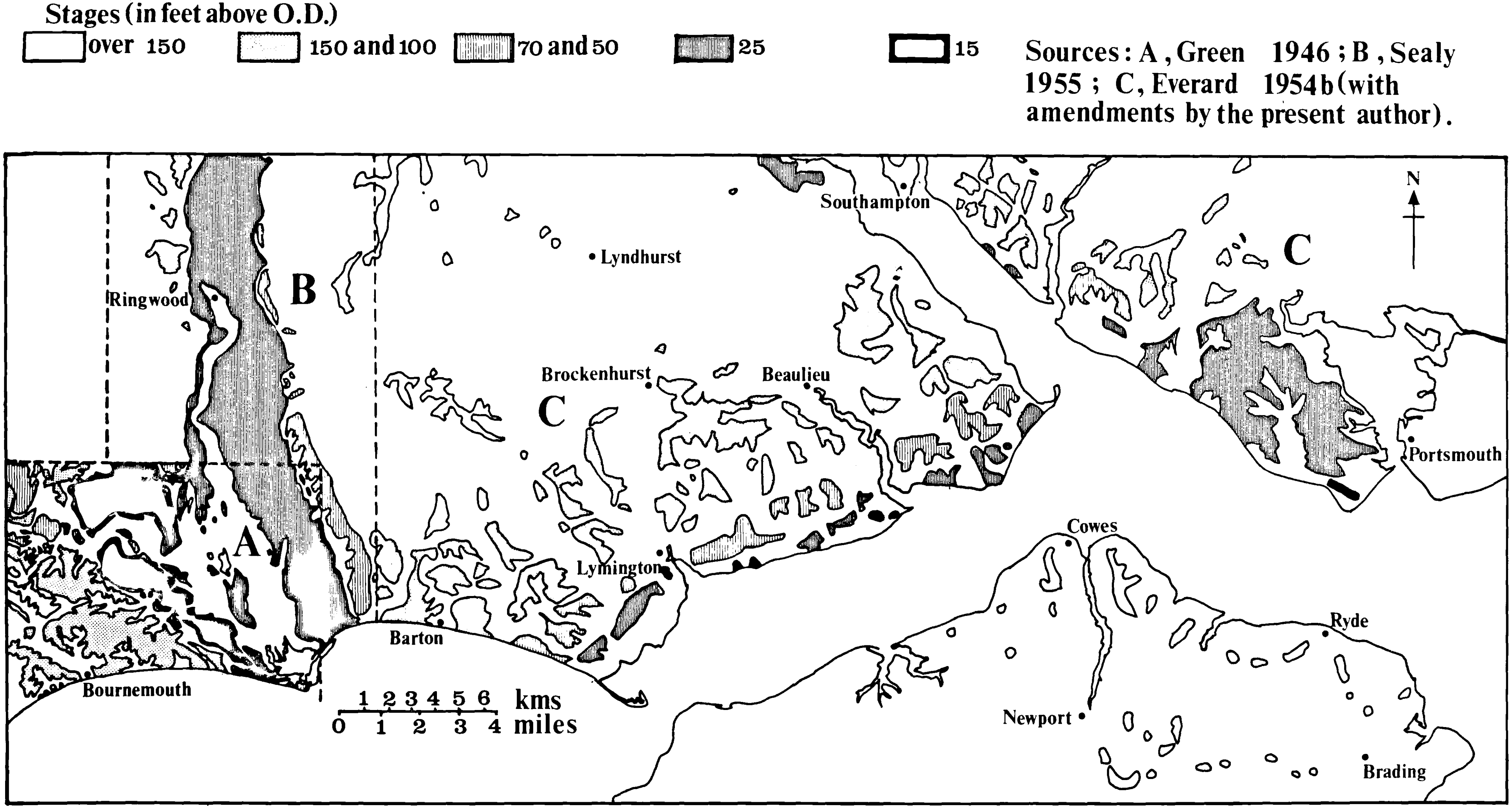
52. Gravel of the 100 ft. (30 m.) beach at Les Vardes, Guernsey.

53. Gravel of the 100 ft. (30 m.) beach at Les Vardes, Guernsey.

Tables

Fig. 1. <u>The main terrace stages of south Hampshire</u>

The map (fig. 1) is based on information from Green (1946), Everard (1954b) and Sealy (1955). The 70 and 50 ft. stage is introduced to allow the incorporation of the intermediate terraces of Green and Everard which are defined as being at different heights by the authors.



Sources: A, Green 1946; B, Sealy 1955; C, Everard 1954b (with amendments by the present author).

Fig. 2. The Solent River

The former line of the Solent River after Everard (1954b).

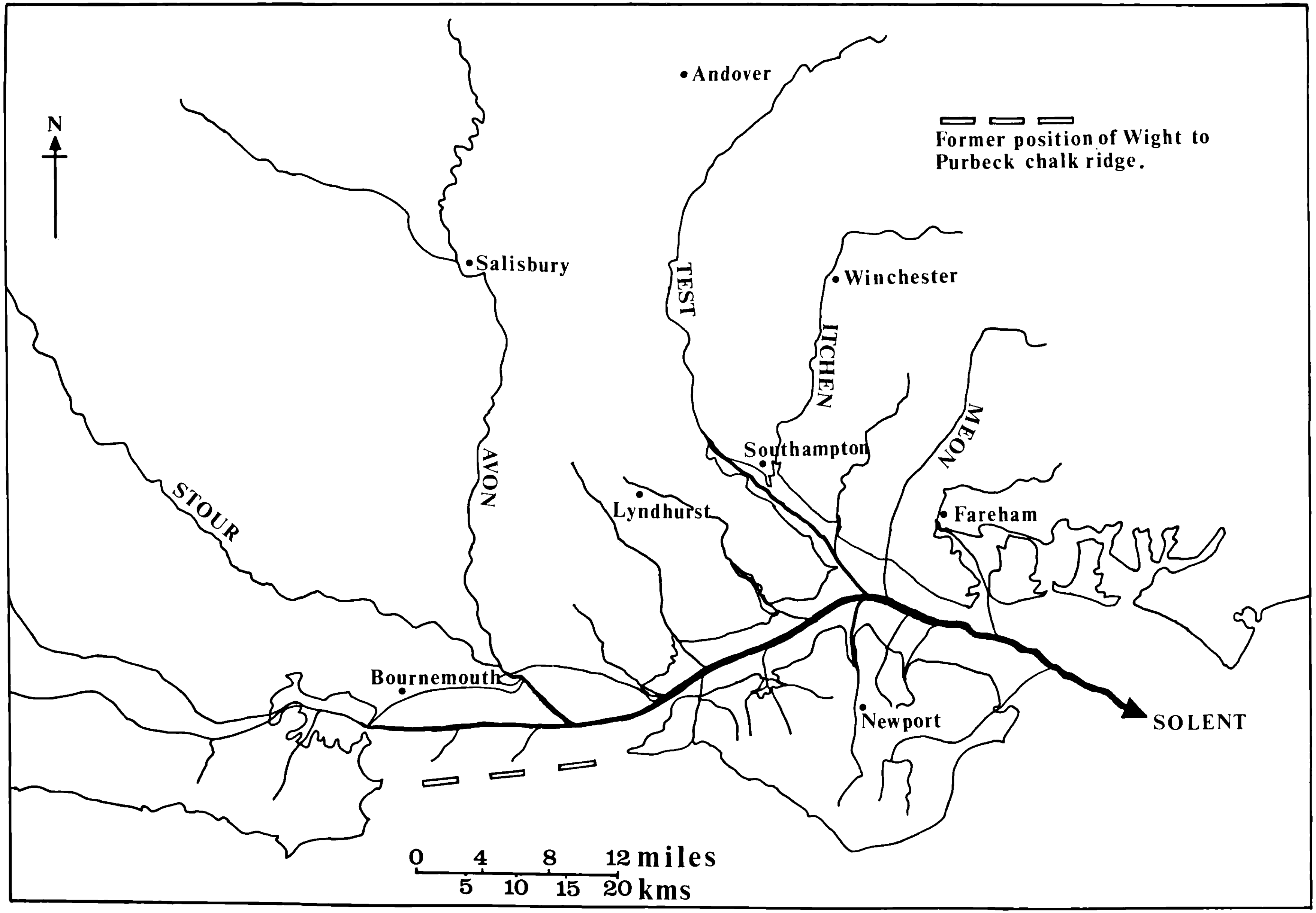

N
Andover
Former position of Wight to
Purbeck chalk ridge.
Salisbury
TEST
Winchester
ITCHEN
MEON
Southampton
STOUR
AVON
Lyndhurst
Fareham
Bournemouth
Newport
SOLENT
0 4 8 12 miles
5 10 15 20 kms

Fig. 3. <u>The Solent River</u>

The Solent River after Reid (1902b) slightly amended by the present author.

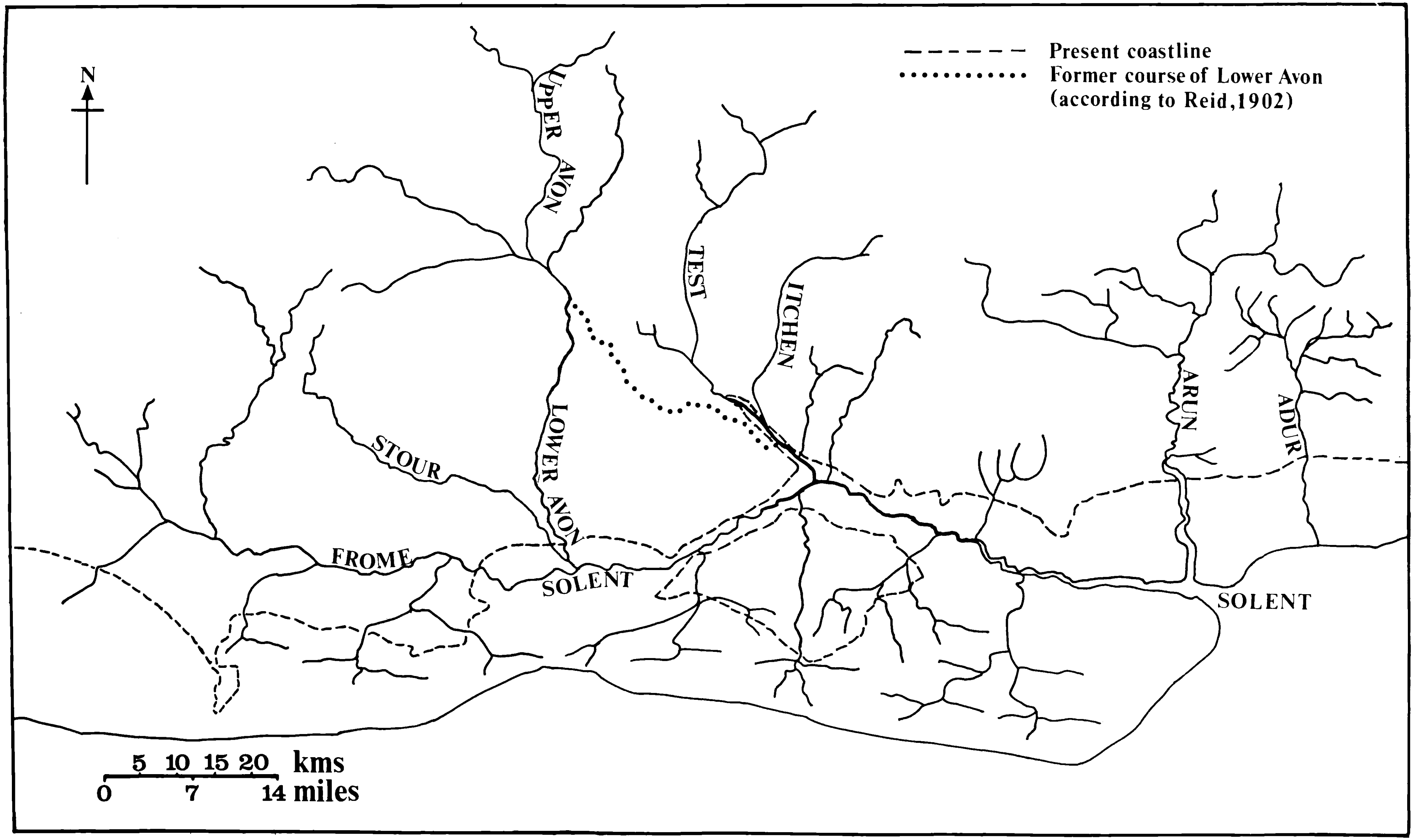

N
Present coastline
Former course of Lower Avon (according to Reid, 1902)
UPPER AVON
TEST
ITCHEN
ARUN
ADUR
STOUR
LOWER AVON
FROME
SOLENT
SOLENT
5 10 15 20 kms
0 7 14 miles

Fig. 4. The minor drainage of the New Forest and the main terrace levels

The broken lines indicate the main terrace levels and mark the highest points of each terrace surface. The poorly developed nature of the drainage net and the adjustment to the maximum slope of the terraces below 150 ft. (45.7 m.) is clearly indicated.

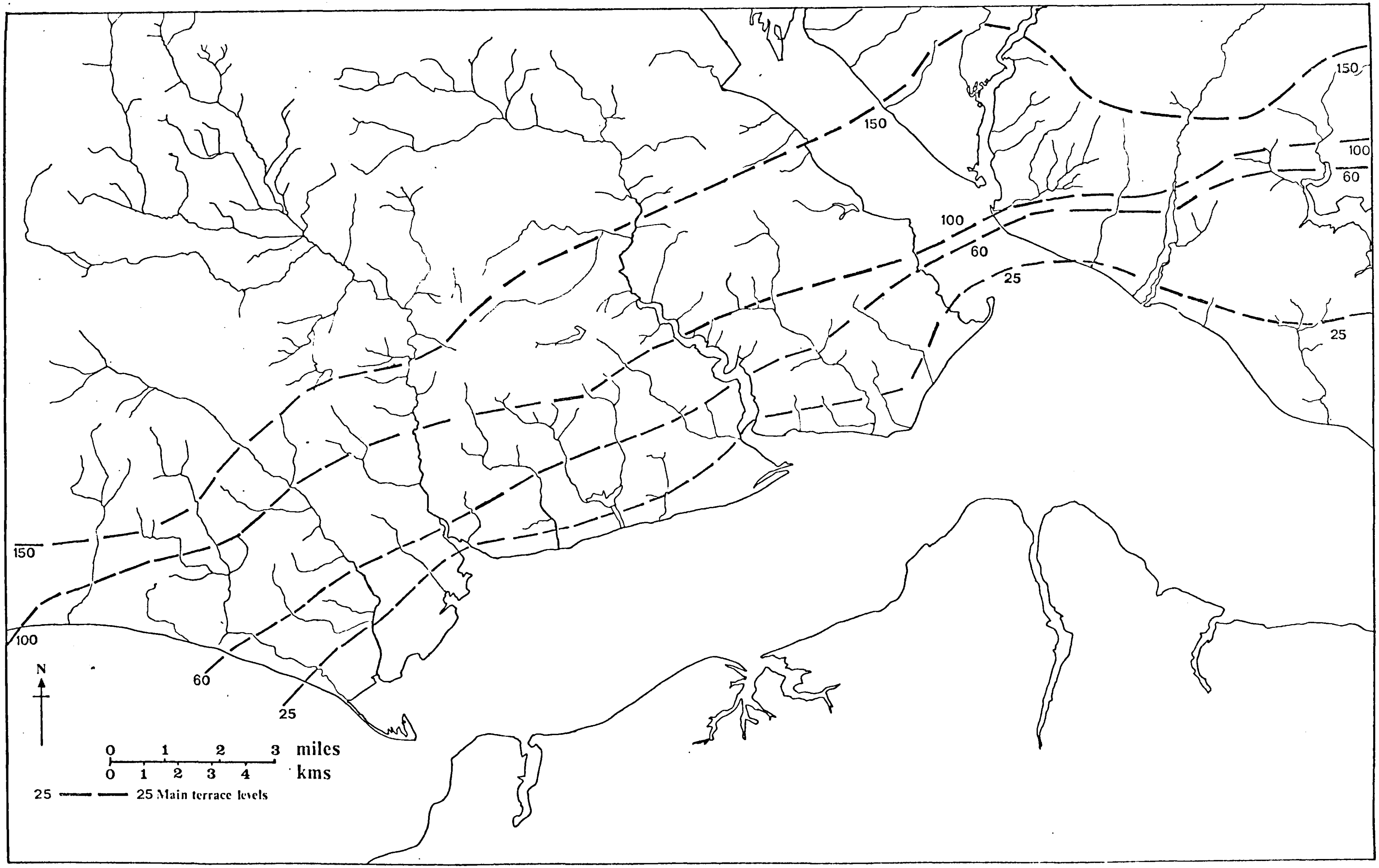

150
100
60
25
150
100
60
25
150
100
60
25
N
0 1 2 3 miles
0 1 2 3 4 kms
25 —— 25 Main terrace levels

Fig. 5. The lower terrace stages of south Hampshire (after Everard, 1954b)

Note the division into fluvial and marine stages is suggested by Everard but is not followed by the present author.

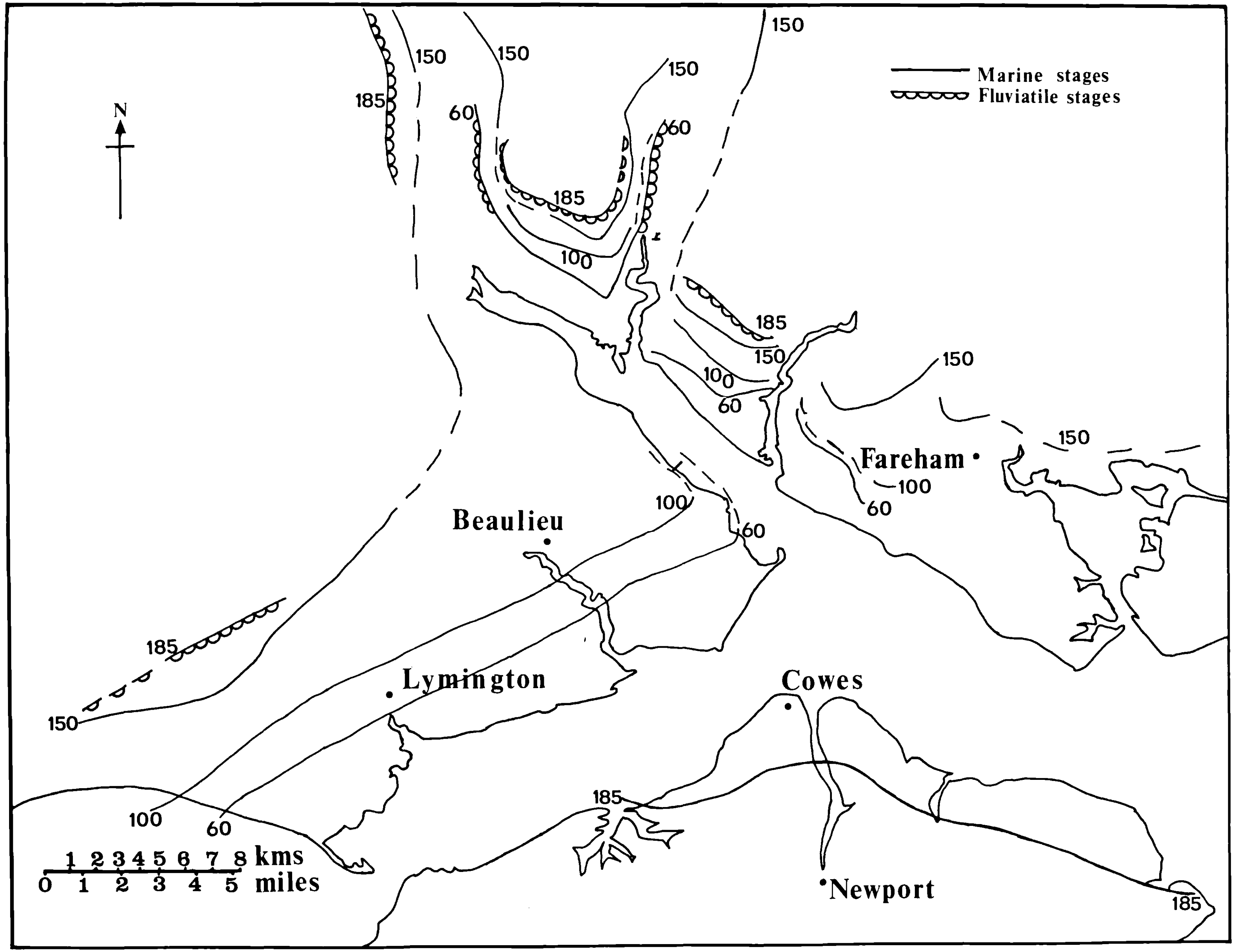

Marine stages
Fluviatile stages
N
150
150
150
150
185
60
60
185
100
185
150
100
60
150
150
Fareham
100
60
Beaulieu
100
60
185
150
Lymington
Cowes
100
60
185
Newport
185
1 2 3 4 5 6 7 8 kms
0 1 2 3 4 5 miles

Fig. 6. Current bedding structure directions in south Hampshire

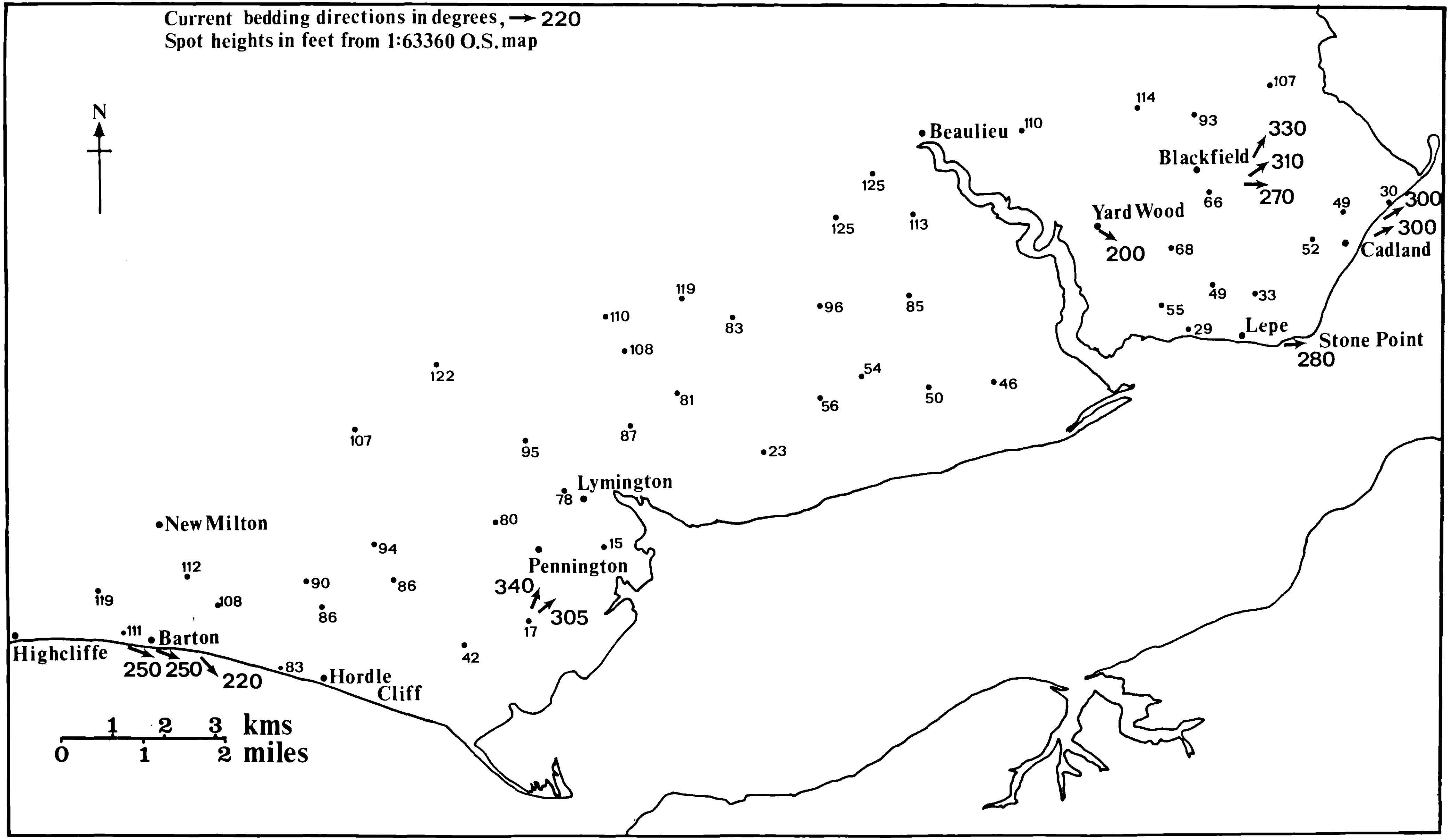

Current bedding directions in degrees, → 220
Spot heights in feet from 1:63360 O.S. map
N
Beaulieu
110
114
93
107
Blackfield
330
310
270
66
Yard Wood
200
68
49
30
300
300
52
Cadland
125
125
113
119
110
83
96
85
55
49
33
29
Lepe
Stone Point
280
108
122
54
46
81
56
50
107
95
87
23
Lymington
78
80
New Milton
94
15
Pennington
112
90
86
340
305
119
108
86
17
111
Barton
Highcliffe
250
250
220
83
42
Hordle
Cliff
1
2
3
kms
0
1
2
miles

Fig. 7. Composition analyses of the gravels of south Hampshire

Sampling sites are indicated by the position of the dots. Two numbers over a dot denote a sample from the base of the gravel and a sample from 3 ft. (1 m.) above the base of the gravel. For actual counts of stones see Table 1.

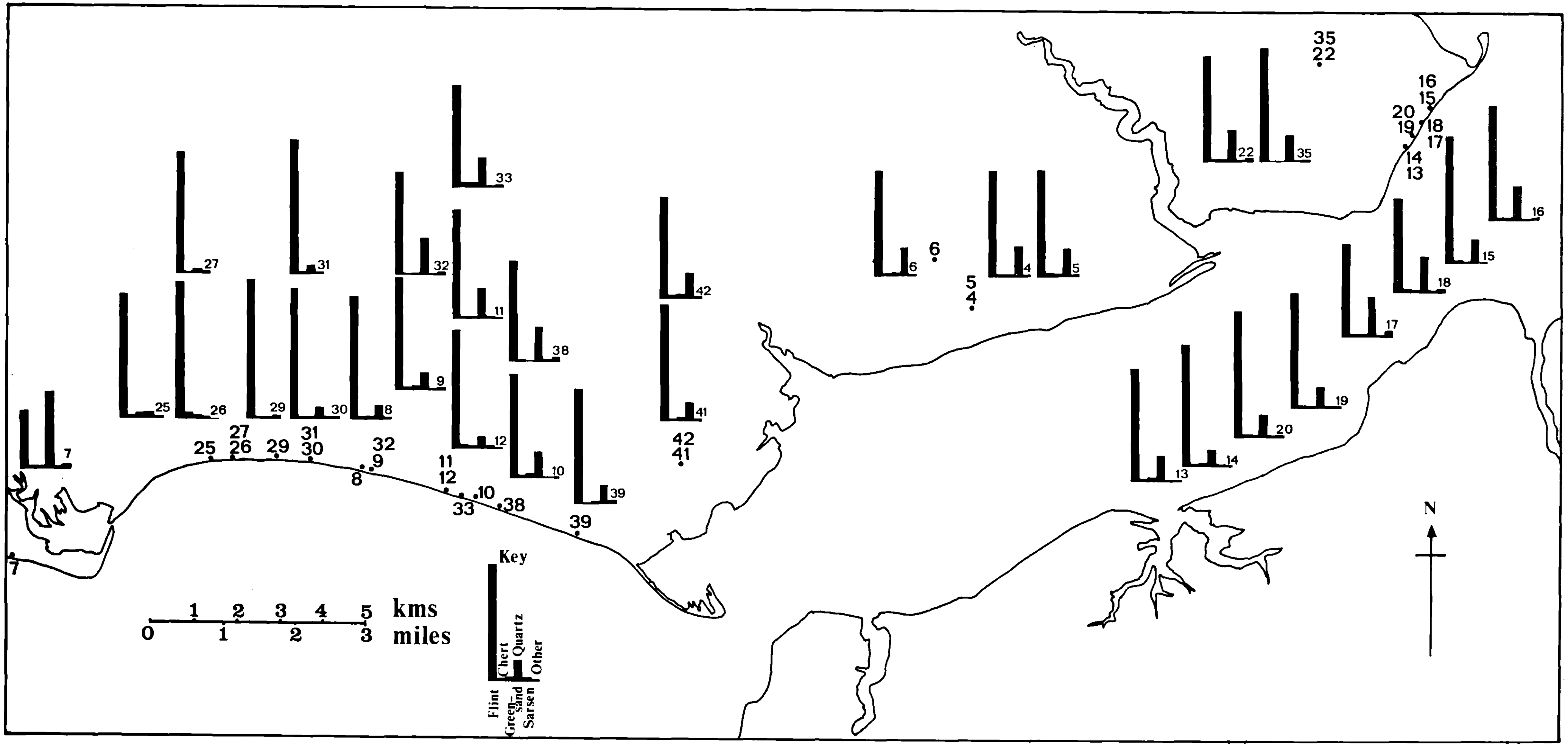
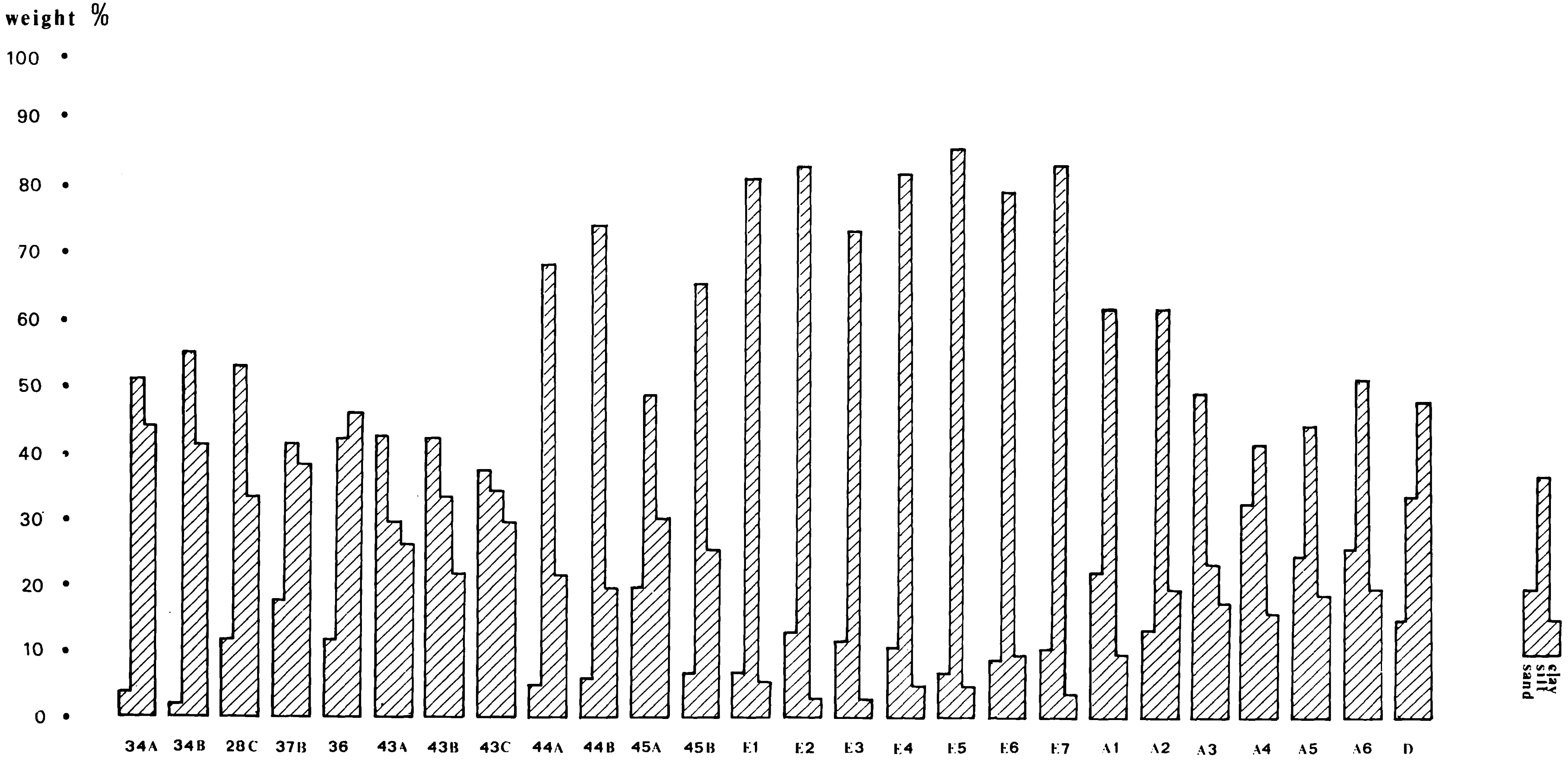

Key
Flint
Chert
Green-sand
Quartz
Sarsen
Other
0 1 2 3 4 5 kms
0 1 2 3 miles
N
7
25
26
27
29
30
31
8
9
32
11
12
33
10
38
39
41
42
4
5
6
22
35
13
14
15
16
17
18
19
20

Fig. 8. Grainsize analysis of selected brickearths from south Hampshire compared with brickearths from other parts of southern England

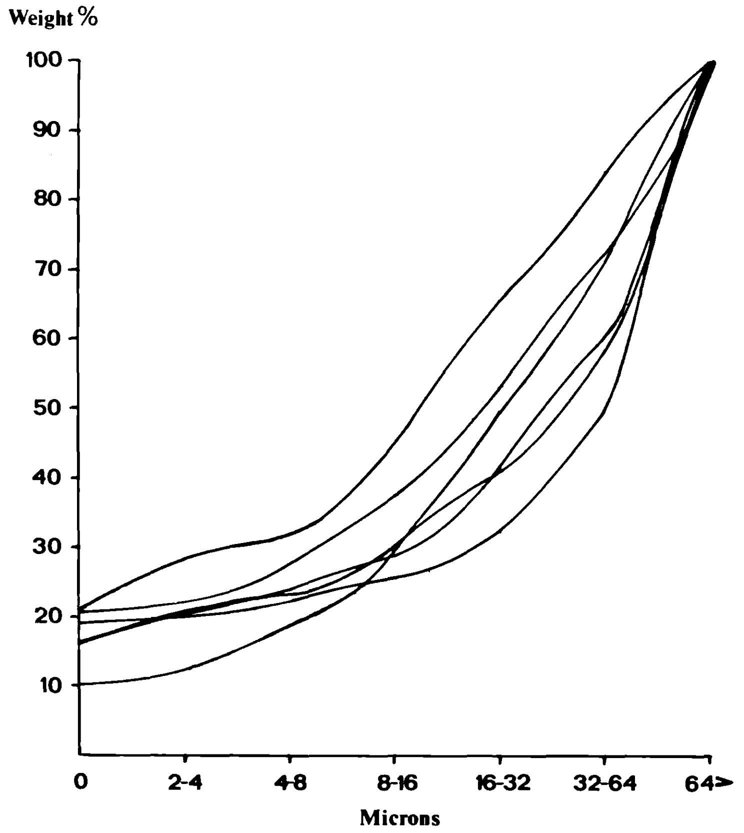
Key to numbers 34 Hordle brickearth 37 Chewton brickearth 43 R.Otter alluvium 45 Selsey brickearth A1 to A6 Barton brickearth measured section

28 Barton brickearth 36 Block in base of gravel, Barton 44 Thanet brickearth E1 to E8 Ebbsfleet loess E Downend brickearth

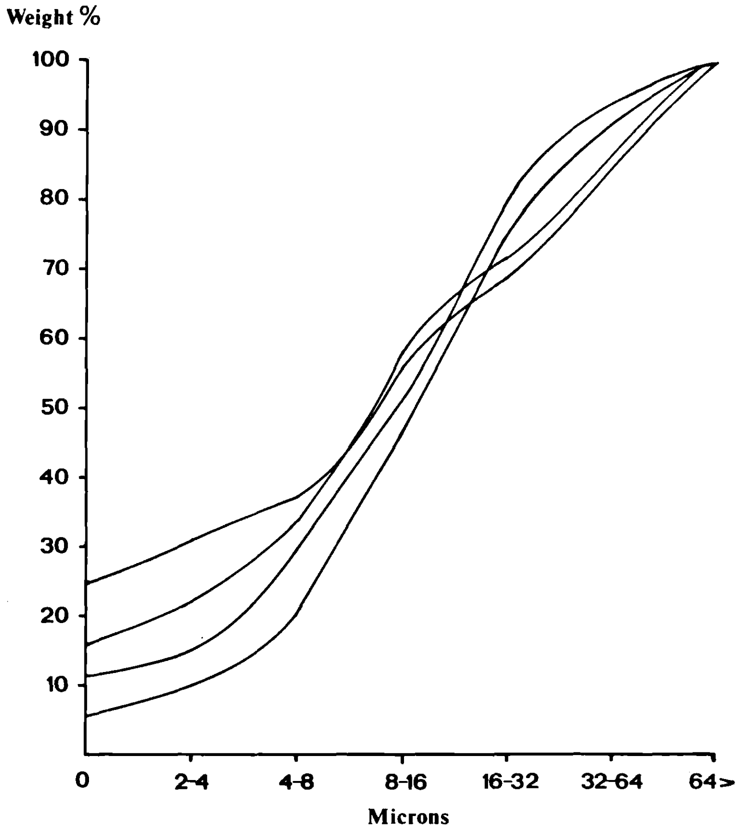


Grain size analysis of selected brickearths from South Hampshire, Sussex, and Kent compared with published histograms from Zeuner (1959) of the Ebbsfleet loess.

Fig. 9. Grainsize analysis of selected brickearths from south Hampshire, Devon, Kent and Sussex - cumulative curves



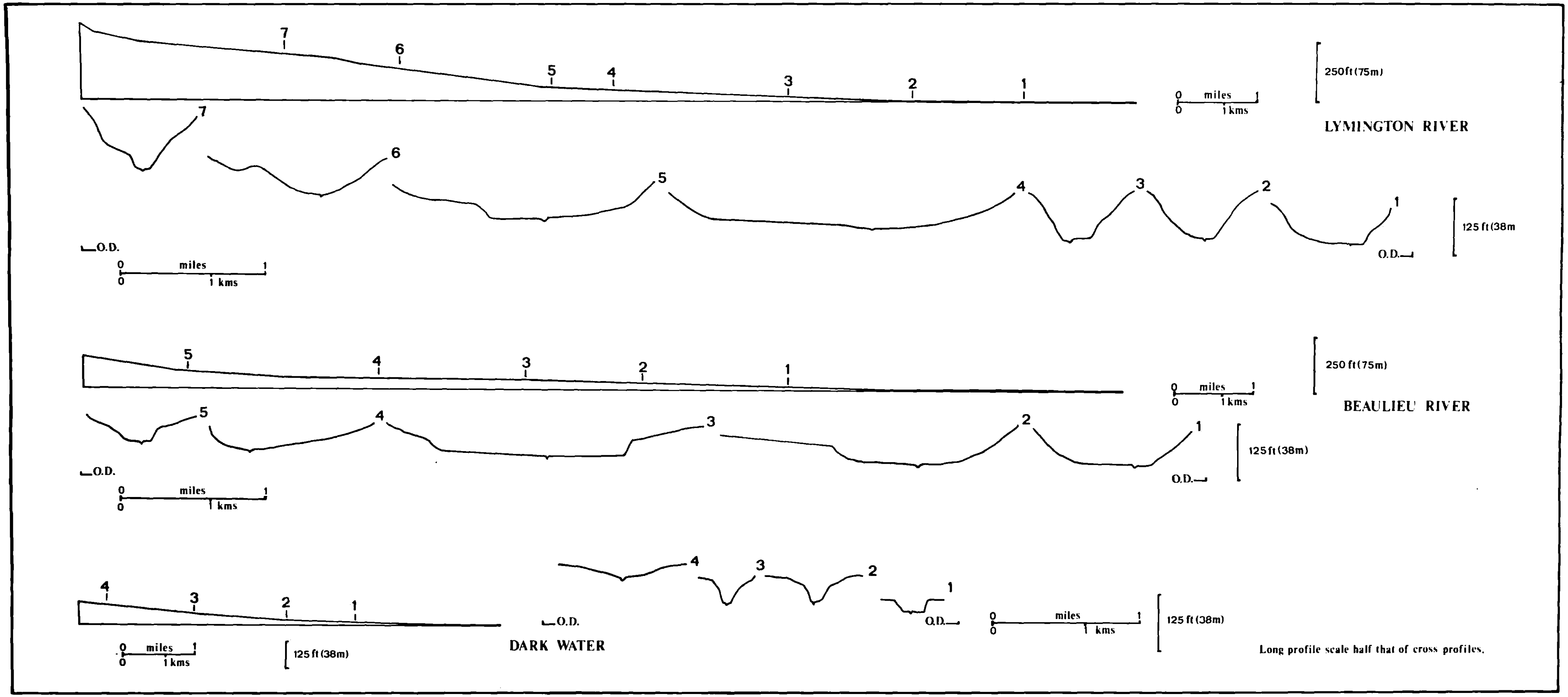
Sample numbers A1-A6 (Barton)



Sample numbers 44A,44B (Thanet) 45A,45B (Selsey)

Fig. 10. Selected profiles of the minor streams of the New Forest

The cross profiles show the great incision of the lower reaches of these streams below their elbows of capture.



Long profile scale half that of cross profiles.

Fig. 11. General map of the Stone Point area showing the surface of the 25 ft. (8 m.) terrace and the exposures of Tertiary rocks below the gravels of this terrace.

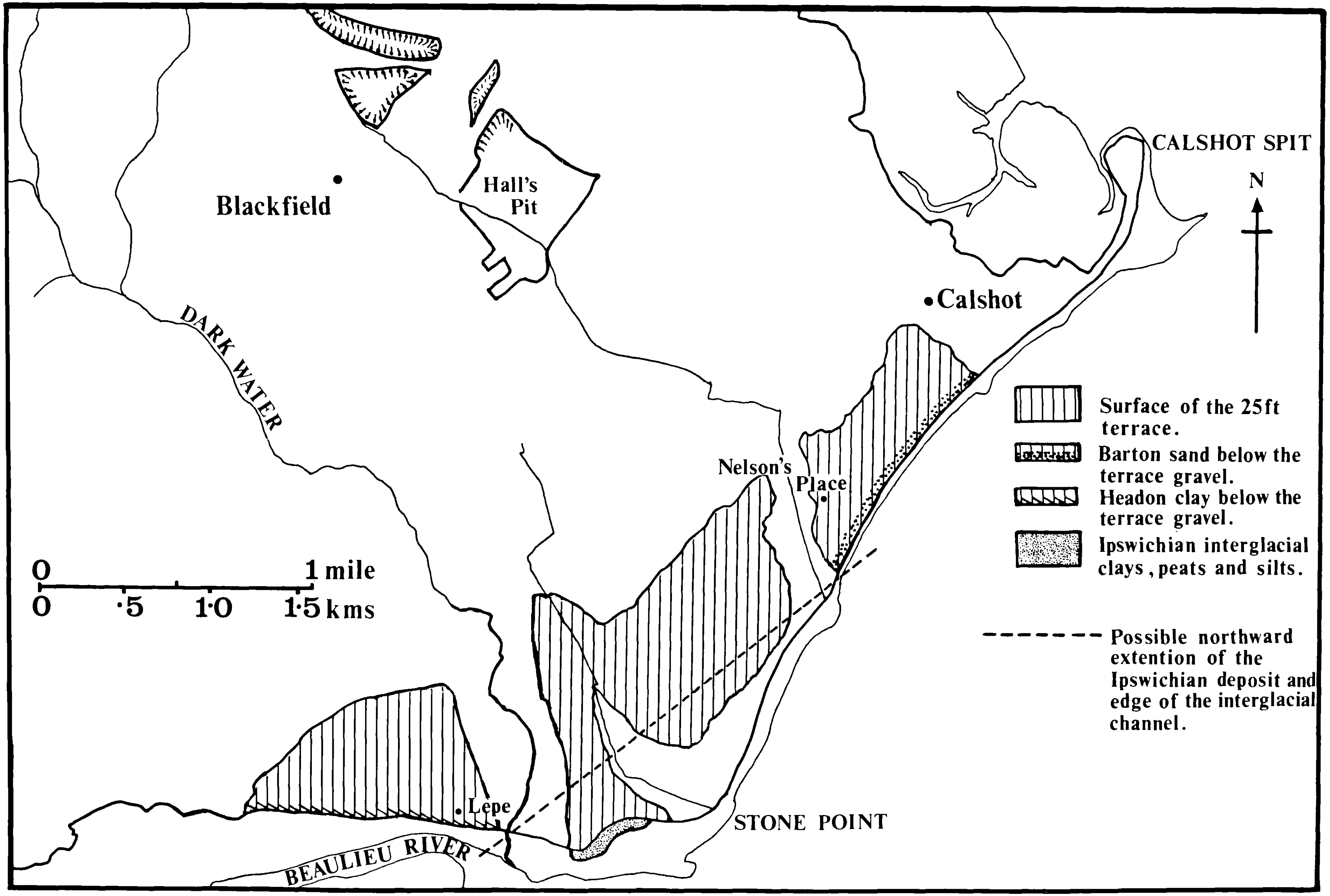

CALSHOT SPIT
N
Calshot
Blackfield
Hall's Pit
DARK WATER
Nelson's Place
Lepe
STONE POINT
BEAULIEU RIVER
0 1 mile
0 ·5 1·0 1·5 kms
Surface of the 25ft terrace.
Barton sand below the terrace gravel.
Headon clay below the terrace gravel.
Ipswichian interglacial clays, peats and silts.
Possible northward extention of the Ipswichian deposit and edge of the interglacial channel.

Fig. 12. The interglacial deposits at Stone Point. The map shows the location of test pits.

(Note: the small area marked Fig. 2 is portrayed in fig. 14 of this thesis.) From Brown et al. 1975.

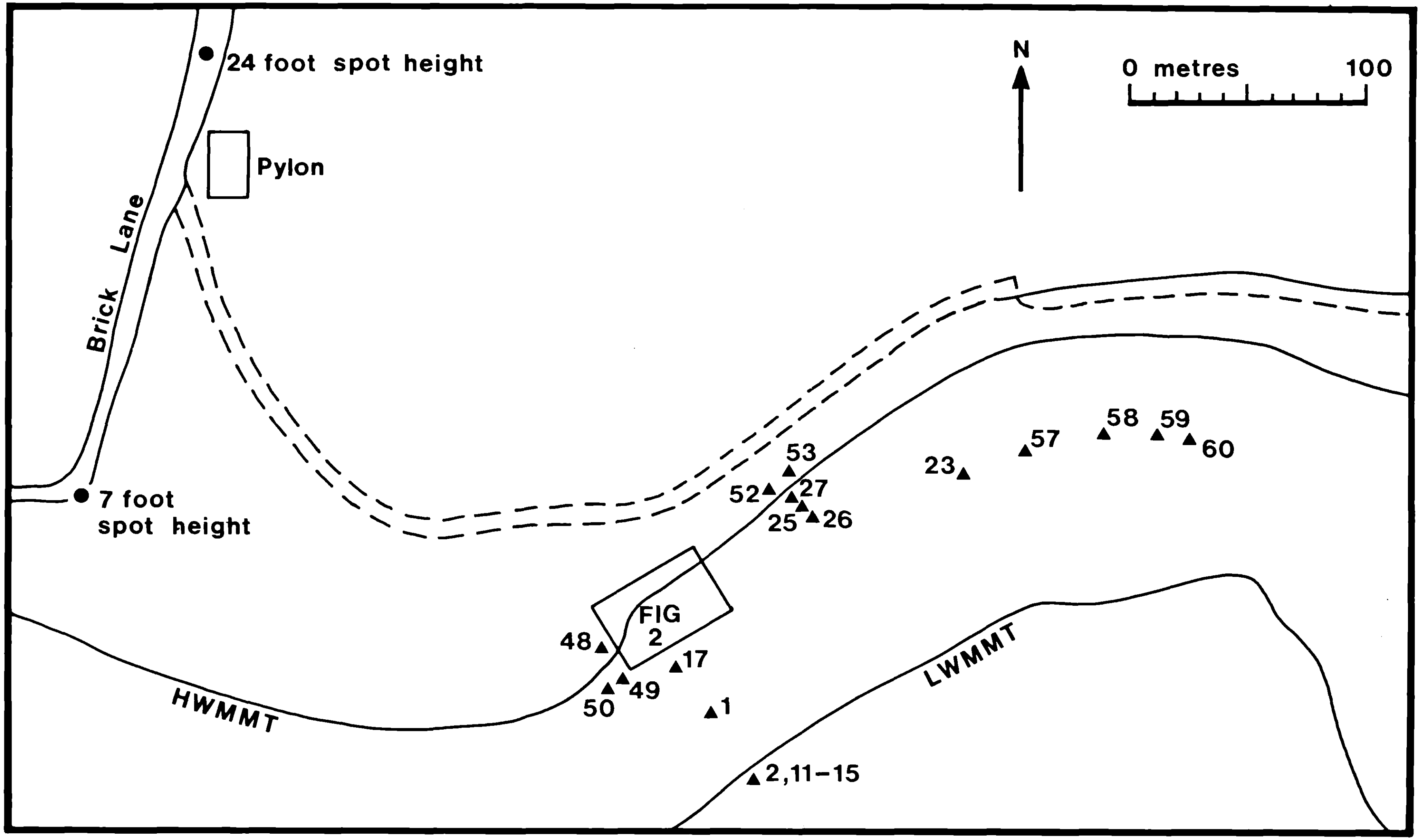

24 foot spot height
Pylon
Brick Lane
7 foot spot height
N
0 metres
100
53
52
27
25
26
23
57
58
59
60
FIG 2
48
17
49
50
1
HWMMT
LWMMT
2,11–15

Fig. 13. Sections through the interglacial deposits at Stone Point. The lines of section are shown on Fig. 14. (From Brown et al. 1975.)

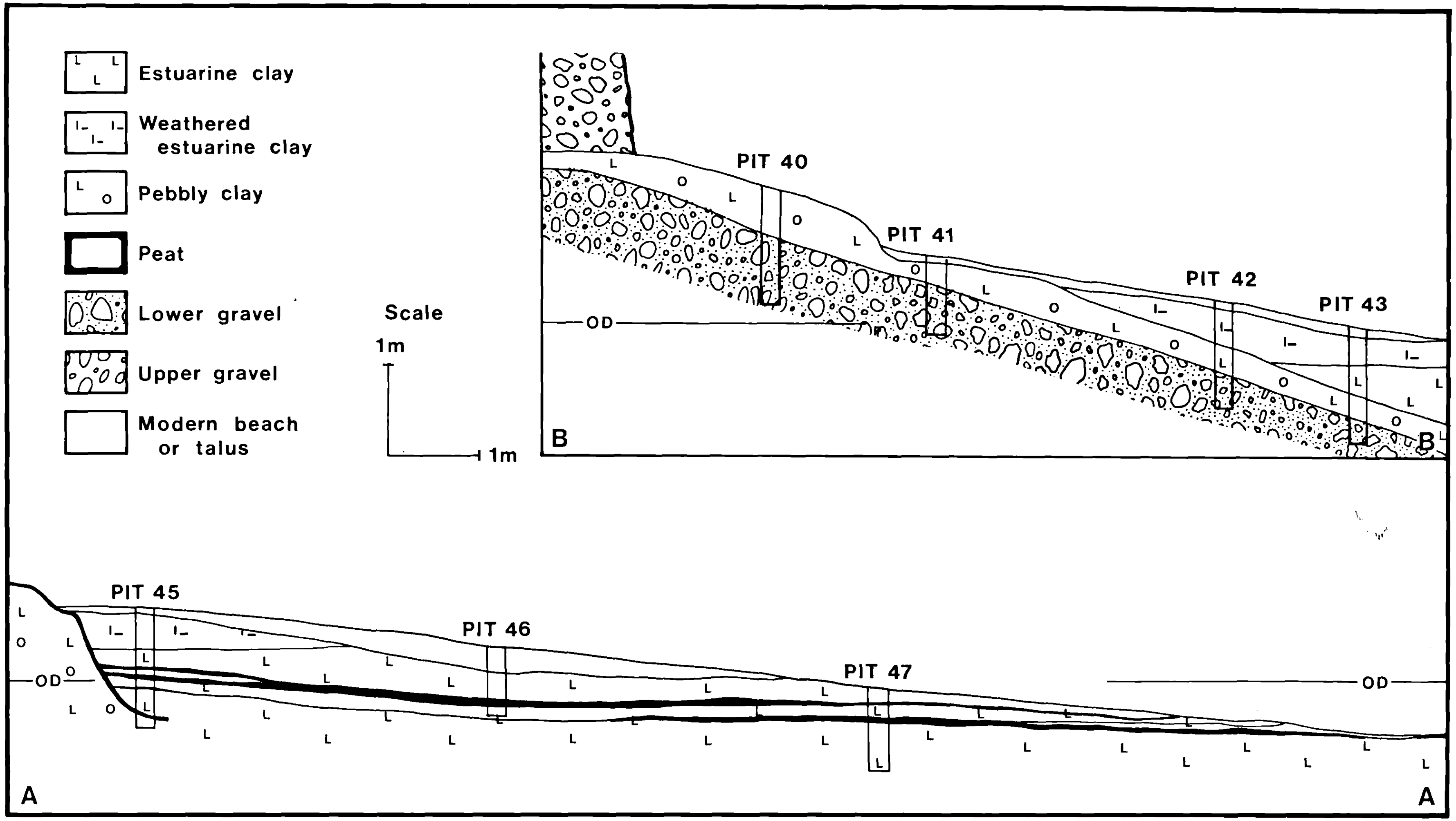

Estuarine clay
Weathered estuarine clay
Pebbly clay
Peat
Lower gravel
Upper gravel
Modern beach or talus
Scale
1m
1m
PIT 40
PIT 41
PIT 42
PIT 43
OD
B
B
PIT 45
PIT 46
PIT 47
OD
OD
A
A

Fig. 14. The interglacial deposits at Stone Point, a map of the peat exposure. Key as for fig. 13 except peat is marked as a black stipple rather than solid black. (From Brown et al. 1975.)

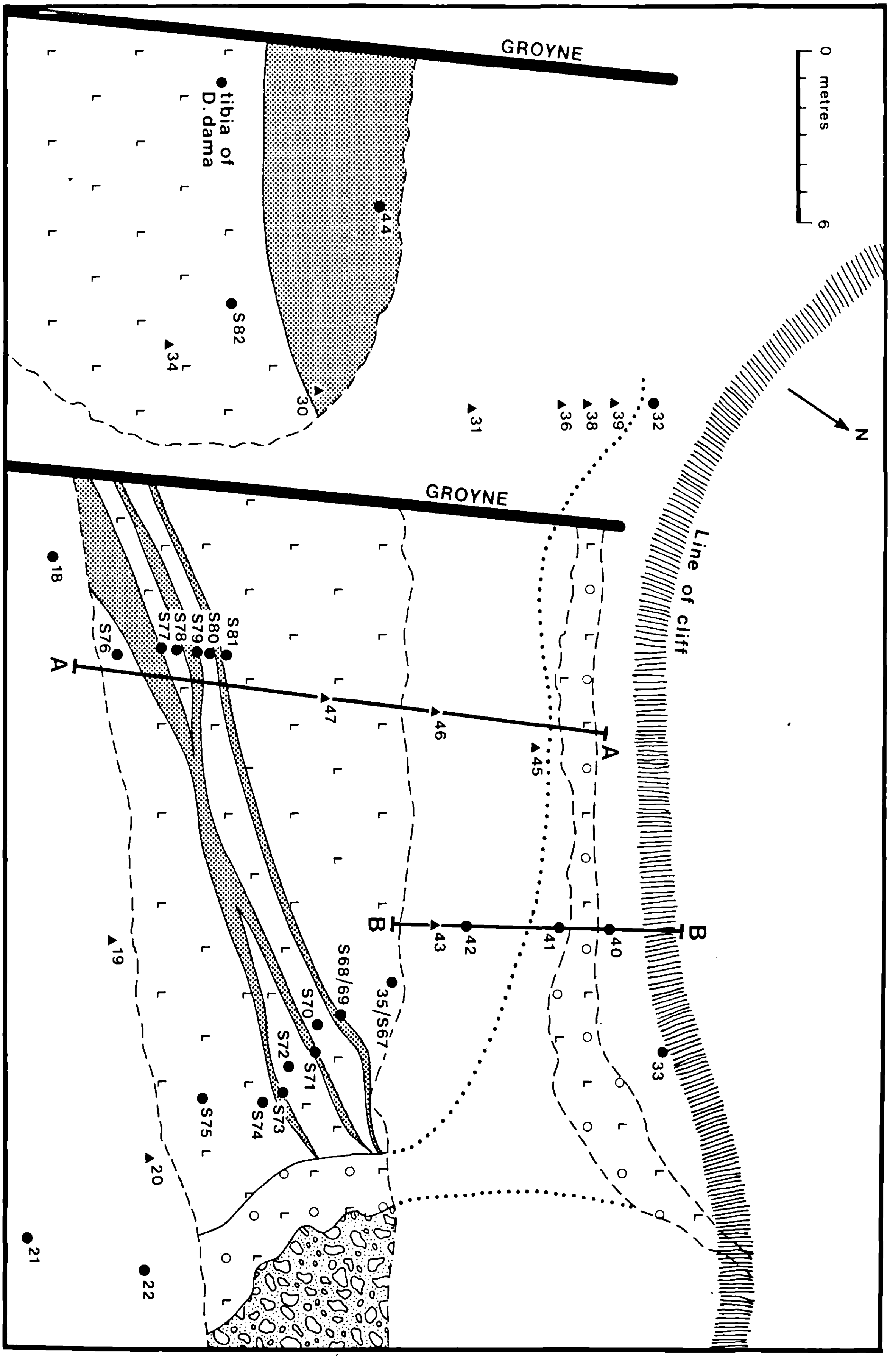
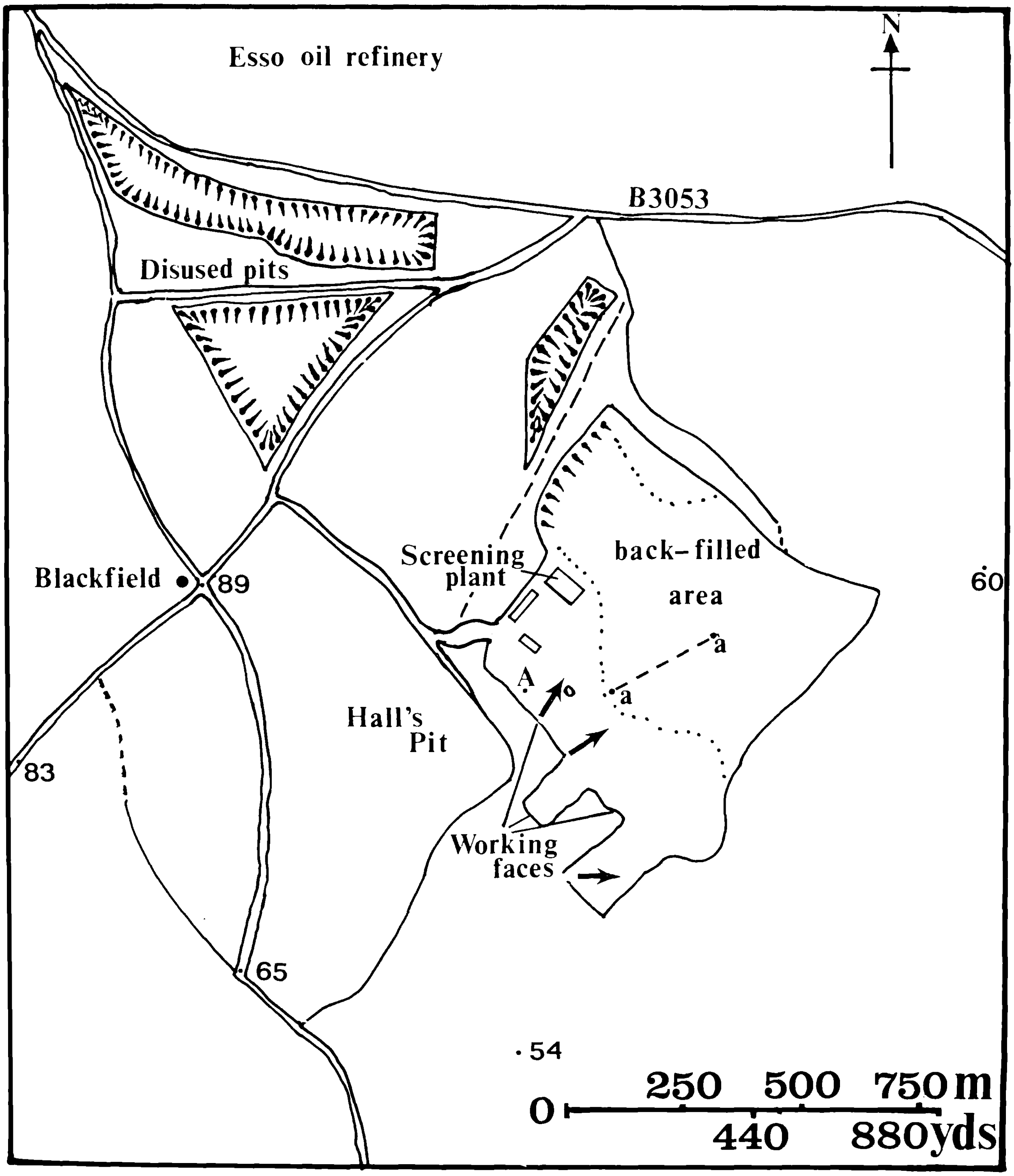

GROYNE
GROYNE
0 metres 6
N
Line of cliff
tibia of D.dama
44
S82
34
30
31
36
38
39
32
18
S76
S77
S78
S79
S80
S81
A
A
47
46
45
B
B
43
42
41
40
19
35/S67
S68/69
S70
S71
S72
S73
S74
S75
20
21
22
33

Fig. 15. The pits in the 100 ft. (30 m.) and 60 ft. (18 m.) terraces at Blackfield.



a-----à Possible eyot of Tertiary sand projecting through the gravel. (The dots at each end of the dashed line indicate actual outcrops of the sand).

Arrows indicate current bedding directions.

Spot heights in feet above O.D.

'A' indicates the position of an Acheulian handaxe.

Fig. 16. The pits in the 25 ft. (8 m.) terrace at Pennington .

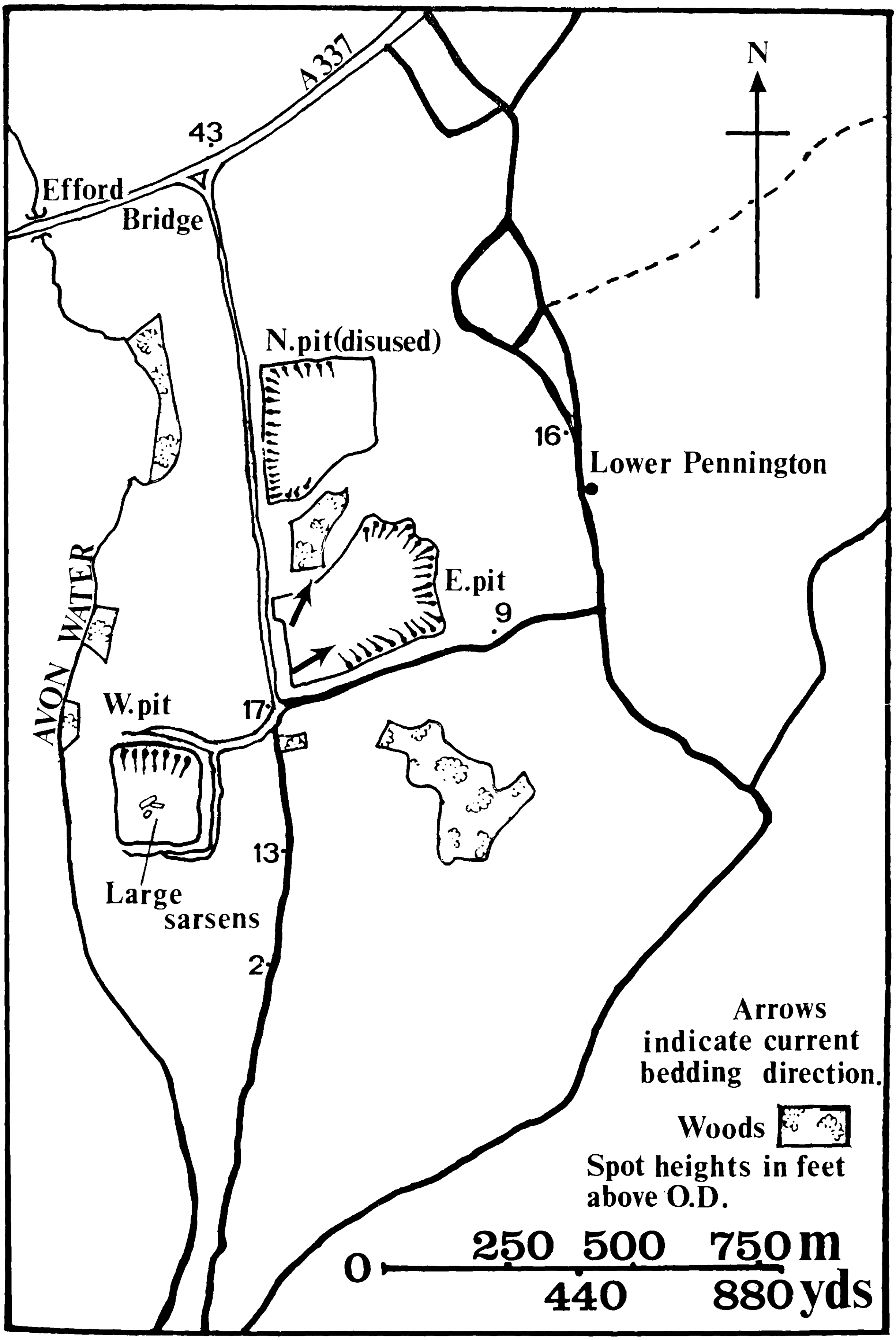

A337
43
Efford
Bridge
N
N.pit(disused)
16
Lower Pennington
E.pit
9
AVON WATER
W.pit
17
13
Large
sarsens
2
Arrows
indicate current
bedding direction.
Woods
Spot heights in feet
above O.D.
0
250
500
750 m
440
880 yds

Fig. 17. A composite north-south section through the pits in the 25 ft. (8 m.) terrace at Pennington .

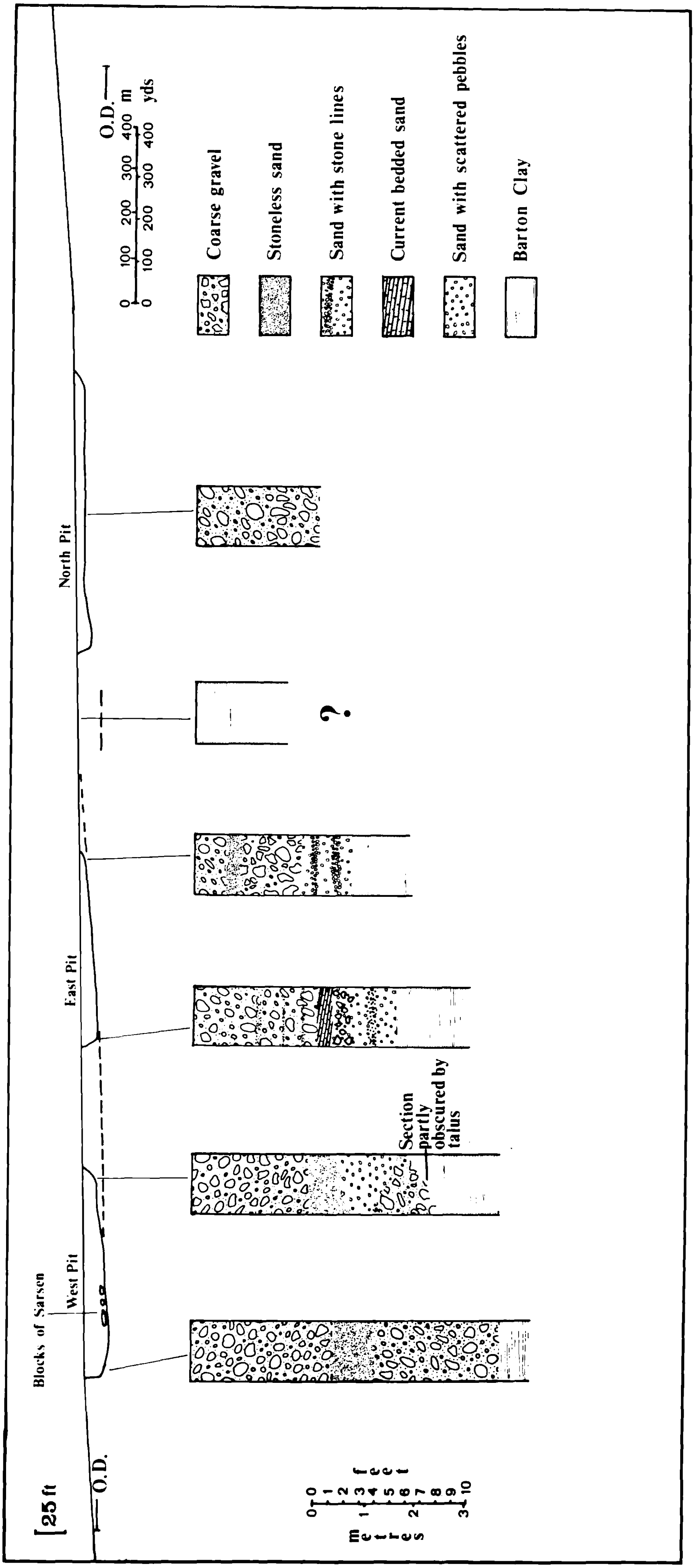

25 ft
O.D.
metres
0 1 2 3
feet
0 1 2 3 4 5 6 7 8 9 10
Blocks of Sarsen
West Pit
Section partly obscured by talus
East Pit
?
North Pit
O.D.
0 100 200 300 400 m
0 100 200 300 400 yds
Coarse gravel
Stoneless sand
Sand with stone lines
Current bedded sand
Sand with scattered pebbles
Barton Clay

Fig. 18. A section across the former buried channel below the 60 ft. (18 m.) terrace at Hordle.

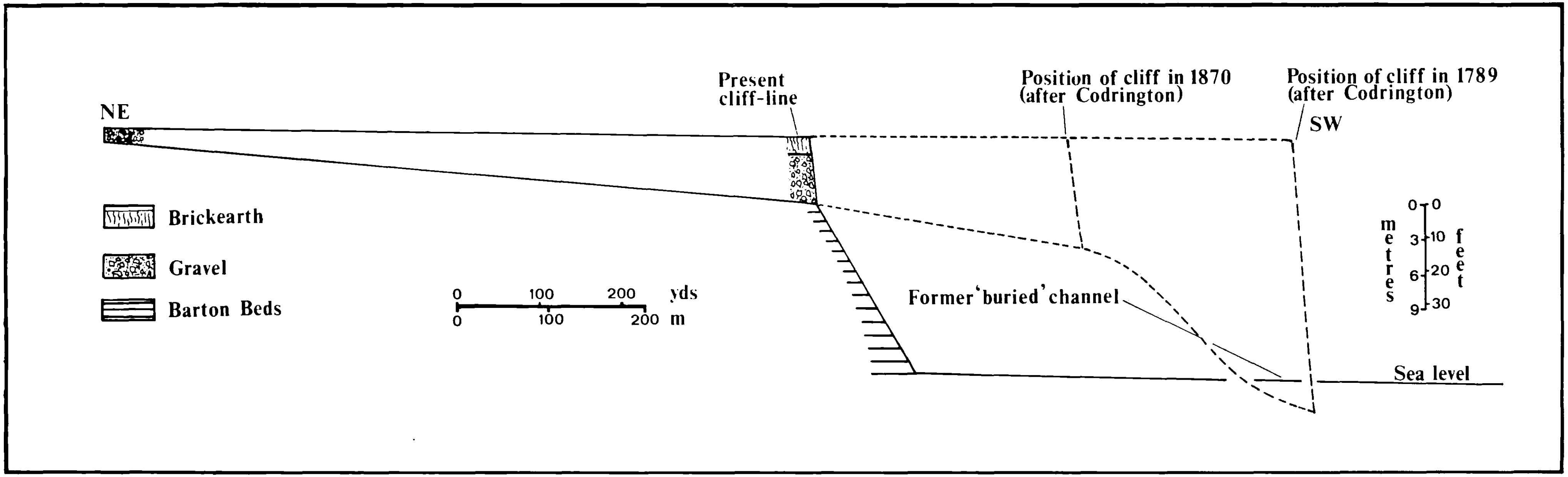

NE
Present cliff-line
Position of cliff in 1870 (after Codrington)
Position of cliff in 1789 (after Codrington)
SW
Brickearth
Gravel
Barton Beds
0 100 200 yds
0 100 200 m
Former 'buried' channel
metres 0 3 6 9
feet 0 10 20 30
Sea level

Fig. 19. Height limits of raised beaches and terraces in the Channel area after various authors.

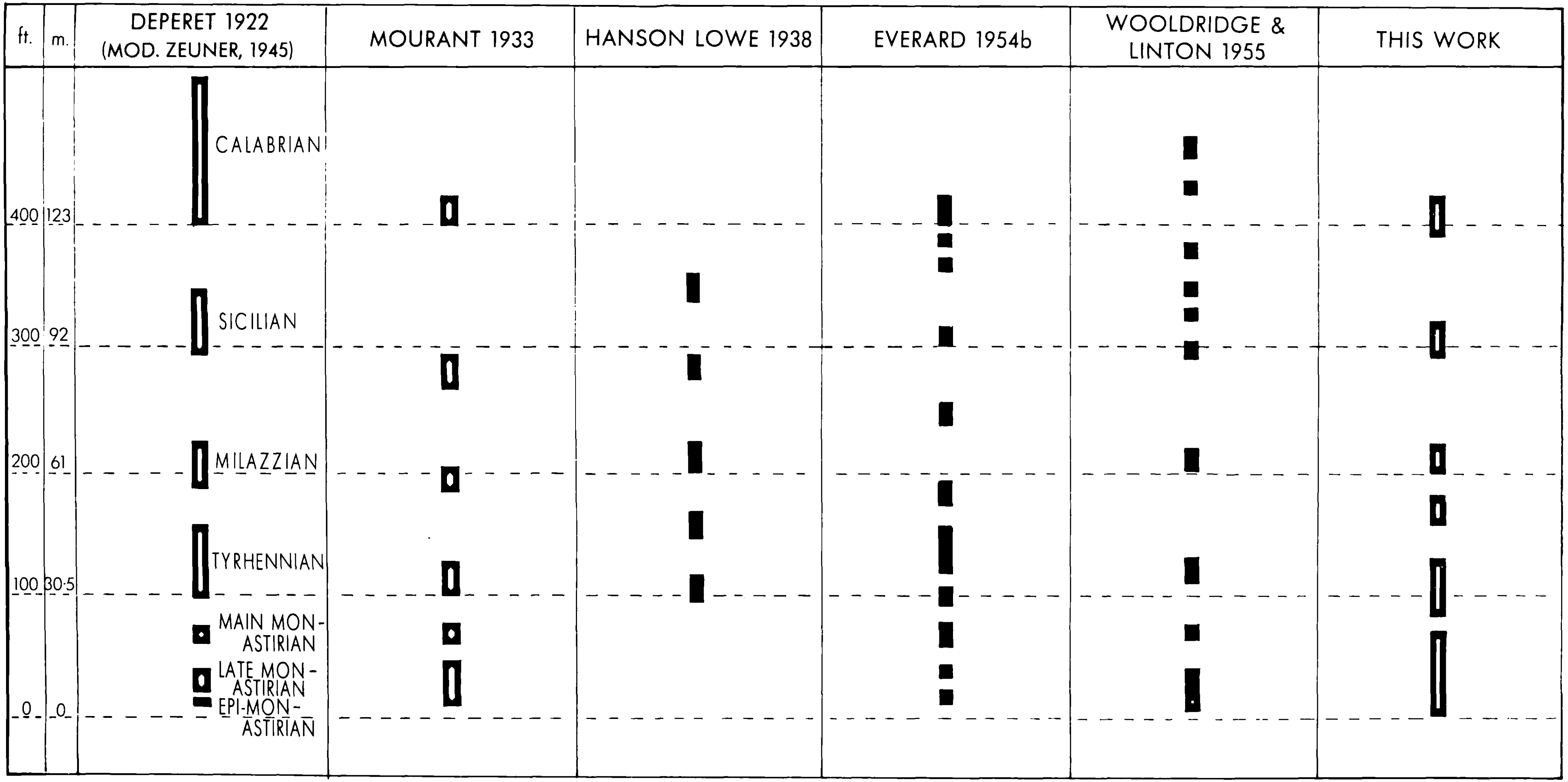
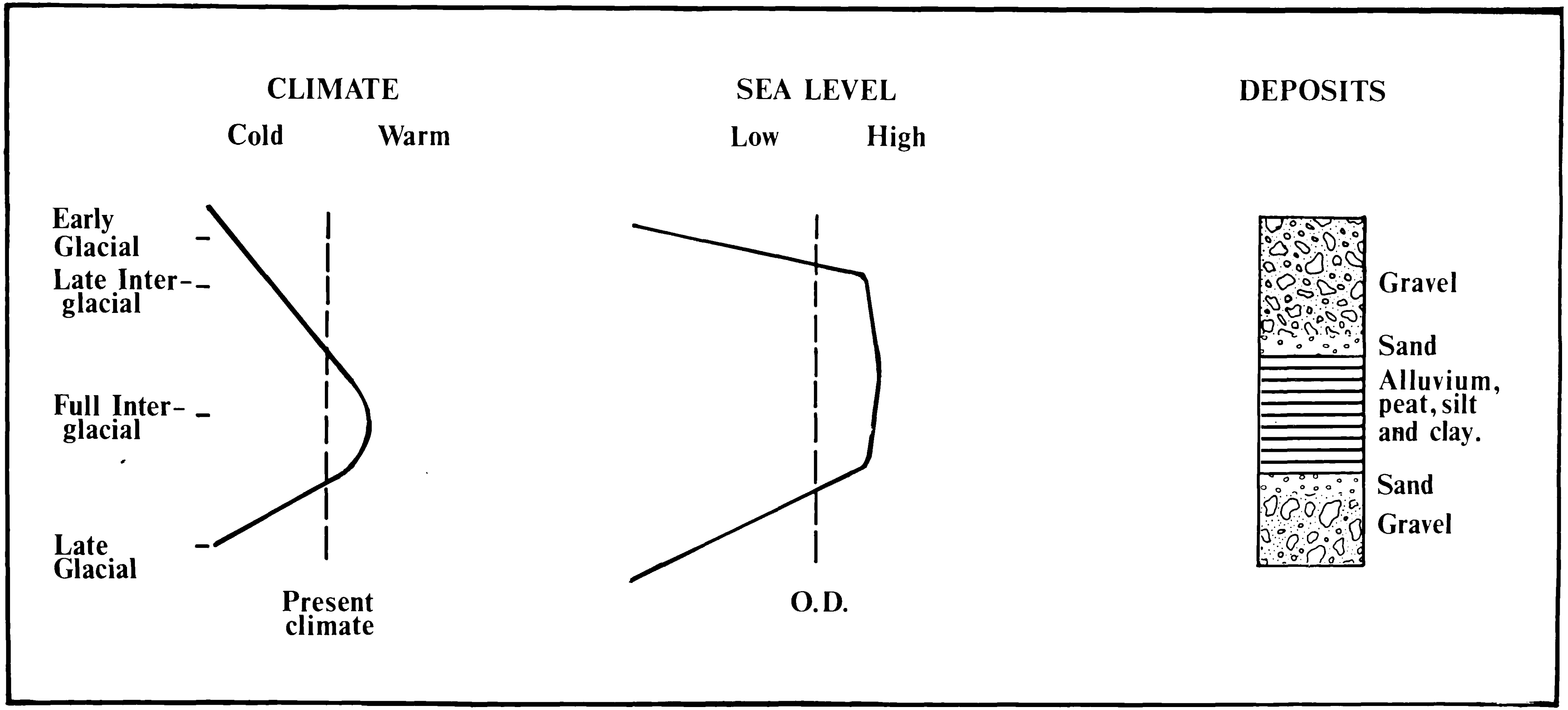

ft.
m.
DEPERET 1922 (MOD. ZEUNER, 1945)
MOURANT 1933
HANSON LOWE 1938
EVERARD 1954b
WOOLDRIDGE & LINTON 1955
THIS WORK
400
123
300
92
200
61
100
30·5
0
0
CALABRIAN
SICILIAN
MILAZZIAN
TYRHENNIAN
MAIN MON-ASTIRIAN
LATE MON-ASTIRIAN
EPI-MON-ASTIRIAN

Fig. 20. <u>An idealised sequence showing the relationship between climate, sea level and fluvial deposition during interglacials</u>



Idealised diagram showing the relationship between climate, sea level and fluvial deposition during interglacials.

Fig. 21. A sequence of cross-sections to show the manner of fluvial deposition in glacials and interglacials and the mode of formation of river terraces.

Stage I Late Glacial
Vegetation : Open but increasing
Sea level : Rising
Climate : Warming
Streams deposit coarse sand and aggrade their courses with the rising sea level.

Stage II Full Interglacial
Vegetation : Climax
Sea level : Stable
Climate : Climatic optimum
Streams deposit only finegrained sediments.

Stage III Late Interglacial
Vegetation : Forest gives way to more open conditions
Sea level : Stable
Climate : Cooling
Increased run-off causes streams to cut laterally and deposit gravel.

Stage IV Early Glacial
Vegetation : Park tundra
Sea level : Falling fast
Climate : Cool becoming cold
Fall in sea level causes streams to begin cutting buried channel. Brickearth deposited possibly by overbank flow.

Stage V Full Glacial
Vegetation : Full tundra
Sea level : Stable at glacial maximum
Climate : Full glacial

Stage VI Full Interglacial
Vegetation : Climax
Sea level : Stable
Climate : Climatic optimum
Previous buried channel filled to new interglacial base level and sediments of previous interglacial left as terraces.

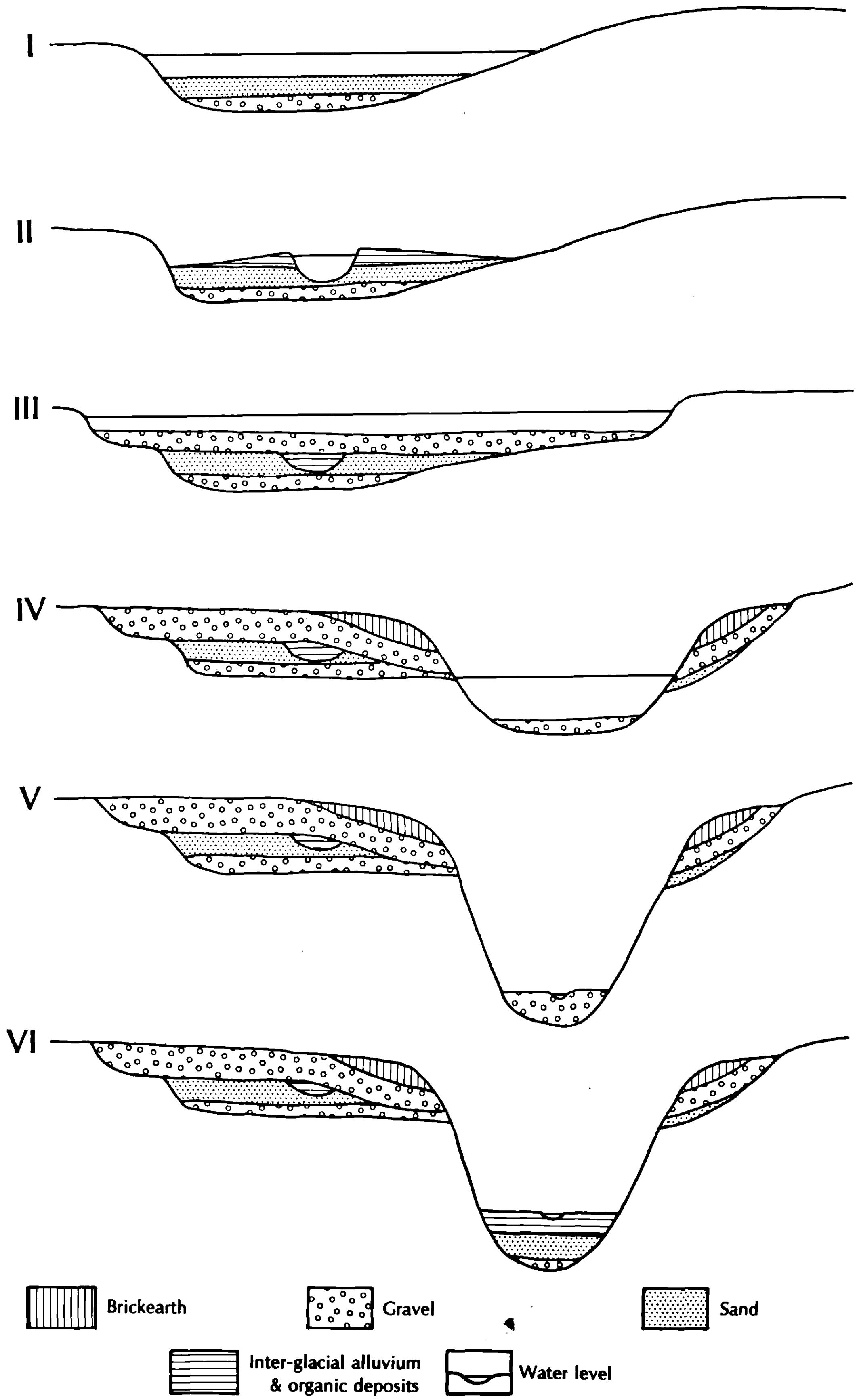

I
II
III
IV
V
VI
Brickearth
Gravel
Sand
Inter-glacial alluvium & organic deposits
Water level

Fig. 22. The stratigraphy of certain sites in Britain where 25 ft. (8 m.) beach or fluvial deposits overlie earlier Pleistocene sediments.

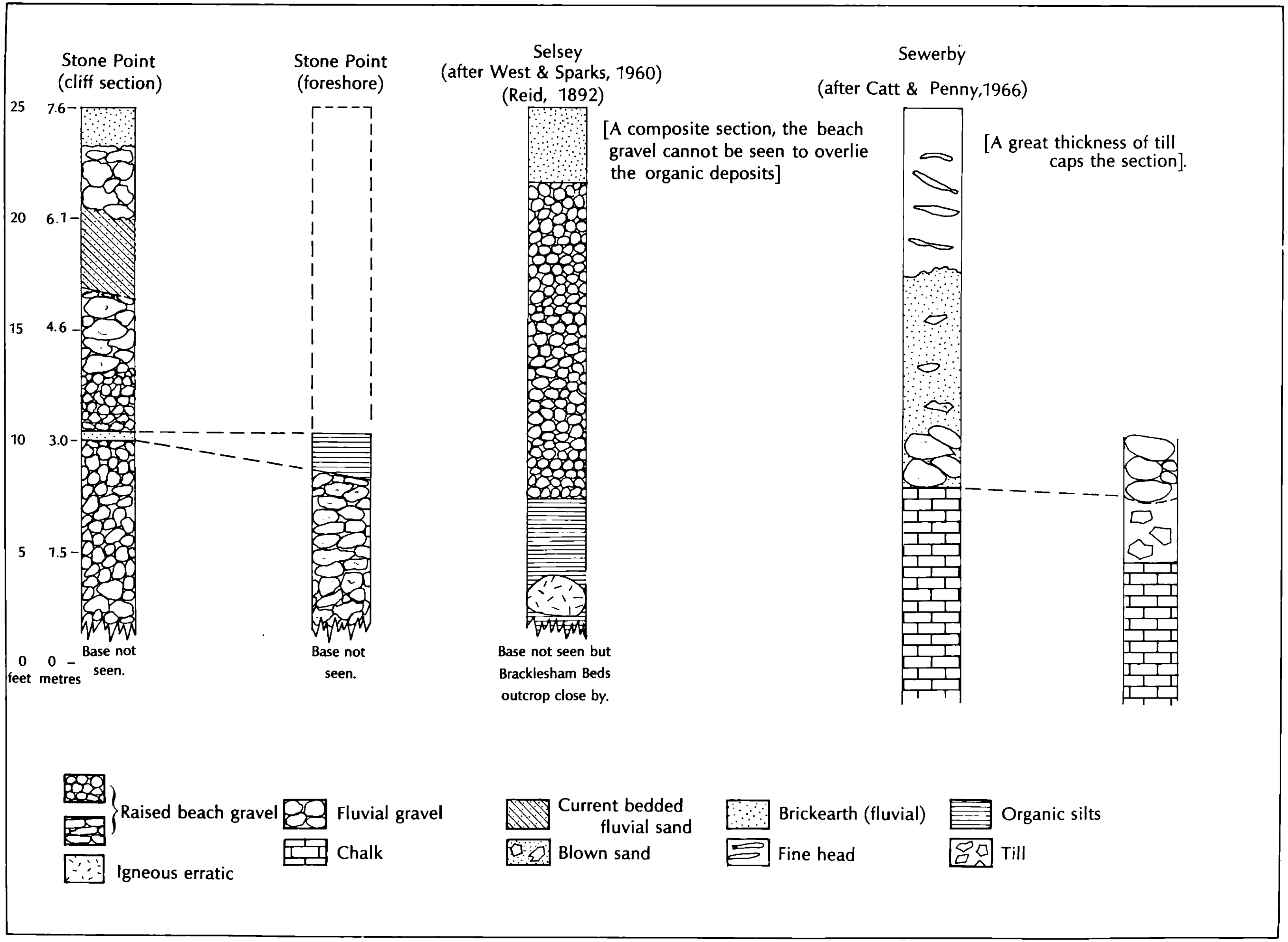

Stone Point
(cliff section)
Stone Point
(foreshore)
Selsey
(after West & Sparks, 1960)
(Reid, 1892)
Sewerby
(after Catt & Penny,1966)
[A composite section, the beach gravel cannot be seen to overlie the organic deposits]
[A great thickness of till caps the section].
25
20
15
10
5
0
feet
7.6
6.1
4.6
3.0
1.5
0
metres
Base not seen.
Base not seen.
Base not seen but Bracklesham Beds outcrop close by.
Raised beach gravel
Igneous erratic
Fluvial gravel
Chalk
Current bedded fluvial sand
Blown sand
Brickearth (fluvial)
Fine head
Organic silts
Till

Fig. 23. The stratigraphy of sites in the Channel Isles where 25 ft. (8 m.) beach gravels overlie head.

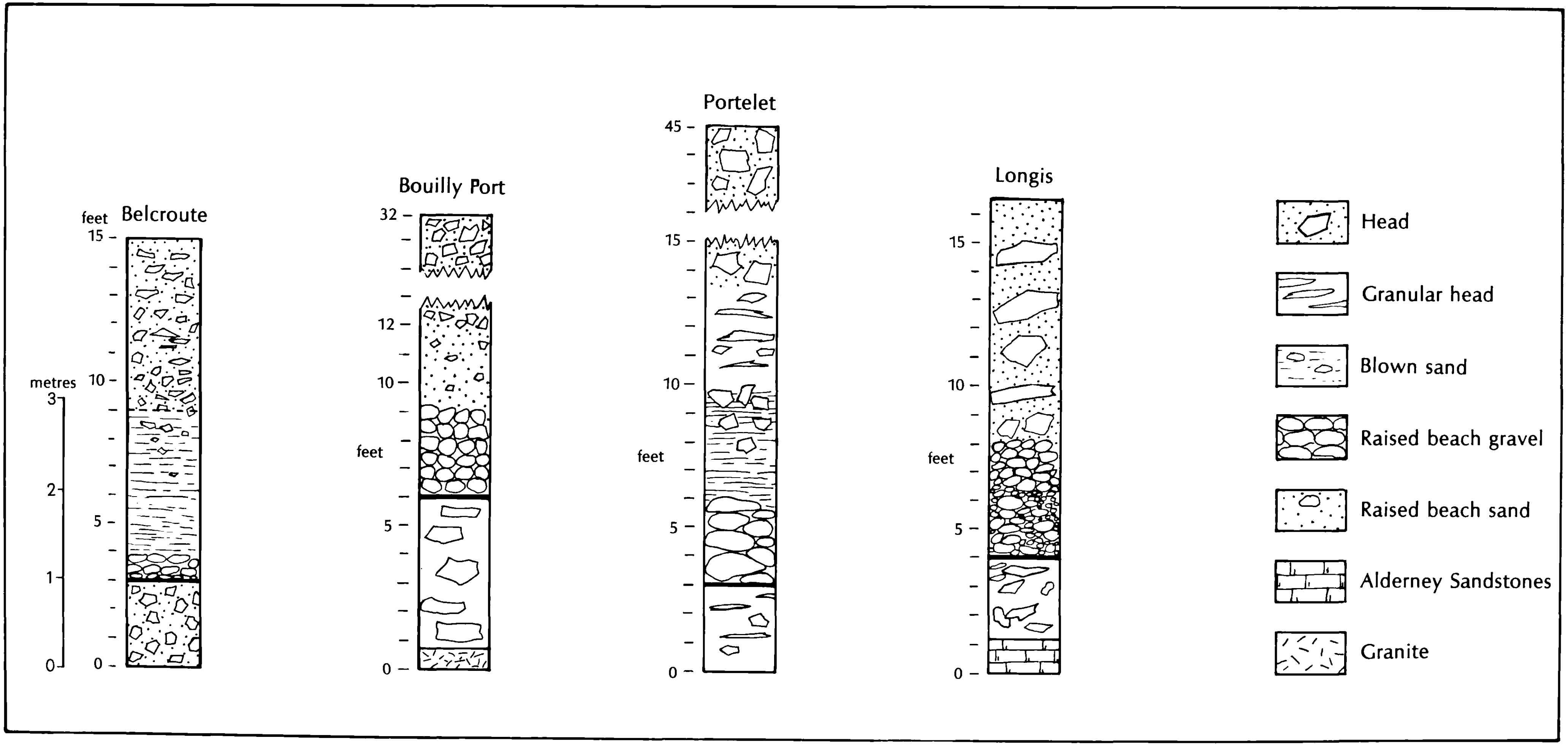
Belcroute
Bouilly Port
Portelet
Longis
feet
metres
0
1
2
3
0
5
10
12
15
32
45
Head
Granular head
Blown sand
Raised beach gravel
Raised beach sand
Alderney Sandstones
Granite

Fig. 24. North-south section through the 25 ft. (8 m.) beach deposits in Portelet Bay, Jersey.

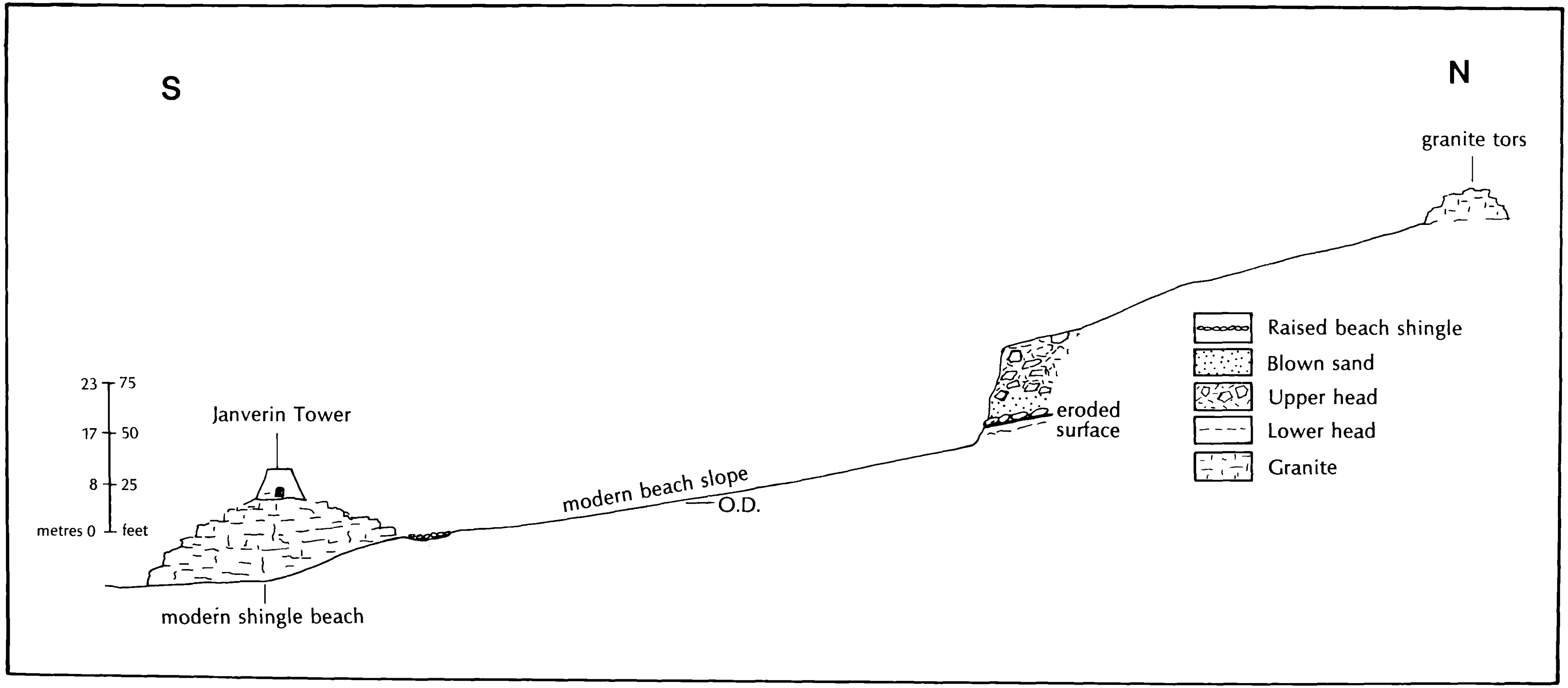

S
N
granite tors
23 — 75
17 — 50
8 — 25
metres 0 — feet
Janverin Tower
modern shingle beach
modern beach slope
O.D.
eroded surface
Raised beach shingle
Blown sand
Upper head
Lower head
Granite

Fig. 25. Section through La Cotte de St. Brelade, Jersey. (Simplified from McBurney & Callow, 1971.)

(Note: the weathering surface separates the upper complex (Devensian) from the lower complex (Wolstonian).)

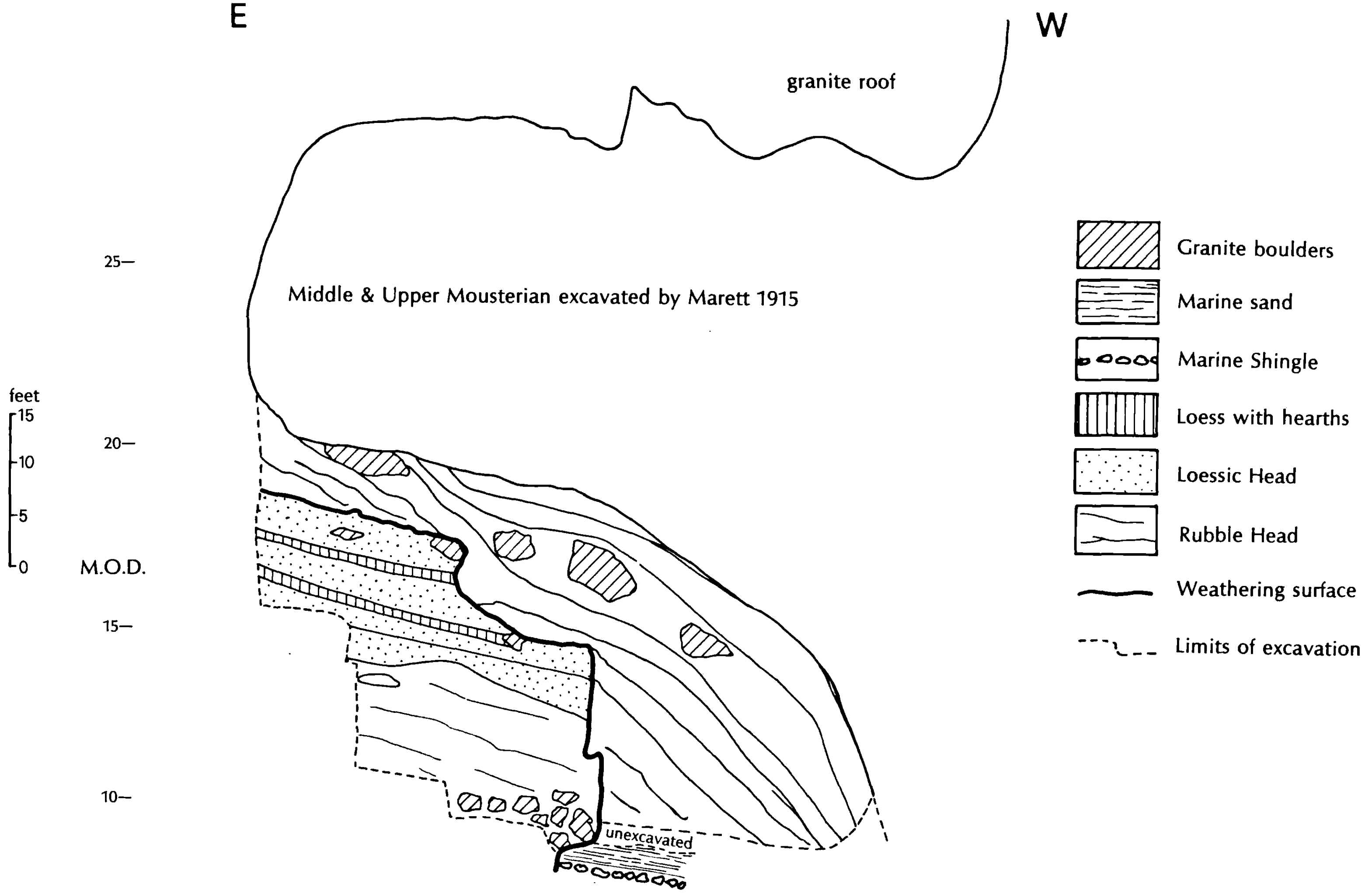

E
W
granite roof
Middle & Upper Mousterian excavated by Marett 1915
feet
15
10
5
0
25—
20—
M.O.D.
15—
10—
unexcavated
Granite boulders
Marine sand
Marine Shingle
Loess with hearths
Loessic Head
Rubble Head
Weathering surface
Limits of excavation

Fig. 26. Section through La Cotte à la Chèvre, Jersey.

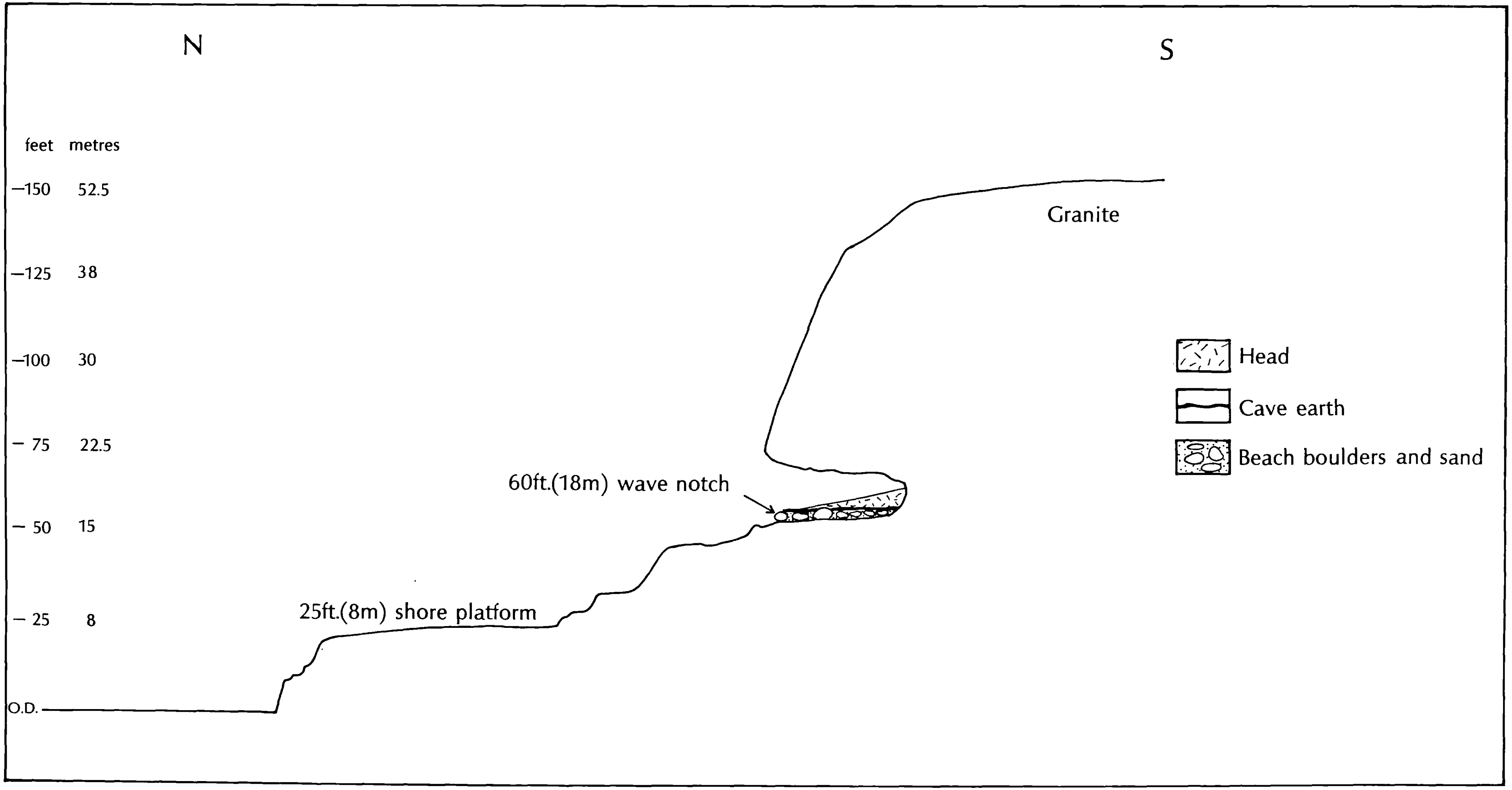

N
S
feet metres
–150 52.5
–125 38
–100 30
– 75 22.5
– 50 15
– 25 8
O.D.
Granite
60ft.(18m) wave notch
25ft.(8m) shore platform
Head
Cave earth
Beach boulders and sand

Fig. 27. Section of a "two-storey" sea cave containing a 60 ft. (18 m.) beach deposit and a 25 ft. (8 m.) wave notch. The section is a composite of several caves on the north-west coast of Jersey.

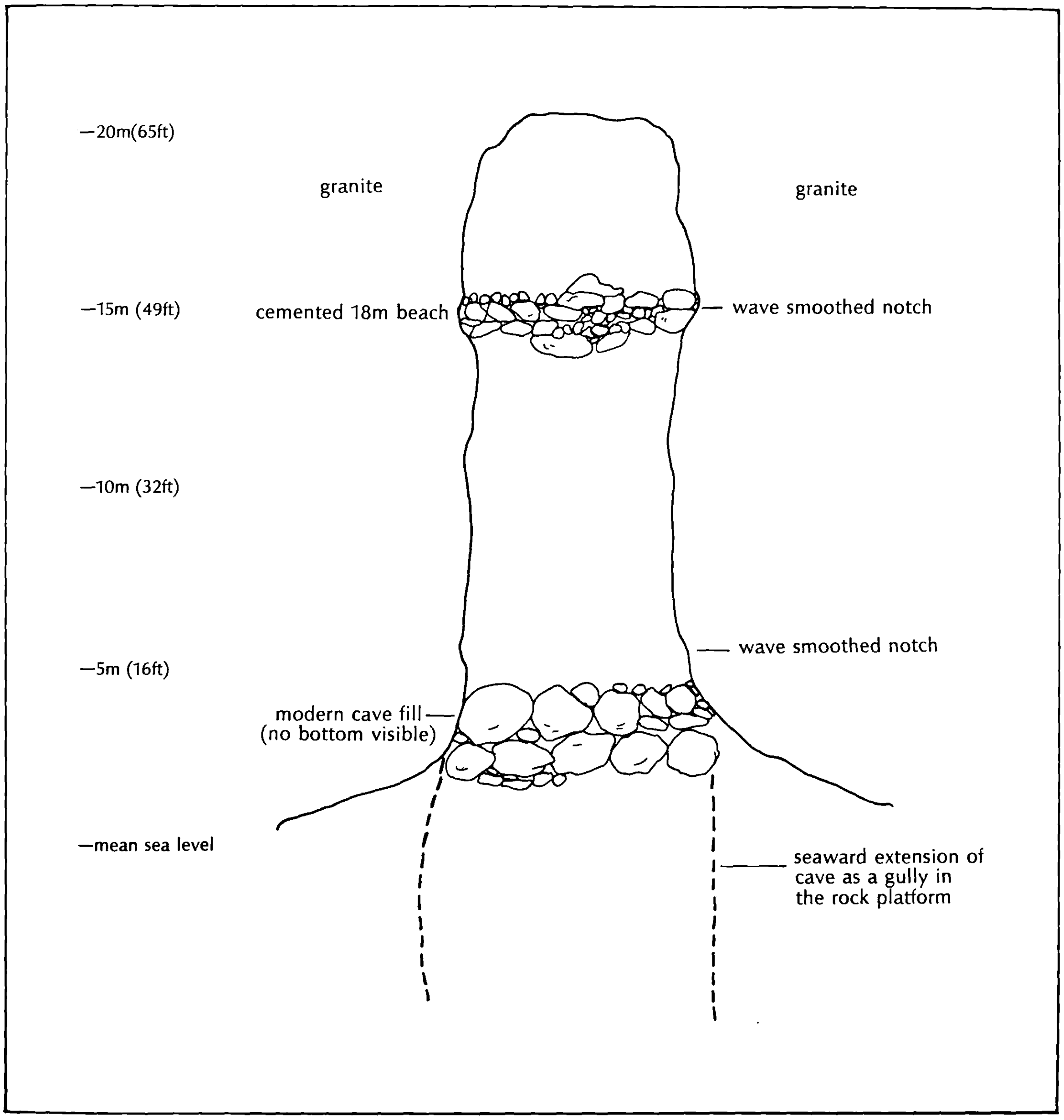

–20m(65ft)
granite
granite
–15m (49ft)
cemented 18m beach
wave smoothed notch
–10m (32ft)
wave smoothed notch
–5m (16ft)
modern cave fill
(no bottom visible)
–mean sea level
seaward extension of cave as a gully in the rock platform

Fig. 28. Section through the two raised beaches at Fermain (WV 339763), Guernsey.

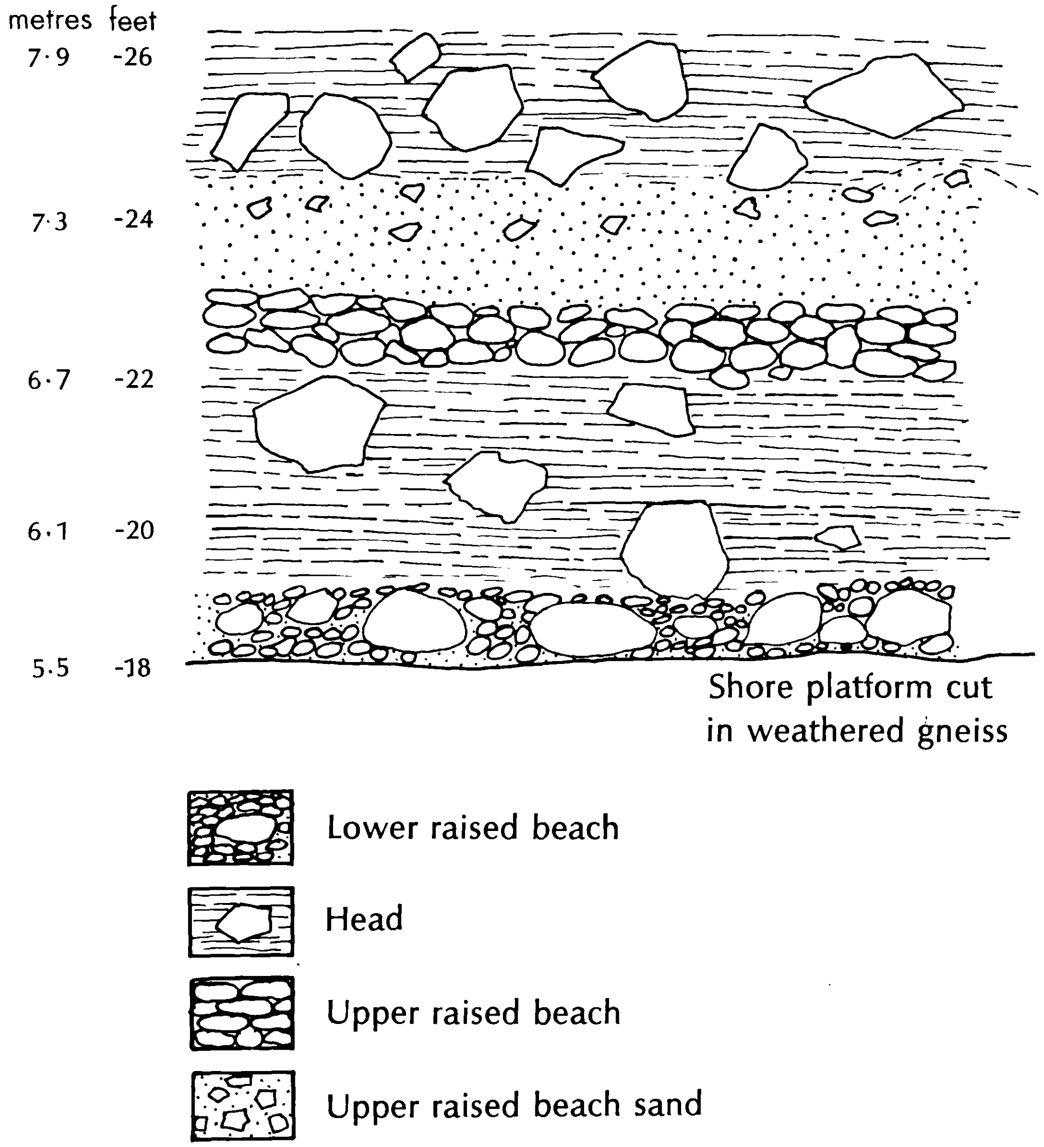

metres feet
7·9 -26
7·3 -24
6·7 -22
6·1 -20
5·5 -18
Shore platform cut in weathered gneiss
Lower raised beach
Head
Upper raised beach
Upper raised beach sand

Fig. 29. Section through the 25 ft. (8 m.) raised beach on the south side of Jethou.

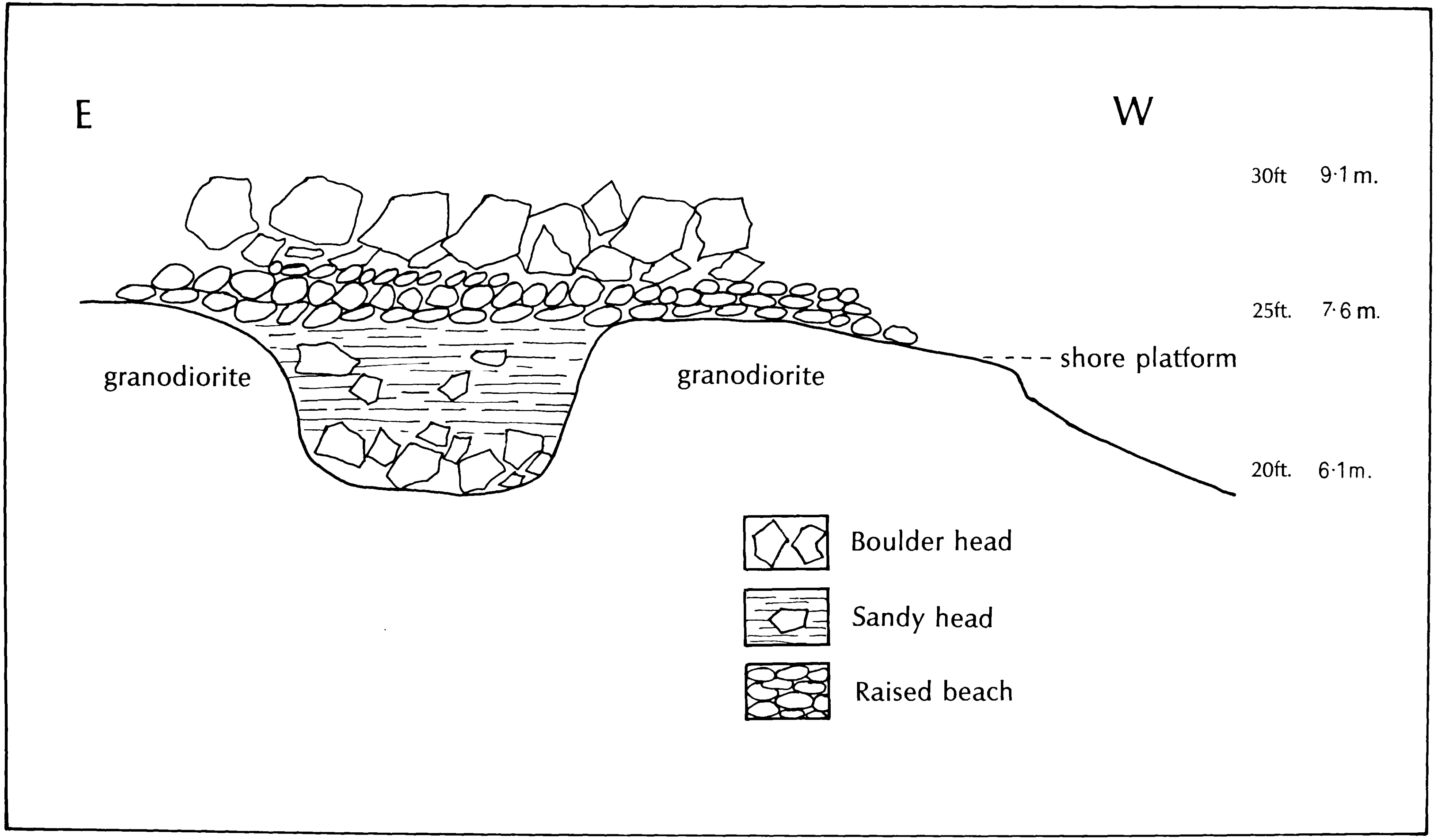

E
W
30ft 9·1 m.
25ft. 7·6 m.
20ft. 6·1 m.
granodiorite
granodiorite
shore platform
Boulder head
Sandy head
Raised beach

Fig. 30. <u>North-south section across central Guernsey showing the 100 ft. (30 m.) and 60 ft. (18 m.) raised beaches.</u>

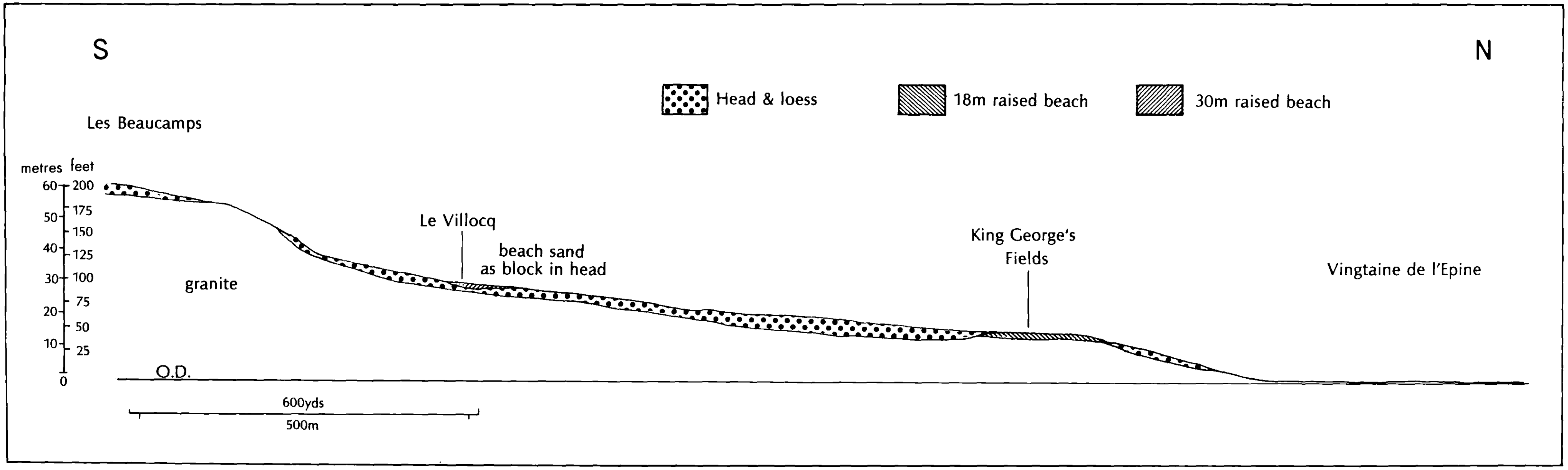
S
N
Head & loess
18m raised beach
30m raised beach
Les Beaucamps
metres
feet
60
50
40
30
20
10
0
200
175
150
125
100
75
50
25
granite
Le Villocq
beach sand
as block in head
King George's
Fields
Vingtaine de l'Epine
O.D.
600yds
500m

Fig. 31. East-west section across part of south-west Guernsey showing the relationship of the 25 ft. (8 m.), 60 ft. (18 m.) and 100 ft. (30 m.) raised beaches.

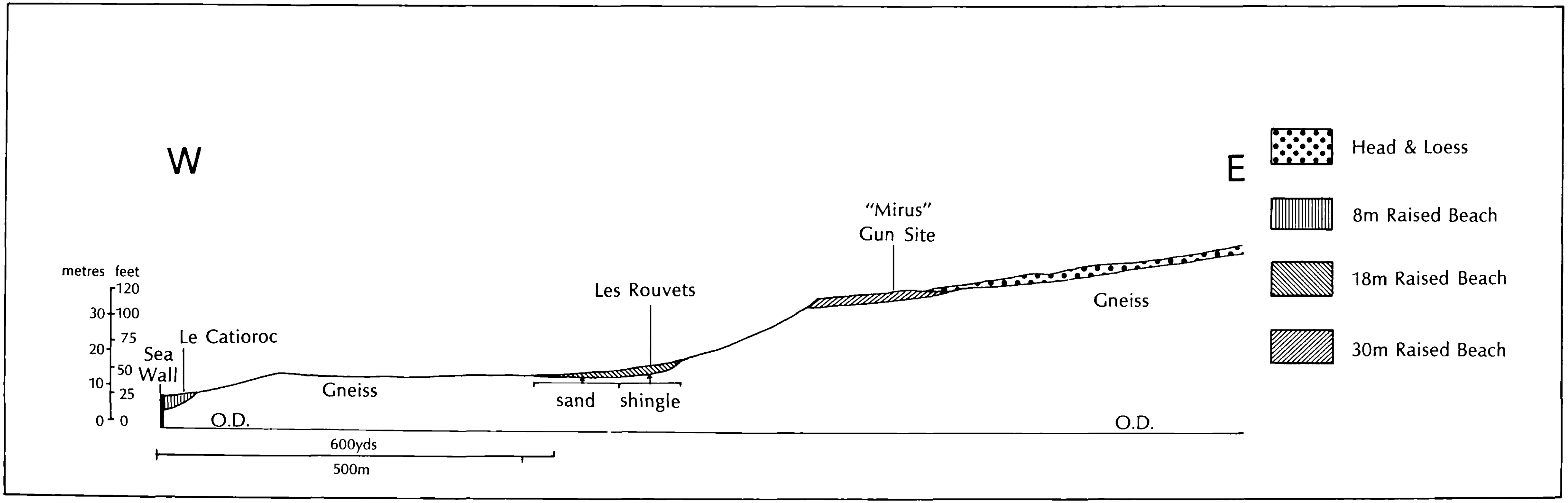
W
E
metres
feet
120
30
100
75
20
50
10
25
0
0
Sea Wall
Le Catioroc
O.D.
Gneiss
600yds
500m
Les Rouvets
sand
shingle
"Mirus" Gun Site
Gneiss
O.D.
Head & Loess
8m Raised Beach
18m Raised Beach
30m Raised Beach

Fig. 32. East-west sections across northern Guernsey showing the relationship of the 25 ft. (8 m.), 60 ft. (18 m.) and 100 ft. (30 m.) raised beaches.

(Note: both these sections are drawn from pairs of superimposed profiles.)

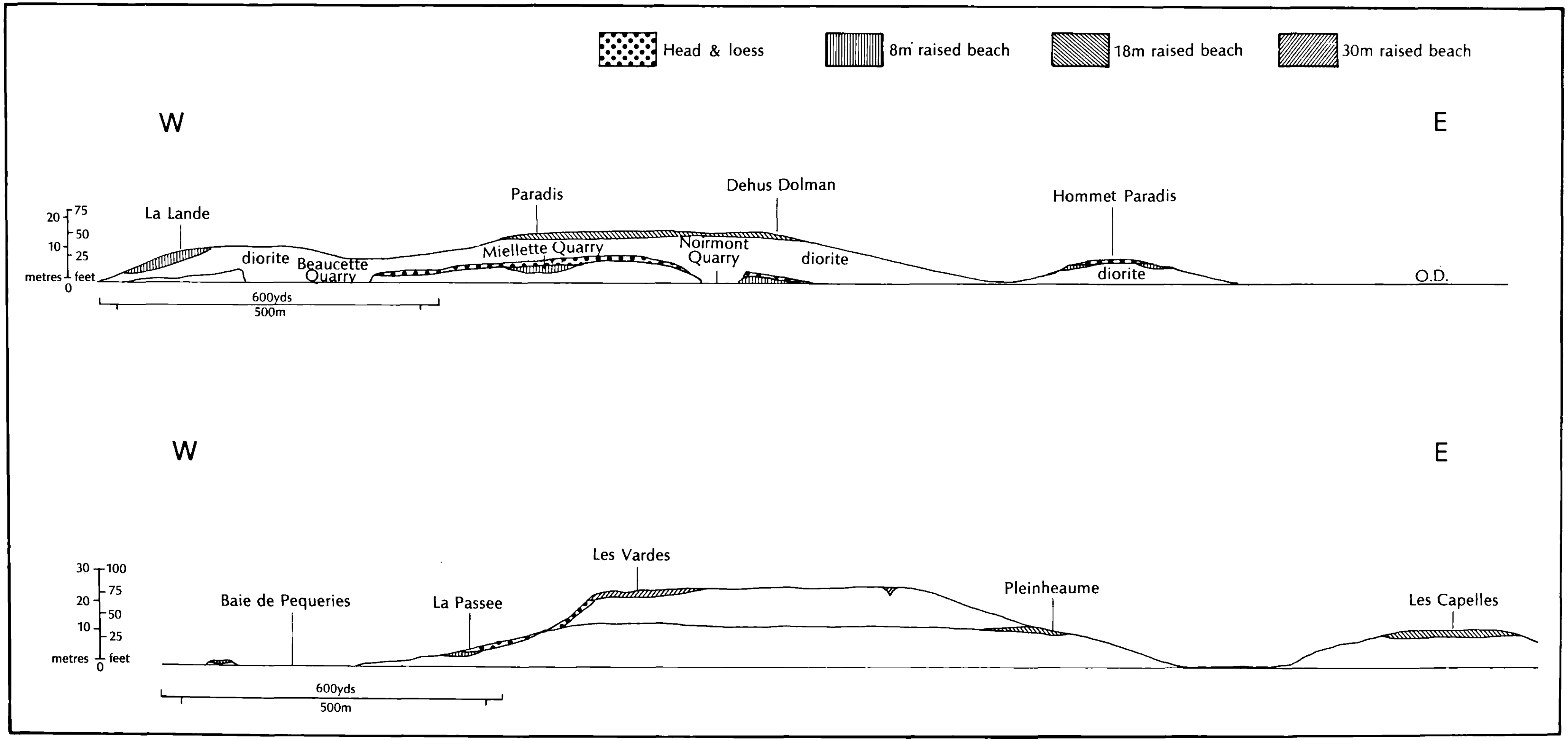

Head & loess
8m raised beach
18m raised beach
30m raised beach
W
E
La Lande
Paradis
Dehus Dolman
Hommet Paradis
diorite
Beaucette Quarry
Miellette Quarry
Noirmont Quarry
diorite
diorite
O.D.
20
10
metres
0
75
50
25
feet
600yds
500m
W
E
Baie de Pequeries
La Passee
Les Vardes
Pleinheaume
Les Capelles
30
20
10
metres
0
100
75
50
25
feet
600yds
500m

Fig. 33. The Moulin Huet cave, Guernsey (WV 330752) showing 25 ft. (8 m.) and 60 ft. (18 m.) raised beaches.

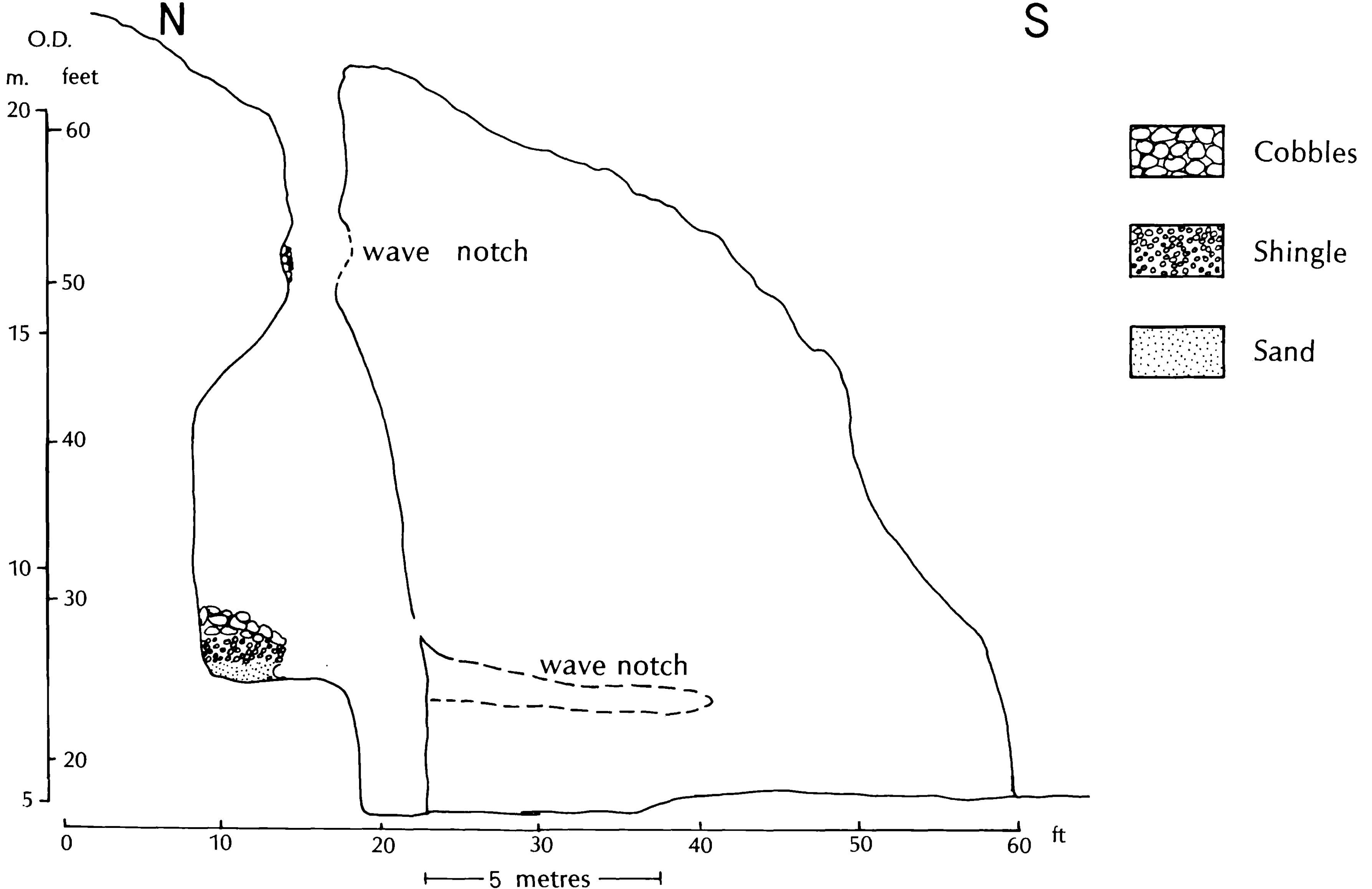

N
S
O.D.
m.
feet
20
15
10
5
60
50
40
30
20
wave notch
wave notch
Cobbles
Shingle
Sand
0
10
20
30
40
50
60
ft
5 metres

Fig. 34. The section in 25 ft. (8 m.) raised beach and head on the south-west side of Longis Bay, Alderney.

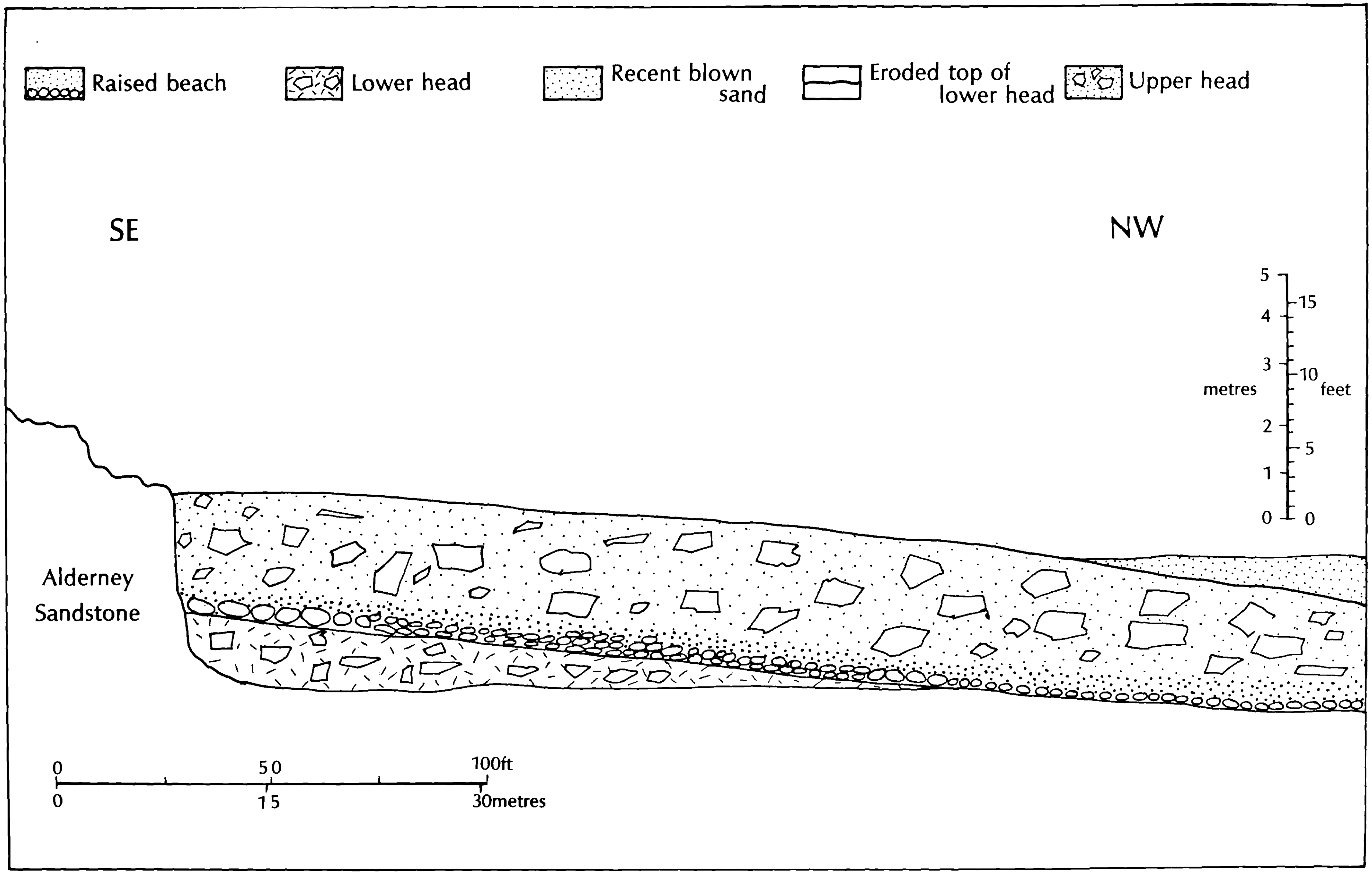

Raised beach
Lower head
Recent blown sand
Eroded top of lower head
Upper head
SE
NW
Alderney Sandstone
metres
feet
5
4
3
2
1
0
15
10
5
0
0
50
100ft
0
15
30metres

Fig. 35. The height ranges[1] of Channel Isles raised beaches

Key to sites

Jersey

1. *St. Clements (WV 686473)
2. *South Hill, St. Helier (WV 652477)

3. *Cotte à la Chèvre (WV 554566)
4. *Ile Agois (WV 597557)
5. *Snow Hill (WV 655484) and Fort Regent Tunnel (WV 655481)
6. *Le Pinacle (WV 545555)
7. Mont Jubilee (WV 575514)
8. *Verclut (WV 699477)
9. Cave at La Saline (WV 631562)
10. Cave at Plemont (WV 558565)

11. Belcroute Bay (WV 607482)
12. Noirmont Point (WV 609469)
13. Portelet Bay (WV 600471)
14. La Cotte de St. Brelade (WV 593475)
15. Bouilly Port (WV 518480)
16. Corbiere (WV 553481)
17. Saie Harbour (WV 705542)
18. Bonne Nuit Bay (WV 642559)
19. Ile Agois (WV 597557)
20. Giffard Bay (WV 649559)
21. Le Sauchet (WV 693549)
22. Belval Cove (WV 710527)
23. Bouley Bay (WV 669549)

Guernsey

24. "Mirus" Battery (WV 264781)
25. Mont Saint (WV 272789)
26. King's Mills (WV 291786)
27. Vale Mill (WV 354824)
28. Les Vardes (WV 317825)
29. Le Villocq (WV 308798)

30. Mont Cuet (WV 334840)
31. Fort Le Marchant (WV 350844)
32. *La Moye (WV 355835)
33. Paradis (WV 359830)
34. La Rochelle (WV 357834)
35. Le Feugre (WV 302809)
36. King George's Fields (WV 314802)
37. La Ramee (WV 325799)
38. *Anneville (WV 322812) - Les Capelles (WV 324813)
39. Pleinheaume (WV 318818)
40. Cailloterie (WV 315824)
41. La Pomare (WV 260770)
42. Les Adams (WV 780258)
43. Les Rouvets (WV 264785)
44. *Moulin Huet (WV 330753)

45. Rousse (WV 324834)
46. *Grande Rocques (WV 298819)
47. Port Infer (WV 308822) - Port Soif (WV 314821)
48. Vazon (WV 284802)
49. Fort Hommet (WV 283805)
50. Fort Le Crocq (WV 270797)
51. *Chouet (WV 334841)
52. *L'Ancresse (WV 349841)
53. Miellette (WV 359834)
54. Spur Point (WV 349807)
55. L'Eree (WV 249785)
56. Catioroc (Chin Chon) (WV 260789)
57. Fermain (WV 339763)
58. Divette (WV 342753)
59. St. Martin's Point (WV 344748)

Alderney

60. Whitegates Railway Cutting (WA 596088)

61. Bibette Head (WA 589091)
62. Corbelets Quarry (WA 596089)
63. Longis Common (WA 601084)

64. Longis Bay (WA 596080)
65. La Grande Folie (WA 605085)
66. Quesnard Quarry (WA 604089)
67. Cat's Bay (WA 605091)
68. Clonque (WA 555073)
69. Hannaine Bay (WA 557073)
70. Fort Tourgis (WA 562079)
71. Bibette Head (WA 589090)
72. Burhou (east end)

[1] Heights marked thus * are from Collenette (1916) or Mourant (1935). Others estimated in the field from spot heights or contours on the six inch map or measured from high water mark by tape.

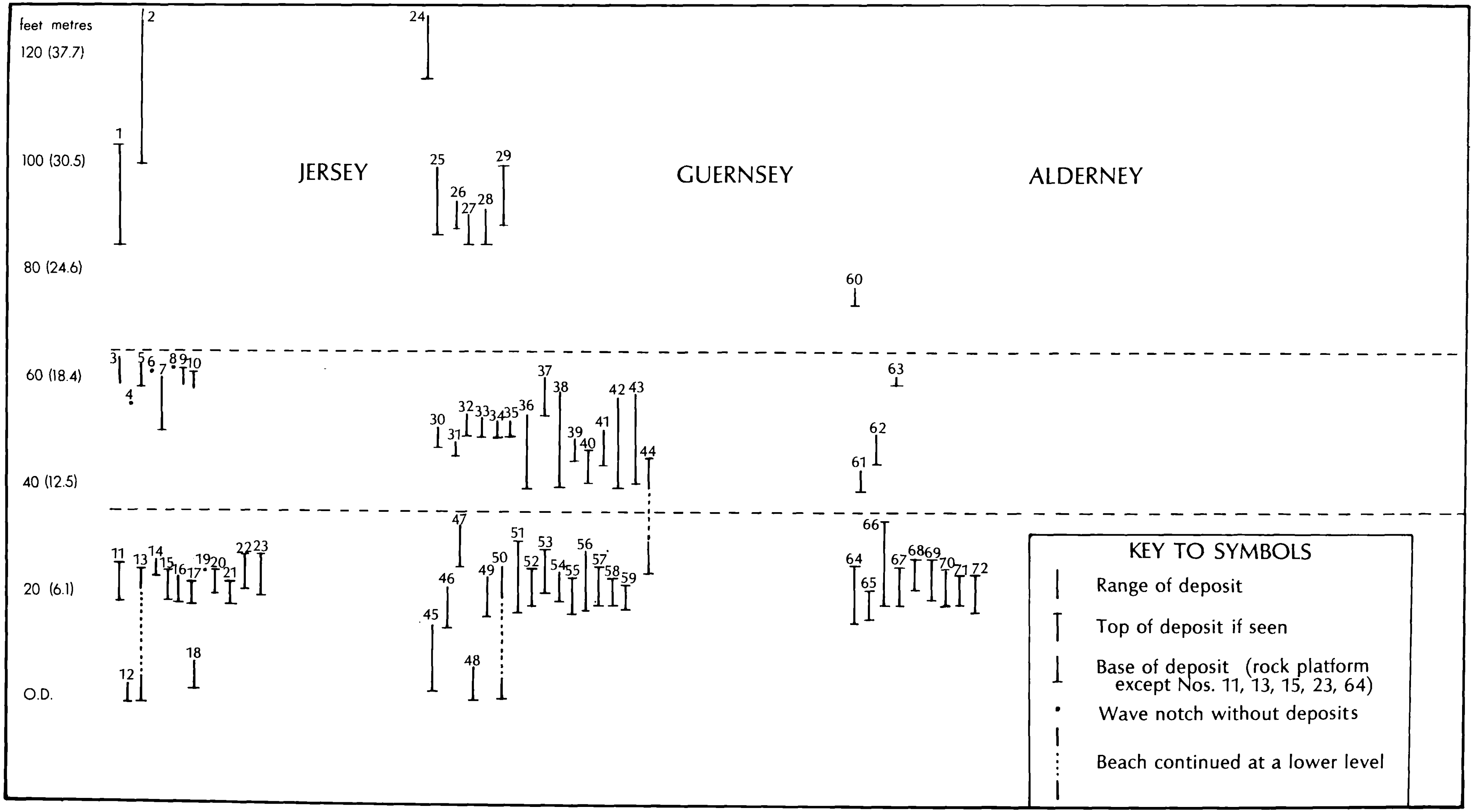
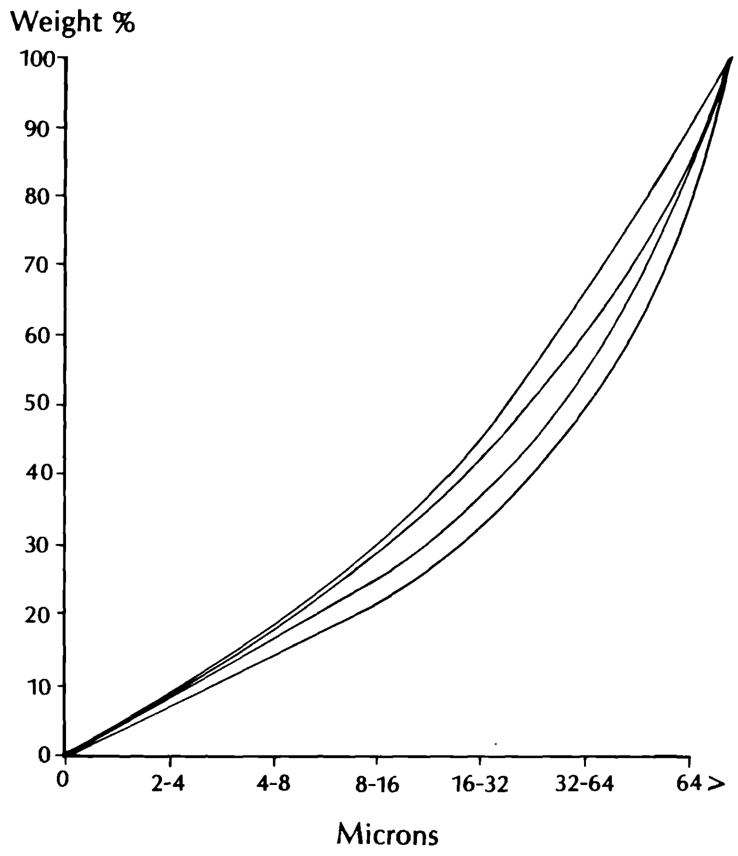
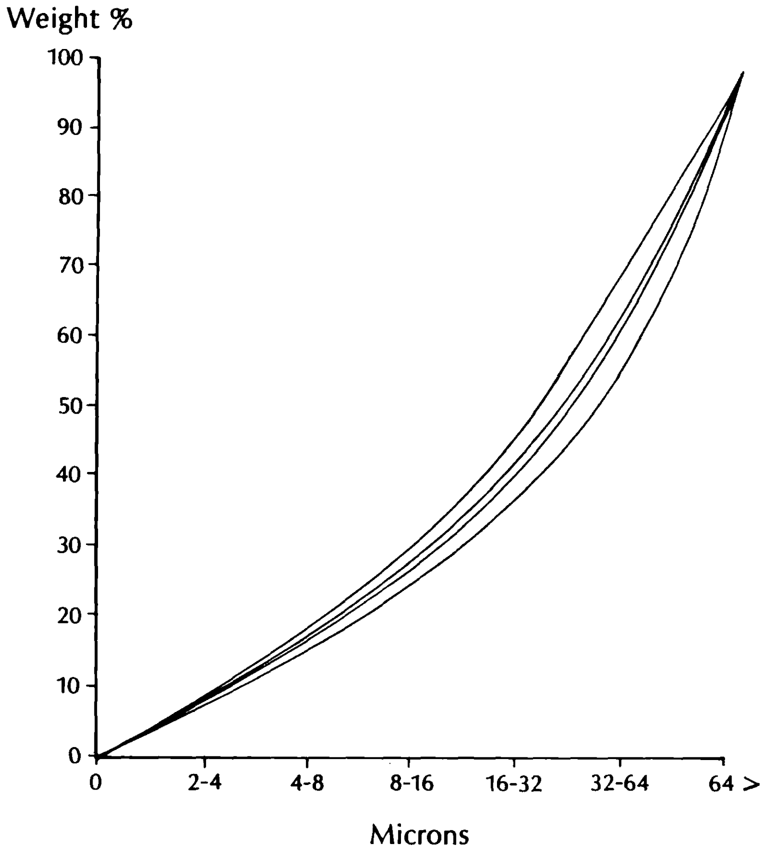

feet metres
120 (37.7)
100 (30.5)
80 (24.6)
60 (18.4)
40 (12.5)
20 (6.1)
O.D.
JERSEY
GUERNSEY
ALDERNEY
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
KEY TO SYMBOLS
Range of deposit
Top of deposit if seen
Base of deposit (rock platform except Nos. 11, 13, 15, 23, 64)
Wave notch without deposits
Beach continued at a lower level

Fig. 36. Grain-size distribution of some Channel Isles loess deposits.



Sample numbers 23, 24, 26, 29 (Jersey)



Sample numbers 26, 29, 41, 53, (Guernsey)

Fig. 37. The composition of the 25 ft. (8 m.) raised beach in the Channel Isles.

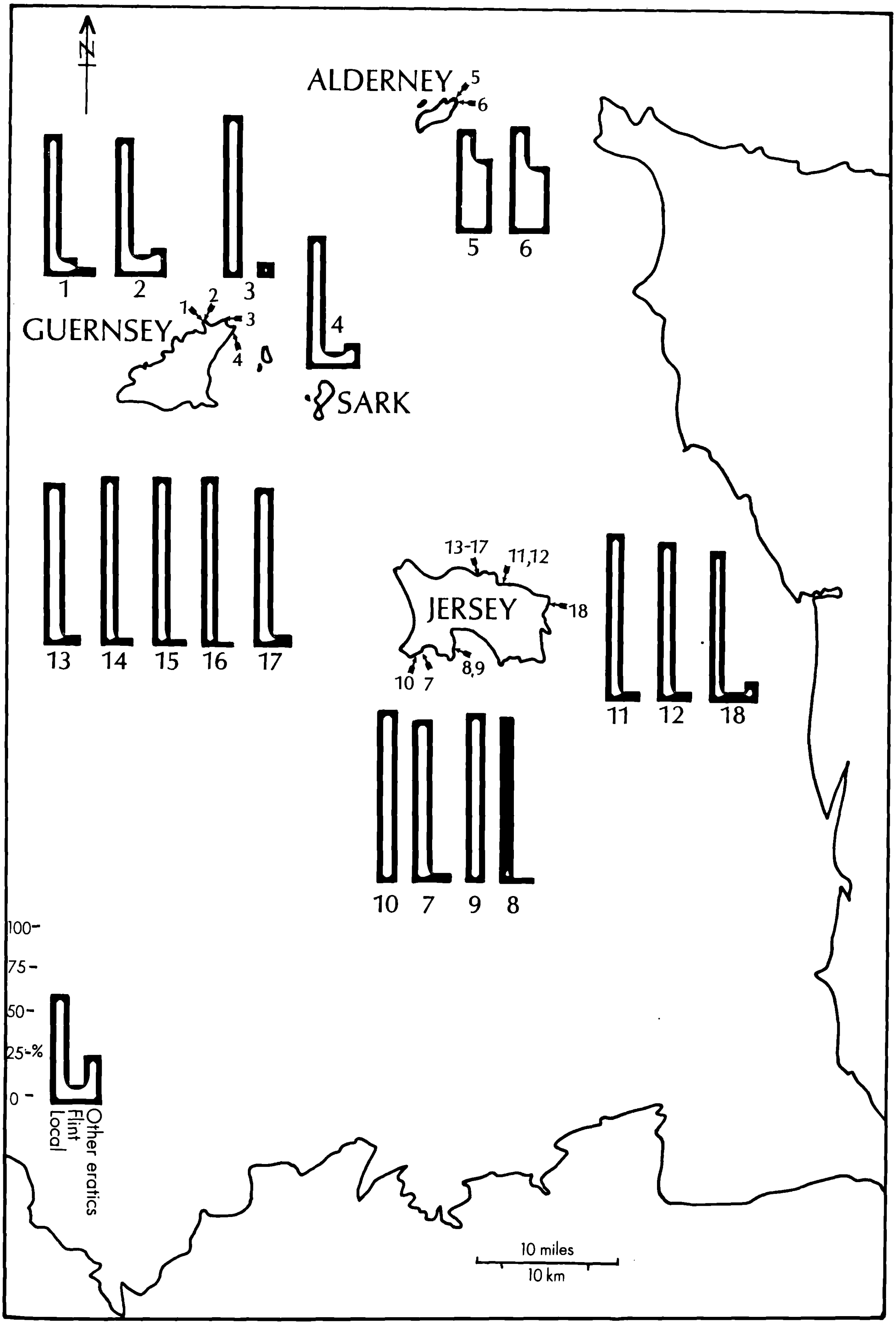

N
ALDERNEY
5
6
1
2
3
GUERNSEY
1
2
3
4
4
SARK
5
6
13
14
15
16
17
13-17
11,12
JERSEY
18
10
7
8,9
11
12
18
10
7
9
8
100-
75-
50-
25-%
0-
Other eratics
Flint
Local
10 miles
10 km

Fig. 38. The Channel Isles - location map (pocket).

Fig. 39. Guernsey - location map (pocket).

Fig. 40. Jersey - location map (pocket). [illegible]
[illegible]

Fig. 41. Interglacial sites in Britain. (Chiefly from Mitchell et al. 1973.) (Pocket).

Plate 1. A panoramic view, looking east, across the surface of the 60 ft. (18 m.) terrace near St. Leonard's Grange (SZ 400977).

Plate 2. The view south from SZ 402977 near St. Leonard's Grange showing the surface of the 60 ft. (18 m.) terrace, with its coarse gravel showing up well on the ploughed field in the foreground. In the middle distance the 25 ft. (8 m.) terrace occurs while in the distance can be seen the Solent and the Isle of Wight.

Plate 3. Hengistbury Head and the mouth of the Avon, showing the 100 ft. (30 m.) level on the summit of the hill and the 60 ft. (18 m.) level forming an extensive flat below the main summit.

Plate 4. View down-stream from Boldre Bridge (SZ 320985) on the Lymington River showing the lack of terraces within the incised section of the lower Lymington River. The steep slopes covered with vegetation rise directly to the surface of the 100 ft. (30 m.) terrace of the Solent from the modern floodplain.

Plate 5. View upstream from Boldre Bridge (SZ 320985) on the Lymington River showing the steep sides of the valley and its narrow floodplain.

Plate 6. View down-stream from Balmer Lawn (SU 305031) on the Lymington River showing the wide open valley form above the elbow of capture.

Plate 7. View down-stream from Bailey's Hard (SU 395014) on the Beaulieu River showing a fragment of the 25 ft. (8 m.) terrace of the Beaulieu River and the slope break of the bluff rising to the forested 100 ft. (30 m.) level on the skyline.

Plate 8. The steep valley sides rising to the surface of the 25 ft. (8 m.) terrace and the peaty valley infill of the climatic misfit valley just to the west of Nelson's Place (SU 470001). The present stream in this valley flows in an artificial channel.

Plate 9. Pennington west pit (SZ 308930) looking east showing the gravels of the 25 ft. (8 m.) terrace and the clay of the Headon beds in the floor of the pit.

Plate 10. Pennington west pit (SZ 308930) looking south showing the horizontally bedded gravel of the 25 ft. (8 m.) terrace, up to 15 ft. (4.6 m.) thick at this point and resting on the Headon beds clay which can be seen in the sides of the pool in the foreground.

Plate 11. Pennington east pit (SZ 311936) showing the working face with low angle cross bedding in a sand layer between two medium coarse gravels. The gravel thins to about 10 ft. (3 m.) in thickness towards the excavator from 15 ft. (4.6 m.) at the south end of the pit.

Plate 12. Hall's Pit (SU 450020) showing the 15 ft. (4.6 m.) of horizontally bedded gravel of the 60 ft. (18 m.) stage. The face in the foreground is current bedded in sand lenses.

Plate 13. Gravels of the 100 ft. (30 m.) stage at Barton (SZ 239930) showing around 15 ft. (4.6 m.) of coarse gravel resting on an eroded bench of Barton Sands. The top 6 ft. (2 m.) of the section is brickearth. The arrow A points to the semi-consolidated block of silt shown in close-up in Plate 35 and arrow B to other blocks of sand as described in Chapter II.


B

Plate 14. A block of fine sand and silt in the base of the gravel at Barton (SZ 239930). The silt block can be seen to have trapped pockets of fine gravel beneath it as it fell and may even have pressed them into the underlying Barton Sand.

Plate 15. A general view of Stone Point viewed from the west. The Ipswichian deposits occur below the figure on the foreshore.

Plate 16. The cliffs of the 25 ft. (8 m.) terrace at Lepe. The Ipswichian deposits underlie the shallow sloping area on the right of the photograph and are buried by the modern beach in the centre of the picture.

Plate 17. A close-up of the foreshore at Lepe. The peaty silts and clays of the Ipswichian interglacial occur in the upper half of the photograph and are generally covered with green seaweed. The black colour of the peat can be seen in the excavations to the right and top left of the picture while the grey area in the centre of the photo shows the eroded surface of the clay. The pebbly clay and ferruginous lower gravel can be seen outcropping on the left of the photo while the junction between the red gravel and the clay can be seen in the centre of the photo.

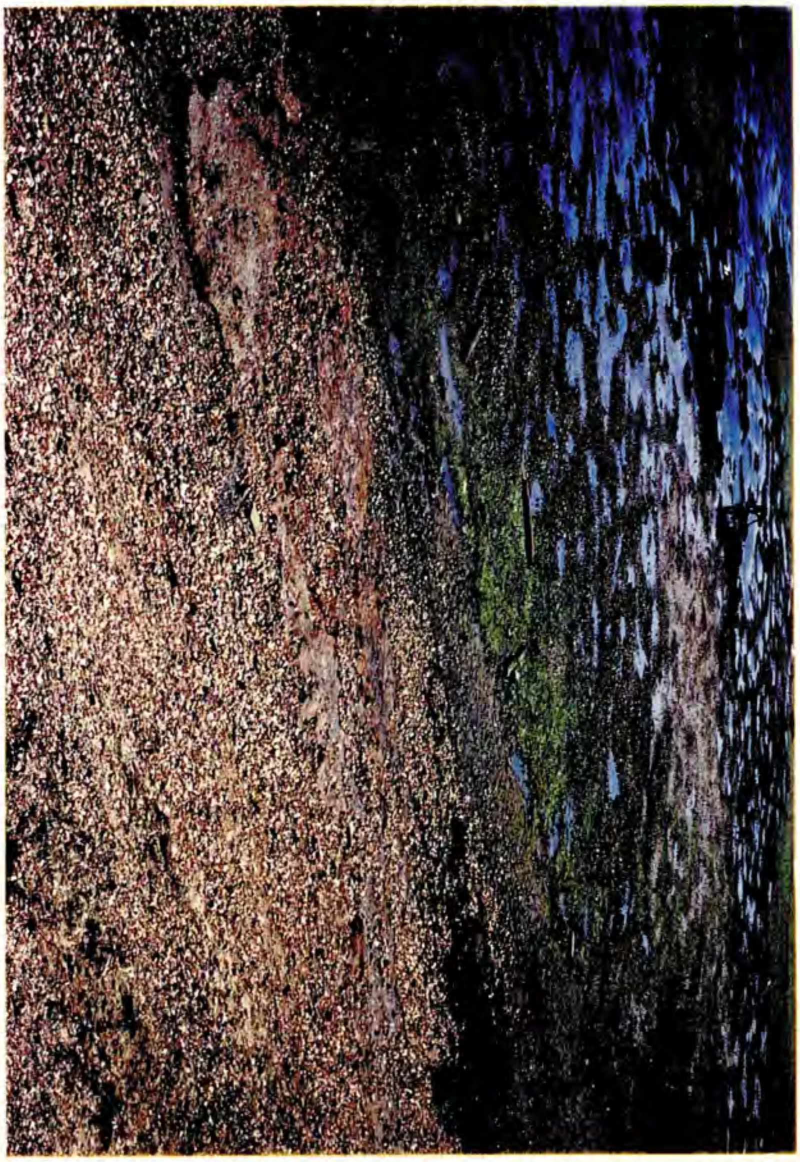


Plate 18. The eroded surface of the Ipswichian clay at Lepe showing carbonised acorn bases (Quercus sp.) in situ. The smaller carbonised particles are also plant debris within the clay but the flint pebbles are from the modern beach.

Plate 19. Lepe. The cliff behind the beach showing the junction between the pebbly clay in the lower half of the photo and the late Ipswichian or early Weichselian gravel of the 25 ft. (8 m.) terrace in the upper half of the photo.

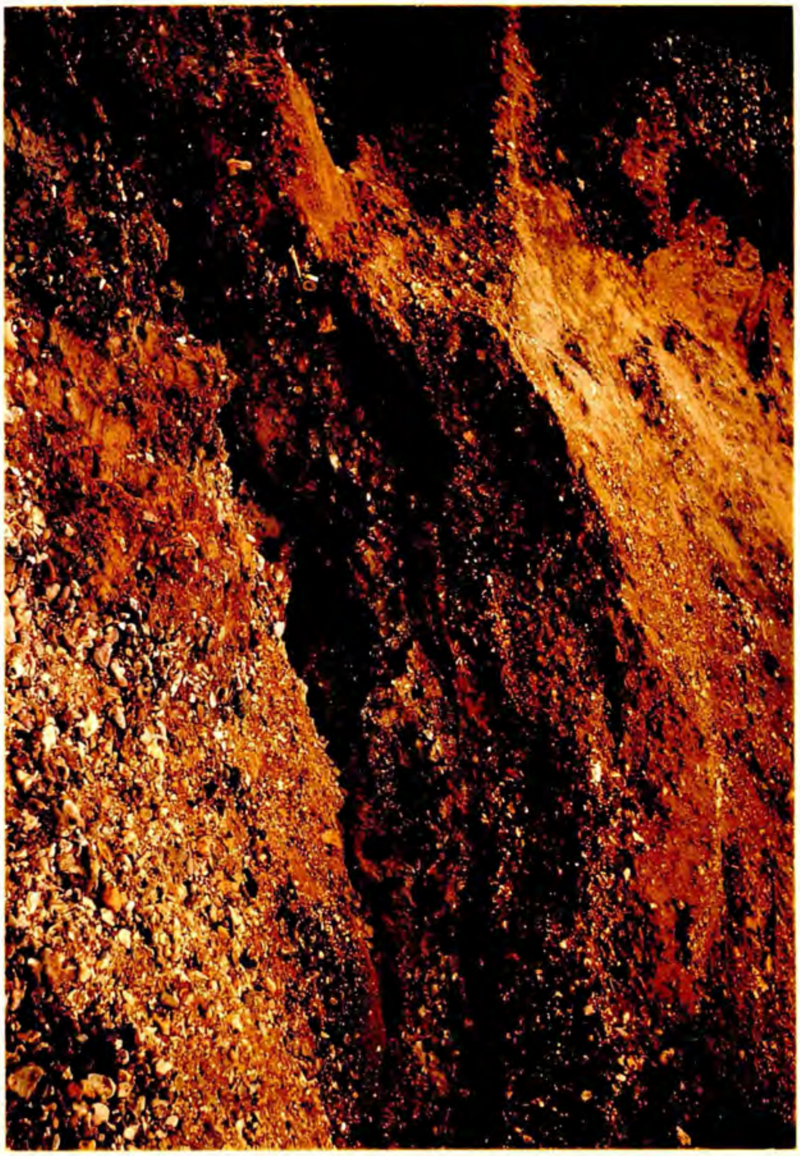


Plate 20. Current bedded sand filling a small channel in the gravel of the 25 ft. (8 m.) terrace at Cadland (SU 471003).

Plate 21. The coarse sand and gravel of the 25 ft. (8 m.) terrace at Cadland (SU 471003).

Plate 22. Coarse gravel with only slight evidence of bedding, Hall's pit (SU 450020) in the 60 ft. (18 m.) terrace.

Plate 23. Medium unbedded gravel of the 100 ft. (30 m.) terrace near Barton (SZ 239930). The base of the gravel in this photo can be seen resting on the Barton sand while the top of the section is composed of a thin, stony brickearth.

Plate 24. Coarse bedded gravel of the 25 ft. (8 m.) terrace at Pennington west pit (SZ 308930).

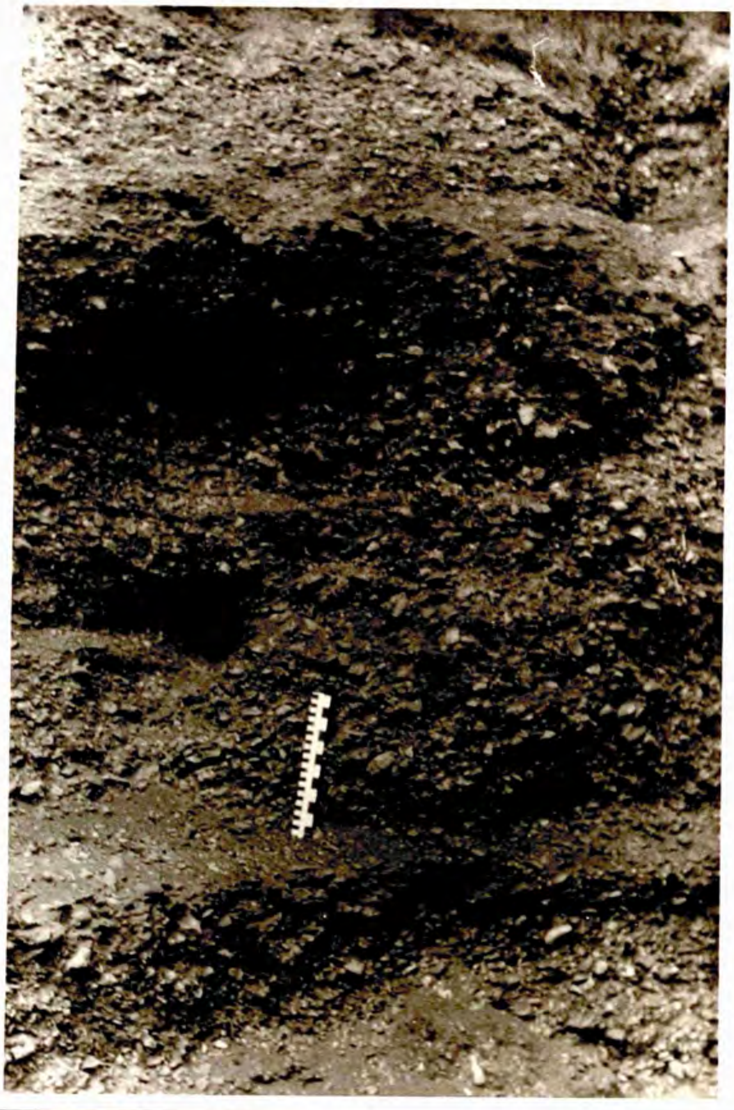


Plate 25. Coarse slightly rolled flint cobble in situ in the top of the 25 ft. (8 m.) terrace at Pennington west pit (SZ 308930). The lens cover in the photo is 2 inches (50 mm.) in diameter.

Plate 26. Coarse gravel of the 100 ft. (30 m.) terrace at Highcliffe (SZ 210931) showing possible slight frost action with the erection of some pebbles so their long axes are vertical.

Plate 27. Minor flame-type involutions in the sandy gravel of the top of the 60 ft. (18 m.) terrace at Hall's Pit (SU 449021). The penetration of frost action into the gravel has only been slight as the sand layers in the bottom of the gravel are undisturbed.

Plate 28. Bedded solifluction deposits on the edge of the 60 ft. (18 m.) terrace at Hengistbury Head (SZ 166907). The individual beds are composed mainly of sand derived from the Tertiaries but also of some of the gravel from the 60 ft. (18 m.) terrace.

Plate 29. The gravel of the 100 ft. (30 m.) terrace at Barton (SZ 245928) showing an irregular junction with the Barton Series below it and a thin brickearth overlying it.

Plate 30. Cliffs cut in the Barton series near Barton (SZ 243928) showing a thin gravel of the 100 ft. (30 m.) terrace overlying the easterly dipping Barton beds rich in iron concretions.

Plate 31. Eroded cliffs of Barton sands near Becton Bunny (SZ 253925) with a cap of gravel of the 100 ft. (30 m.) terrace at the top.

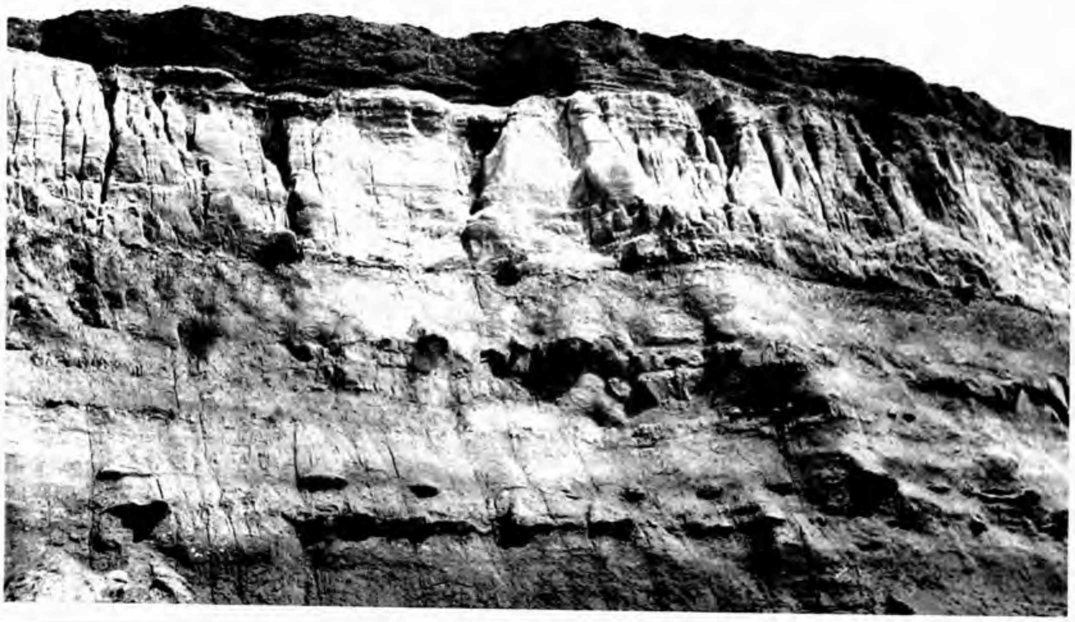


Plate 32. An Acheulian handaxe found on the floor of Hall's Pit (SU 449021).

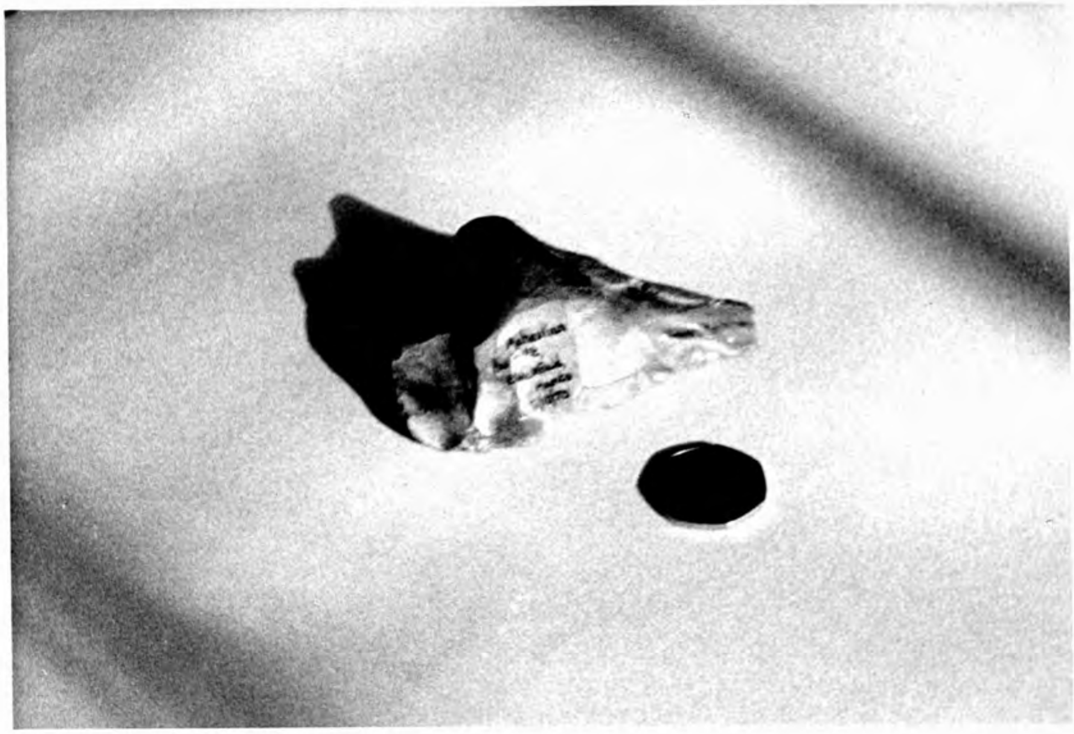


Plate 33. Deeply weathered granodiorite in Beaucette Quarry (WV 359837), Guernsey. Note the large core stones and intensified weathering along vertical joints.

Plate 34. Deeply weathered granodiorite in Beaucette Quarry, Guernsey. Note the large core stones in pockets of rock decomposed to sand and the 6 ft. (2 m.) of loess (arrowed) at the south side of the quarry.


C1

Plate 35. The low shore platform at La Bette, Guernsey (WV 315748). The modern sandy beach in the foreground is at around mean sea level so the rock platform here is at around 20 ft. (6 m.) O.D.

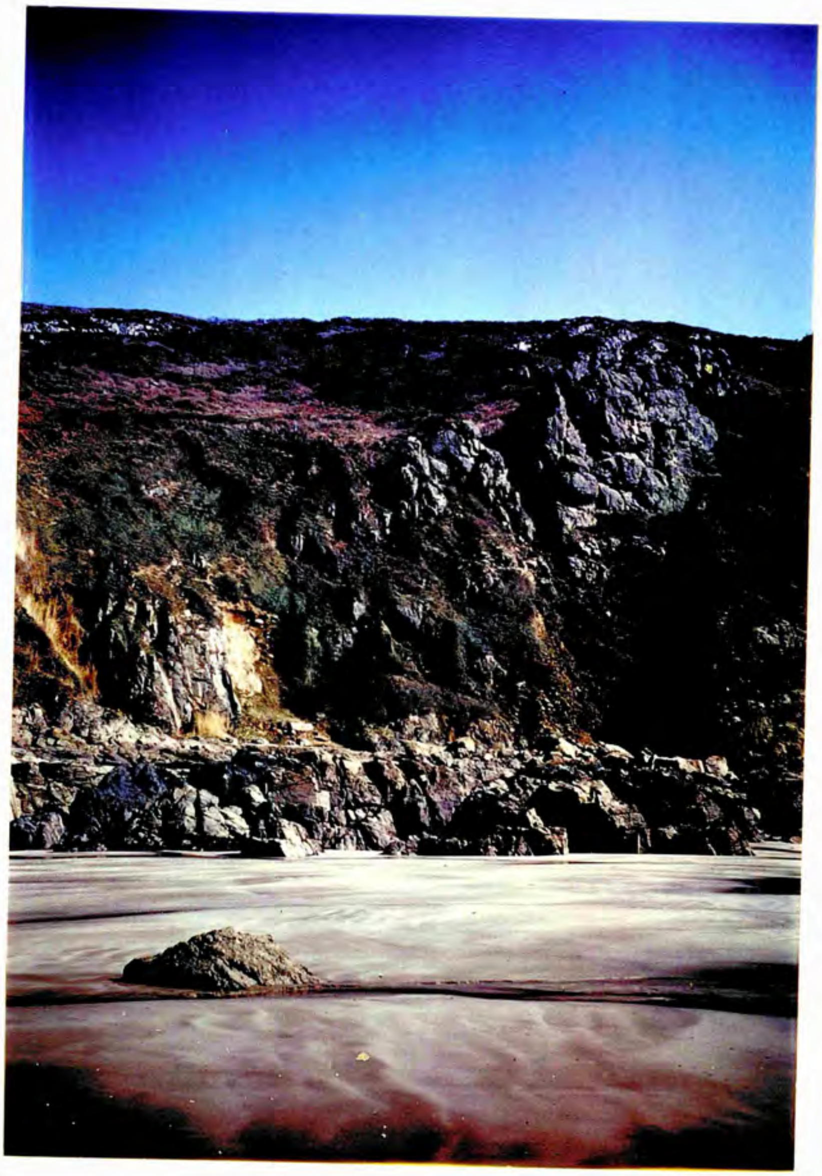


Plate 36. The reefs in Cobo Bay, Guernsey, looking north from La Guet Battery (WV 295805). Note the generally accordant level of the top of the rocks formed by remnants of the low shore platform.

Plate 37. The classic section in Belcroute Bay, Jersey (WV 607482). In the section can be seen (a) bedded head of greywacke, inclinedat 30° to the east (left); (b) level with the figure's head, the 25 ft. (8 m.) raised beach composed primarily of granite; (c) up to 5 ft. (c. 2 m.) of horizontally bedded blown sand becoming more stony near the top; and (d) loessic head of greywacke fragments. The raised beach gravel can be clearly seen to rest unconformably on the lower head.

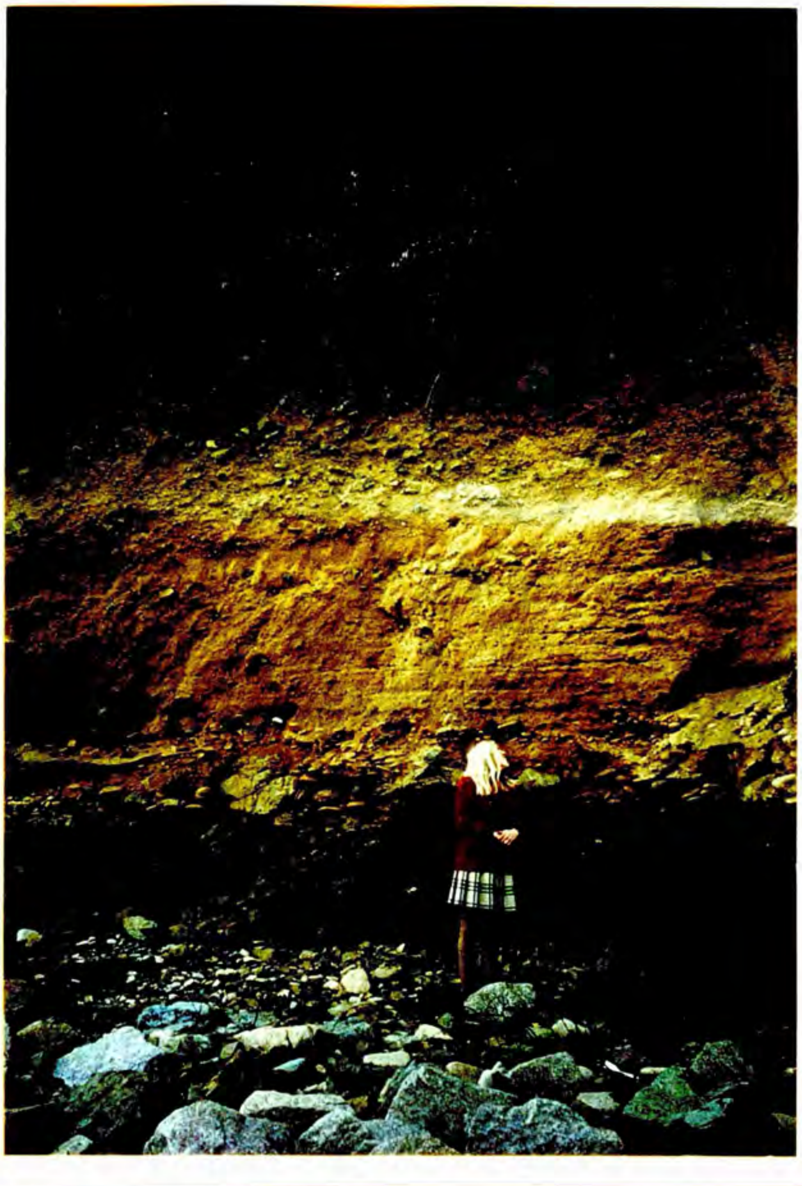


Plate 38. The cemented 25 ft. (8 m.) raised beach 200 yds. (180 m.) north of Noirmont Point, Jersey (WV 609469). Note the cemented nature of the beach and the way it forms an upstanding mass in the modern beach. At the back of the modern beach is a 50 ft. (15 m.) cliff of head rubbly at the base but more loessic upwards.

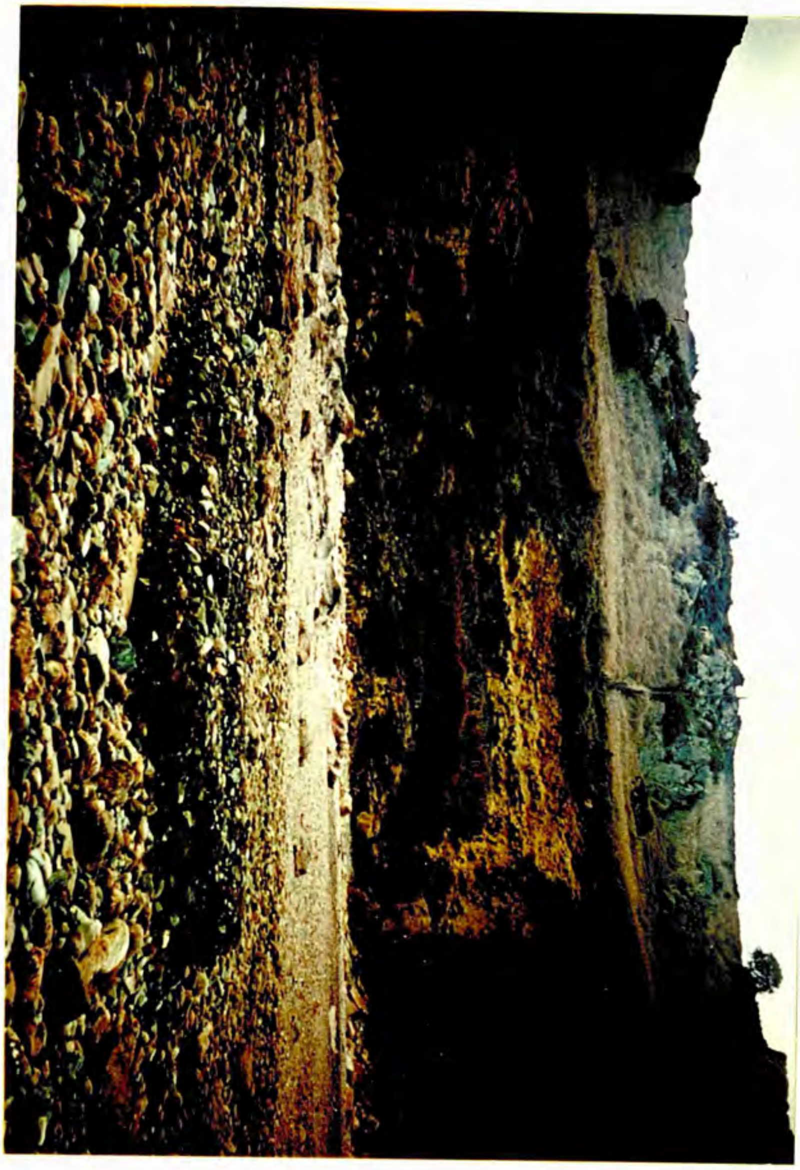


Plate 39. The 25 ft. (8 m.) beach on the north-east end of Burhou, Alderney. To the right of the photograph the beach can be seen to rest on a well polished platform of steeply dipping Pre-Cambrian Alderney sandstone.

Plate 40. The low raised beach in the Moulin Huet Cave, Guernsey (WV 330753). The beach can be seen to be resting on a smooth platform of Pre-Cambrian Icart Gneiss. Note that the beach becomes increasingly coarse upwards and is very well cemented by iron oxides.

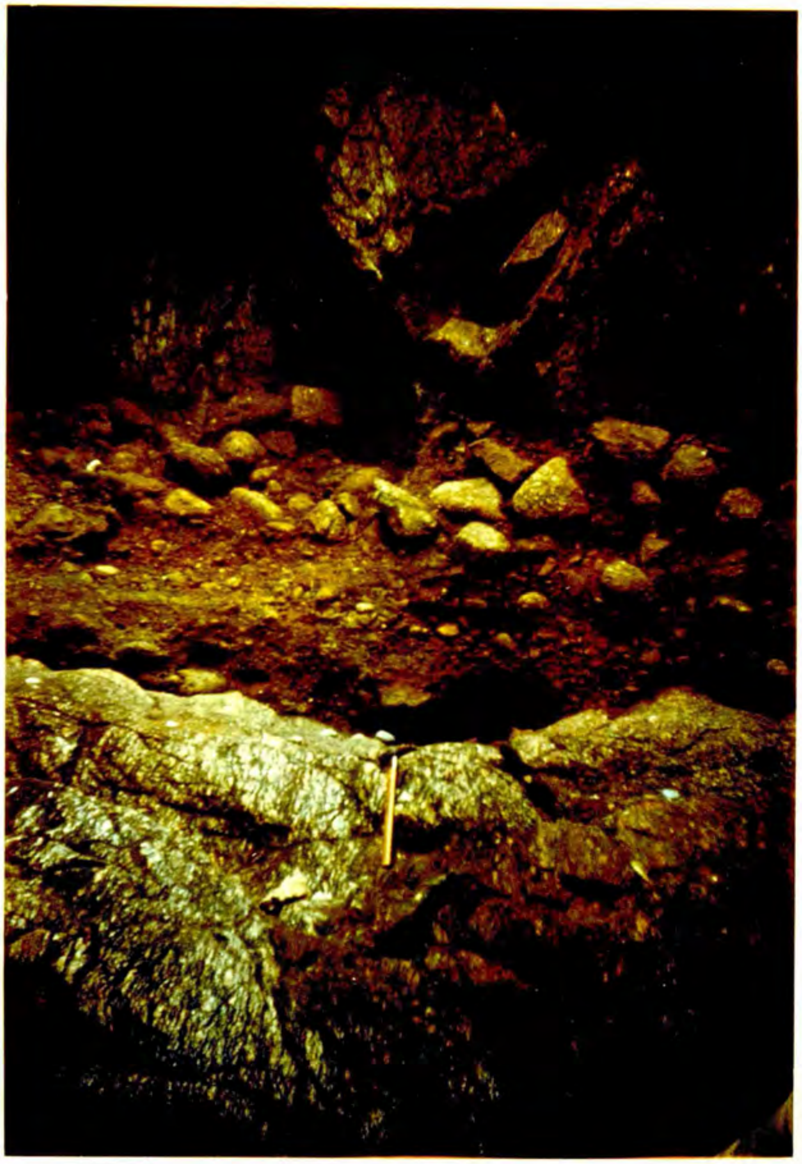


Plate 41. The 25 ft. (8 m.) beach on the west side of La Bette, Guernsey (WV 314748). The beach fills a gully cut along a small fault in Pre-Cambrian Icart Gneiss and its top is at 33 ft. (10 m.) O.D.

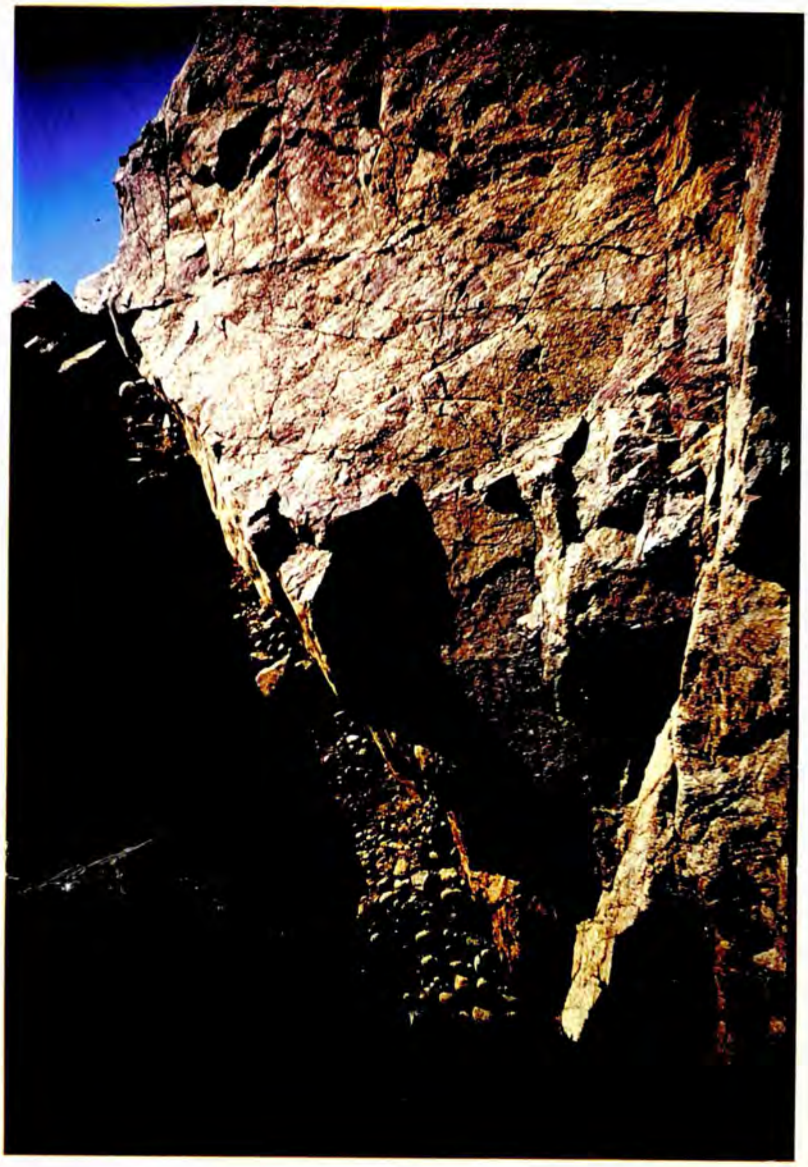


Plate 42. 25 ft. (8 m.) raised beach on the south side of Hommet Paradis (WV 364828), Guernsey. This section is on a low island and is only covered with a thin soil and made ground of quarry waste. The great variation in rounding in the beach material can be seen in the photograph.

Plate 43. General view of the south side of Hommet Paradis, Guernsey (WV 364828). The section in Plate 42 is arrowed. Note the low level of the islet, typical of many in the Channel Isles, which still retain a partial cover of raised beach.

Plate 45. 25 ft. (8 m.) raised beach at Chouet (WV 332842), Guernsey. Up to 5 ft. (1.5 m.) of well rounded beach gravel with several conspicuous flints (arrowed) overlying deeply weathered granodiorite. Above the beach gravel is around 2 ft. (65 cm.) of loessic head.

Plate 46. 25 ft. (8 m.) raised beach at Rousse (WV 323833), Guernsey. General view showing the large expanse of ancient beach uncovered by the stripping of the modern beach sand, a small remnant of which can be seen in the bottom right-hand corner.

Plate 47. Raised beach at the east side of Mont Cuet Quarry (WV 333842) revealed by quarrying, June 1974. The height of the beach is unknown, although it is probably the lower edge of the 60 ft. (18 m.) beach which occurs in the back of the quarry. The unstable edge of the quarry has made close examination of this deposit impossible.

Plate 48. The shore platform cut across phyllite at Divette (WV 341754), Guernsey. Note some 25 ft. (8 m.) of head and raised beach gravel still forming a vertical section even though the base of the superficial deposits is only rarely washed by the sea.

Plate 49. 25 ft. (8 m.) raised beach at L'Eree slip (WV 248785), Guernsey. The beach is bedded sandy gravel at its base where it rests on a worn surface of L'Eree adamellite, but grades up into coarser gravel. The beach deposits are succeeded by loessic head (indicated by the hammer).

Plate 50. The 25 ft. (8 m.) beach at L'Eree, Guernsey (WV 249785). This photograph is 30 ft. (9 m.) to the south-west of Plate 49 and several differences can be seen from this section. The beach gravel is not sandy at its base and the overlying head has less angular material in it. This rapid change of deposits is typical of raised beach / head sections in the Channel Isles.

Plate 51. View of the granodiorite quarry at Les Vardes looking south, November 1972. The position of the 100 ft. (30 m.) raised beach exposures is indicated by the arrows.

Plate 52. 100 ft. (30 m.) raised beach in Les Vardes Quarry (WV 317826), Guernsey. Note the extremely weathered nature of the granodiorite below the beach gravel.

Plate 53. The 100 **ft.** (30 m.) beach gravel at Les Vardes, Guernsey (WV 317825). Note the extremely weathered granodiorite below the beach and the cemented nature of the beach gravel itself.

Table I

Granulometry and composition distribution of the South Hampshire gravels

(For the location of sampling sites, see map, fig. 7)

(A) 15 ft. (4.5 m.) terrace

Sample 7. W. of Hengistbury Head

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	3	22	53	90	38.40
Quartz			3	13	221	53.86
Chert			1	2	4	1.59
Sandstone	1			3	9	2.94
Other				3	11	3.18

Total count 440

(Note: This sample was taken from the very quartzose gravels of the Avon).

(B) 25 ft. (8 m.) terrace

Sample 4. Sowley Pond Pit

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2	5	15	53	94	72.22
Quartz			1	5	45	21.78
Chert			1	2	3	2.56
Sandstone					5	2.13
Other					3	1.27

Total count 234

Sample 5. E. of Sowley Pond Pit

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	3	27	143	365	73.33
Quartz			1	5	136	19.31
Chert			2	7	19	3.80
Sandstone				4	11	2.04
Other					11	1.49

Total count 735

Sample 13. Cadland

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	5	29	94	169	84.18
Quartz				1	38	11.01
Chert				1	2	0.84
Sandstone			5	4	3	3.38
Other					2	0.56

Total count 354

Sample 15. Cadland

Total count 407

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	2	16	94	207	78.24
Quartz			1	1	67	16.95
Chert				5	4	2.21
Sandstone				3	5	1.96
Other				1		1.41

Sample 17. Cadland

Total count 463

	1½"	1"	½"	¼"	⅛"	% of total
Flint		1	31	113	152	64.14
Quartz				12	114	27.21
Chert			4	2	6	2.59
Sandstone				3	11	3.01
Other				1	13	3.01

Sample 19. Cadland

Total count 345

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	9	22	65	169	77.10
Quartz				4	48	15.07
Chert				6	4	2.89
Sandstone			2	4	8	4.33
Other					2	0.56

Sample 39. Milford

Total count 214

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2	5	19	52	90	78.50
Quartz				2	31	3.73
Chart				2		0.93
Sandstone				3	8	5.13
Other						

Sample 41. Pennington West Pit

Total count 575

	1½"	1"	½"	¼"	⅛"	% of total
Flint		3	32	115	329	83.30
Quartz				6	66	12.52
Chert			2			0.34
Sandstone			3	6	13	3.81
Other						

Sample 42.   Pennington West Pit

Total count 350

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	6	21	63	154	70.00
Quartz			1	9	78	25.14
Chert					5	1.42
Sandstone			1	1	8	2.85
Other					1	0.28

(C) 60 ft. (18 m.) terrace

Sample 6.   East End Pit

Total count 404

	1½"	1"	½"	¼"	⅛"	% of total
Flint			22	92	177	72.02
Quartz		1	1	2	78	20.29
Chert			1	3	7	2.72
Sandstone		1	1	2	9	3.21
Other					7	1.73

Sample 10.   Hordle House

Total count 445

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	2	24	86	210	72.35
Quartz				4	80	18.87
Chert				3	8	2.47
Sandstone		1	1	1	15	4.03
Other				1	8	2.01

Sample 22.   Hall's Pit

Total count 500

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	3	24	105	227	72.00
Quartz				18	94	22.00
Chert					9	1.80
Sandstone				4	6	2.00
Other				2	8	2.32

Sample 33.   Hordle Cliff

Total count 417

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2	4	19	70	192	68.80
Quartz				4	79	19.90
Chert				7	8	3.59
Sandstone				4	18	5.26
Other					6	1.43

Sample 35. Hall's Pit

Total count 361

	1½"	1"	½"	¼"	⅛"	% of total
Flint	4		20	59	201	78.67
Quartz				5	57	17.17
Chert				2	2	1.10
Sandstone			1		5	1.65
Other					5	1.38

Sample 38. Hordle Cliff

Total count 827

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2	1	24	118	432	69.77
Quartz			1	18	186	24.78
Chert			3	3		0.72
Sandstone					38	5.59
Other				1		0.12

(D) 100 ft. (30 m.) terrace

Sample 8. Barton Cliff

Total count 361

	1½"	1"	½"	¼"	⅛"	% of total
Flint		1	15	89	206	85.87
Quartz				2	31	9.14
Chert			1	1	2	1.10
Sandstone				4	10	3.86
Other						

Sample 9. Barton Cliff

Total count 417

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2		12	74	237	77.93
Quartz				3	51	12.94
Chert	1		1	2	7	2.63
Sandstone				4	13	4.06
Other				2	8	2.38

Sample 11. Barton Cliff

Total count 261

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	3	11	52	157	81.99
Quartz					20	7.66
Chert			2	3	5	3.83
Sandstone				4	9	4.97
Other					4	2.05

Sample 25. Highcliffe

Total count 342

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	1	16	63	219	87.71
Quartz					13	3.80
Chert			3	2	3	2.35
Sandstone			1	1	19	6.12
Other						

Sample 26. Highcliffe

Total count 398

	1½"	1"	½"	¼"	⅛"	% of total
Flint	2		19	93	260	93.96
Quartz				1	2	0.75
Chert			2	4	8	3.51
Sandstone			1		5	1.51
Other					1	0.36

Sample 27. Highcliffe

Total count 442

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	3	17	100	288	92.54
Quartz					10	2.26
Chert			2	3	1	1.35
Sandstone				4	13	3.84
Other						

Sample 29. Chewton Bunny

Total count 259

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	2	21	67	156	95.36
Quartz				1	6	2.70
Chert			1		1	0.77
Sandstone		1		1	1	1.15
Other						

Sample 30. Barton Cliff

Total count 189

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	8	28	40	94	90.47
Quartz					9	4.76
Chert				1	2	1.58
Sandstone					4	2.10
Other					2	1.80

Sample 31. Barton Cliff

Total count 391

	1½"	1"	½"	¼"	⅛"	% of total
Flint			28	142	187	91.30
Quartz					5	1.27
Chert			2	4	2	2.04
Sandstone			2	5	14	5.37
Other						

Sample 32. Barton Cliff

Total count 494

	1½"	1"	½"	¼"	⅛"	% of total
Flint	1	2	23	92	225	69.43
Quartz				6	117	24.89
Chert			1	1	7	1.82
Sandstone				2	18	2.02
Other					9	1.82

Note 1: The classes "sandstone" and "other" are used in the above tables for uniformity and comparison purposes. The "sandstone" class contains material which is almost entirely of sarsen origin but some of these white sandstone pebbles may be bleached greensand.

The "other" class contains a wide variety of far travelled material all in the lower size grades and very well rounded and so almost certainly derived from the Eocene pebble beds to the west of the area under consideration. Rock types identified include sandstone of Lower Palaeosoic ? type (92 pebbles), fine grained igneous (10 pebbles), iron cemented sandstone (35 pebbles, of which 23 - 2.78% of sample - were in Sample 38), and lignite (1 pebble). The iron cemented sandstone and lignite occur only in the gravel directly overlying the Tertiaries containing these deposits while the Lower Palaeozoic sandstones occur throughout the gravels sampled and include a wide range of lithologies from coarse sandstone/grit to very fine sandstones. Similarly the fine grained igneous is not concentrated in any one sample and is evenly distributed, no sample having more than one pebble of this rock type.

Note 2: Metric equivalents of the mesh sizes used: 1½" (37.5 mm.); 1" (25 mm.); ½" (12.5 mm.); ¼" (6.25 mm.); " (3.35 mm.).

Table Ia. Solent Gravels (3.3-6.3 mm.)*

Site	Flint and Upper Greensand	Quartz	Other far-travelled rocks	Sample size
25 ft. (8 m.) terrace				
Cadland (2)	77.3	22.2	0.9	514
Sowley	72.8	25.1	2.0	542
Milford	76.0	24.0	0.0	129
60 ft. (18 m.) terrace				
Blackfield	77.0	21.1	1.9	270
Hordle	72.6	24.9	2.5	321
Upper Gravel				
Stone	75.3	23.2	1.5	1258
Lower Gravel				
Stone	77.2	21.0	1.8	3935

* From Brown et al., 1975.

Table II. Some suggested correlations for the Pleistocene of south Hampshire.

General British Stages (see Mitchell et al., 1973)	South Hampshire (The levels refer to the terraces of the Solent River)	
Post Glacial (Flandrian)	Estuarine clays, peat, present drainage, coastal erosion. Final cutting of buried channels.	
Late Devensian	Last phase of Solent at low sea levels.	
Early Devensian	Destruction of Isle of Wight - Purbeck Ridge. Headward erosion on the minor drainage of the New Forest.	
Early Devensian	25 ft. (8 m.) Brickearth	25 ft. (8 m.) terrace
Late Ipswichian	25 ft. (8 m.) Gravel	
Full Ipswichian	zone f (I IIb) deposits at Stone Point	
Late Wolstonian	No deposits. Possible buried channel below O.D. and dissection at Stone Point.	
"Ilfordian" ?	60 ft. (18 m.) Brickearth	60 ft. (18 m.) terrace
	60 ft. (18 m.) Gravel	
Early Wolstonian	Hordle buried channel	
Late Hoxnian	100 ft. (30 m.) Brickearth	100 ft. (30 m.) terrace
	100 ft. (30 m.) Gravel	
Early Hoxnian	Terrace gravels up to 130 ft. (39.6 m.)	
Older Pleistocene stages	Gravels up to 420 ft. O.D.	

Table III. Some suggested correlations for the Pleistocene of the Channel Isles

British Stages (after Mitchell et al., 1973)	Channel Isles
Flandrian	Peat, blown sand, recent alluvium, coastal erosion.
Late Glacial	Rising sea level, final cutting of island valleys.
Late Devensian	Loess and head deposition.
Early Devensian	Loess and head deposition, La Cotte de St. Brelade occupied by Neanderthal man with an Upper Mousterian culture.
Late Ipswichian	Widespread blown sand associated with falling sea level, regression sediments in north Guernsey.
Full Ipswichian	25 ft. (8 m.) raised beach, blown sand on Jersey's west coast, deposits of Belle Hougue cave.
Late Wolstonian	La Cotte de St. Brelade. La Cotte à la Chèvre occupied by Neanderthal men with an early Mousterian culture, loess and head deposited.
Mid-Wolstonian high sea level ("Ilfordian"?)	60 ft. (18 m.) beaches deposited after an aggradation from at least O.D.
Early Wolstonian	Fall in sea level to at least O.D.
Late Hoxnian	Maximum rise in sea level of interglacial of c. 130 ft. (40 m.)
Early Hoxnian	Rise in sea level from c. 70 ft. (21 m.) O.D.
Older Pleistocene stages	Erosion surfaces with fragmentary deposits up to 450 ft. (138 m.)

Table IV. Localities where head occurs below the 8 m. beach.

Guernsey			
	L'Eree	c. WV 248784	(Reported in Elhai, 1963)
	Divette	c. WV 342754	(Described by Collenette, 1916, now destroyed by marine action)
	Jethou		(On the south side of the island)
Alderney			
	Longis Bay	WA 595081	(A continuous section 100 m. long south-east of the Roman Fort)
Jersey			
	Bouley Bay	WV 669549	(Cliff section NNW of jetty)
	Belcroute Bay	WV 607482	(Cliff section south of St. Aubin, the classic locality)
	Portelet Bay	WV 601471	(Cliff section in the centre of the bay)
	Bouilly Port	WV 581481	(Cliff section south of battery)
	Beauport	WV 580479	(Section in a gully on the east side of the bay)

Table V. <u>Composition of Channel Isles Raised Beaches</u>.

				Fl.*	Err.*	Lo.*		Fl	Err	Lo
Alderney										
	Hommet Herbe	(a)	WA 606087	43.0	-	57.0	Mean	40.5		59.5
		(b)	WA 606086	38.0	-	62.0				
Guernsey										
	L'Ancresse		WV 348838	10.6	15.5	74.8				
	Chouet	(a)	WV 332841	12.2	15.1	72.2	Mean	11.1	11.75	80.1
	(Mont Cuet)	(b)	WV 333842	10.6	8.6	80.4				
	Hommet Paradis		WV 365828	-	7.8	93.2				
Jersey										
	Belcroute	(a)	WV 607482	1.41	-	98.4				
		(b)	WV 607482	-	-	100.0				
		(c)	WV 607482	-	-	100.0				
	Bouilly Port		WV 581481	1.2	-	98.8				
	Bouley Bay	(a)	WV 669548	3.2	-	96.8				
		(b)	WV 669548	1.7	-	98.3				
	Bonne Nuit	(a)	WV 641559	6.9	-	93.1				
		(b)	WV 641559	4.0	-	96.0				
		(c)	WV 641559	3.8	-	96.2				
		(d)	WV 641559	2.8	-	97.2				
		(e)	WV 641559	7.2	-	92.8				
	Belval Cove		WV 710528	3.8	1.3	94.9				
Jersey. Mean north coast				4.2	1.3	94.5				
Mean south coast				1.3	-	98.6				
Mean all sites				3.6	1.3	96.1				
Modern Beach in Bonne Nuit Bay (Between WV 644558 and WV 646558)										
		(a)		1.7	-	98.3				
		(b)		1.0	-	99.0				
		(c)		2.0	-	98.0	Mean	2.12		97.01
		(d)		1.8	-	98.2				
		(e)		1.9	-	98.1				
		(f)		3.9	-	96.1				
		(g)		3.0	-	97.0				
		(h)		1.6	-	98.4				

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* Fl - Flint
Err - Other erratics
Lo - Local rock types

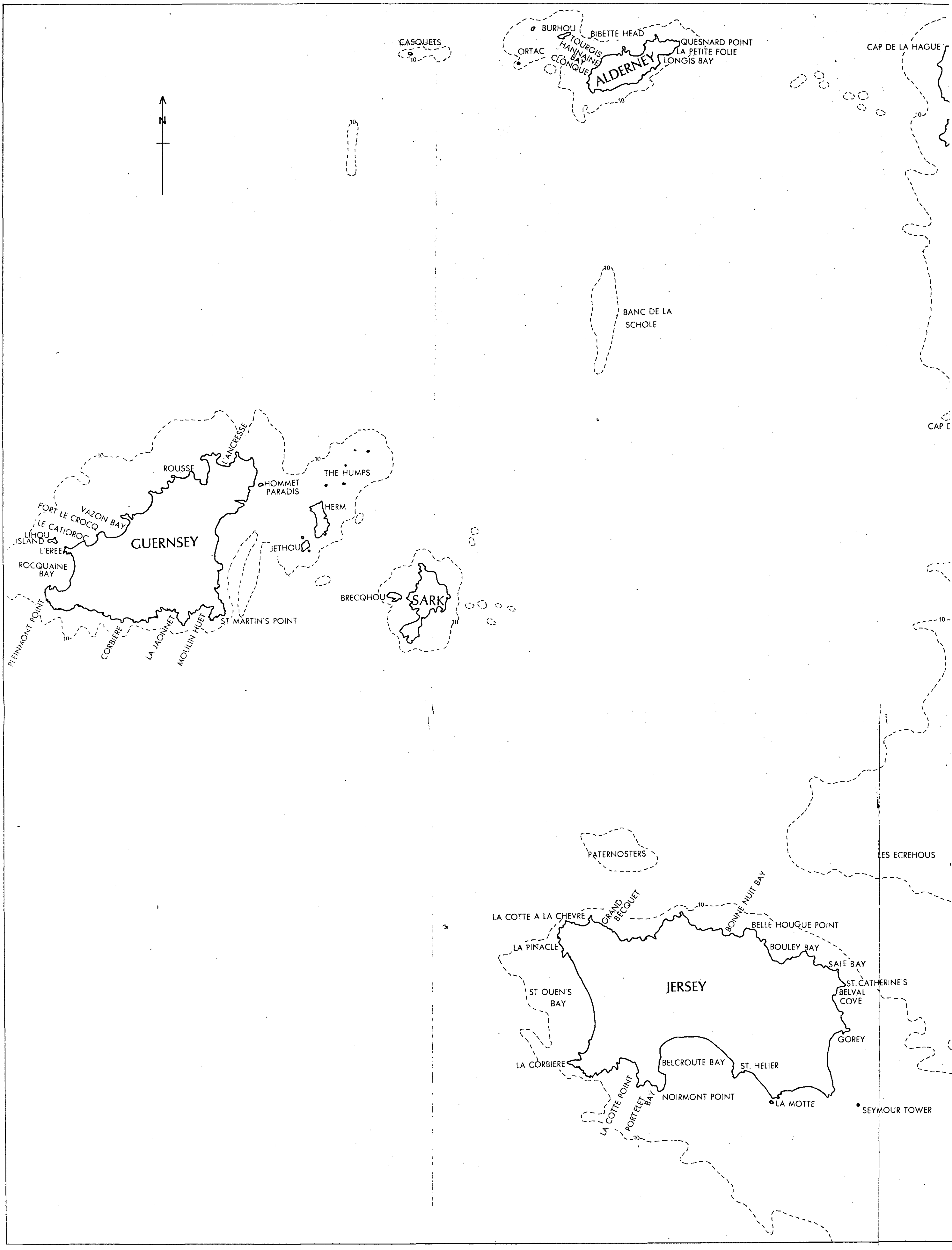
Table VI. <u>List of sites in the Channel Islands for the 60 ft. (18 m.) raised beach.</u>

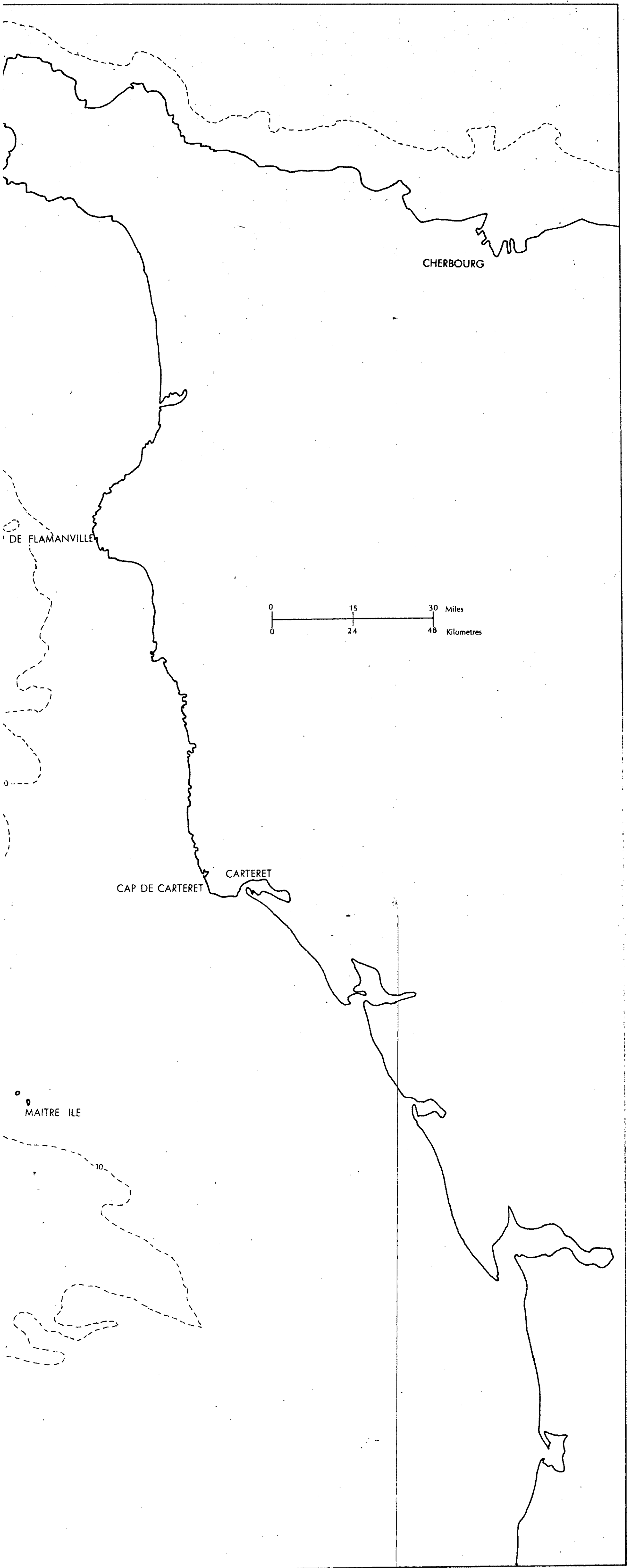
	Grid ref.	
Jersey		
Cotte à la Chèvre	WV 554567	DN[4]
Ile Agois	WV 597557	N
Le Bourg	WV 690490	D
Verclut	WV 698476	D[1]
Pontac	WV 689469	D
Snow Hill cutting	WV 655483	D
Fort Regent Tunnel	WV 655482	D[2]
Le Pinacle	WV 545555	N
Jubilee Hill	WV 576515	D[1]
Mont Millais	c. WV 664485	D[1]
Caves near Plemont	WV 658566	D[4]
Cave at La Saline	WV 630562	D[4]
Guernsey		
Mont Cuet	WV 333840	D
Fort Le Marchant	WV 350844	D
" " "	WV 350843	D
La Moye	WV 356833	D
Paradis	WV 359830	D
La Rochelle	WV 357833	D
Le Feugre	WV 300809	D
St. Catherines	WV 325799	D[1]
Blancs Bois - King George's Fields	c. WV 311804	D[3]
Anneville - Les Capelles	c. WV 326813	D[3]
Pleinheaume	WV 318818	D
Cailloterie	WV 316824	D
La Pomare (south of)	WV 260774	D[1]
Les Adams (south of)	WV 258731	D[1]
Les Rouvets	WV 265784	D

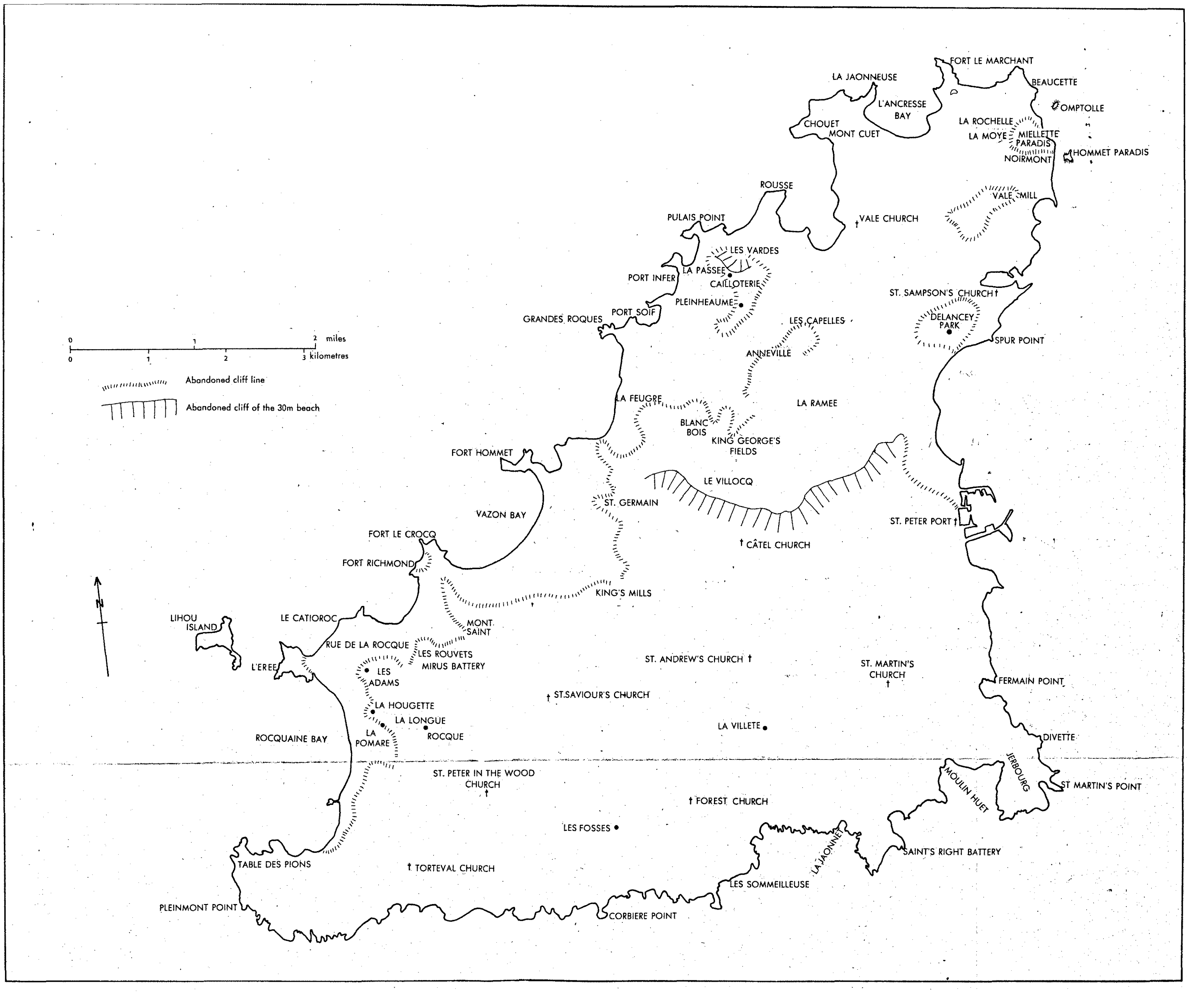
D - Deposits, N - Notch only, DN - Deposits and Notch.

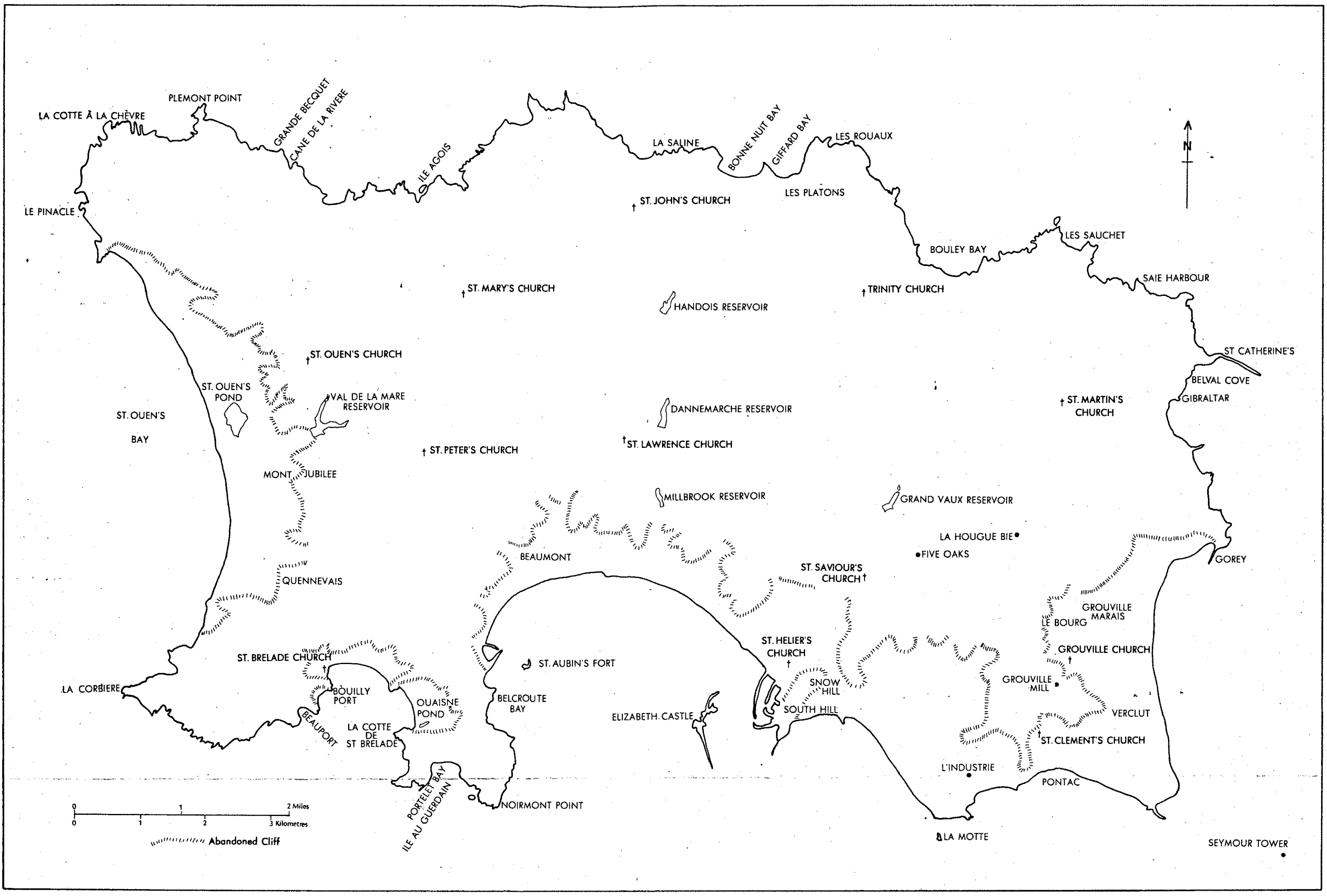
1 - Temporary exposure; 2 - Landscaped but beach still just visible;

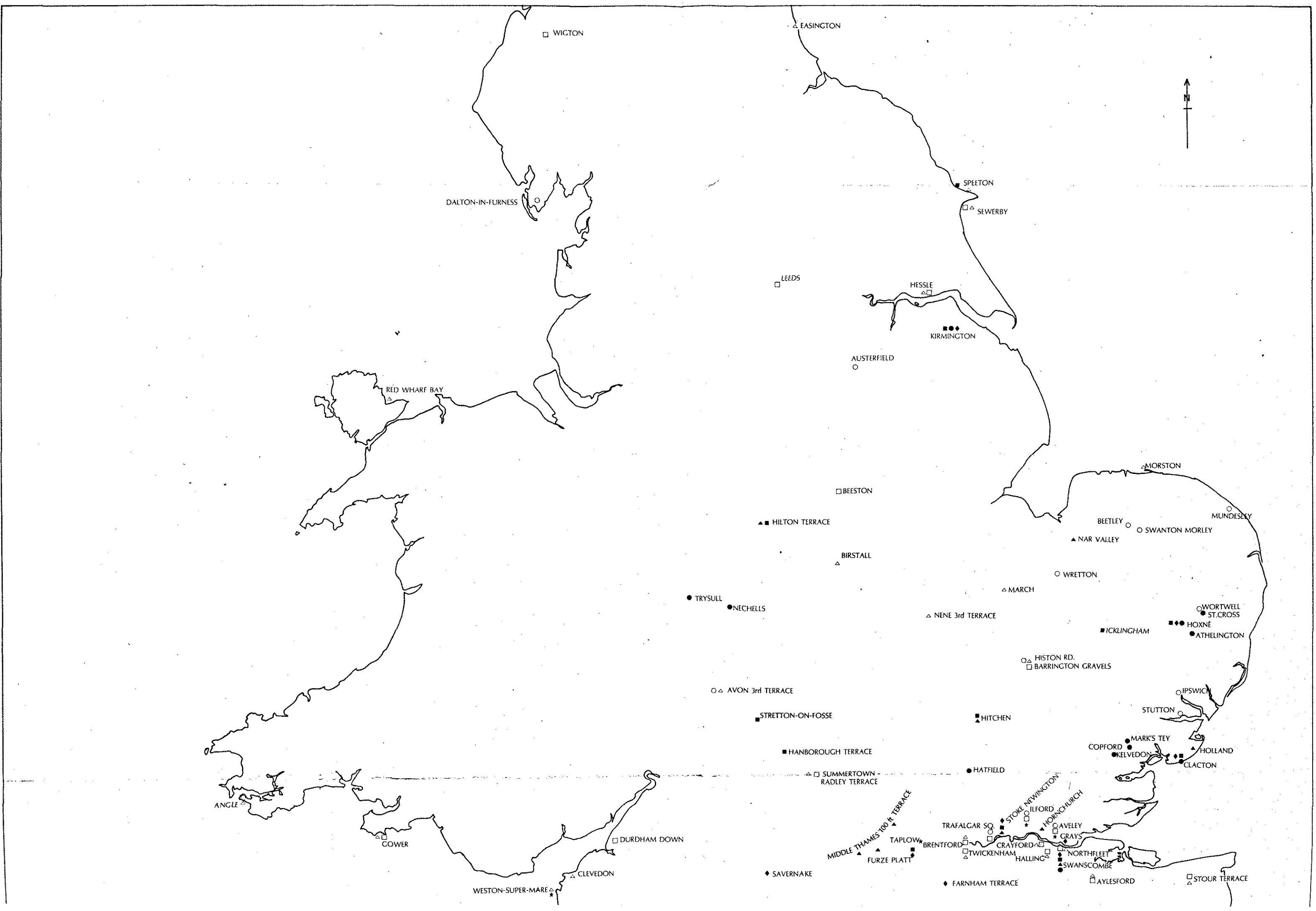
3 - Very large area covered; 4 - Beach in cave.

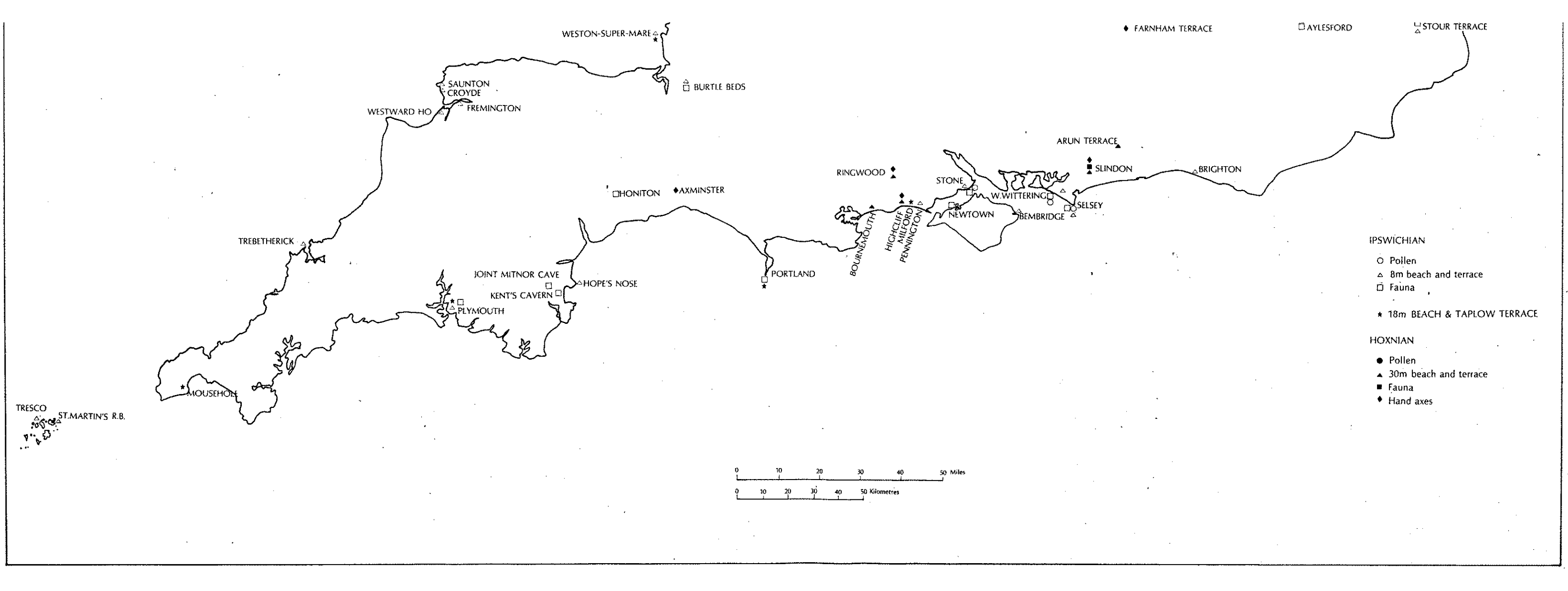

N
CASQUETS
BURHOU
BIBETTE HEAD
ORTAC
TOURGIS
HANNAINE BAY
CLONQUE
ALDERNEY
QUESNARD POINT
LA PETITE FOLIE
LONGIS BAY
CAP DE LA HAGUE
BANC DE LA SCHOLE
CAP D
L'ANCRESSE
ROUSSE
HOMMET PARADIS
THE HUMPS
HERM
VAZON BAY
FORT LE CROCQ
LE CATIOROC
LIHOU ISLAND
L'EREE
GUERNSEY
JETHOU
ROCQUAINE BAY
BRECQHOU
SARK
PLEINMONT POINT
CORBIERE
LA JAONNET
MOULIN HUET
ST MARTIN'S POINT
PATERNOSTERS
LES ECREHOUS
GRAND BECQUET
BONNE NUIT BAY
LA COTTE A LA CHEVRE
BELLE HOUGUE POINT
LA PINACLE
BOULEY BAY
SAIE BAY
ST. CATHERINE'S
BELVAL COVE
JERSEY
ST OUEN'S BAY
GOREY
LA CORBIERE
BELCROUTE BAY
ST. HELIER
NOIRMONT POINT
LA COTTE POINT
PORTELET BAY
LA MOTTE
SEYMOUR TOWER
10

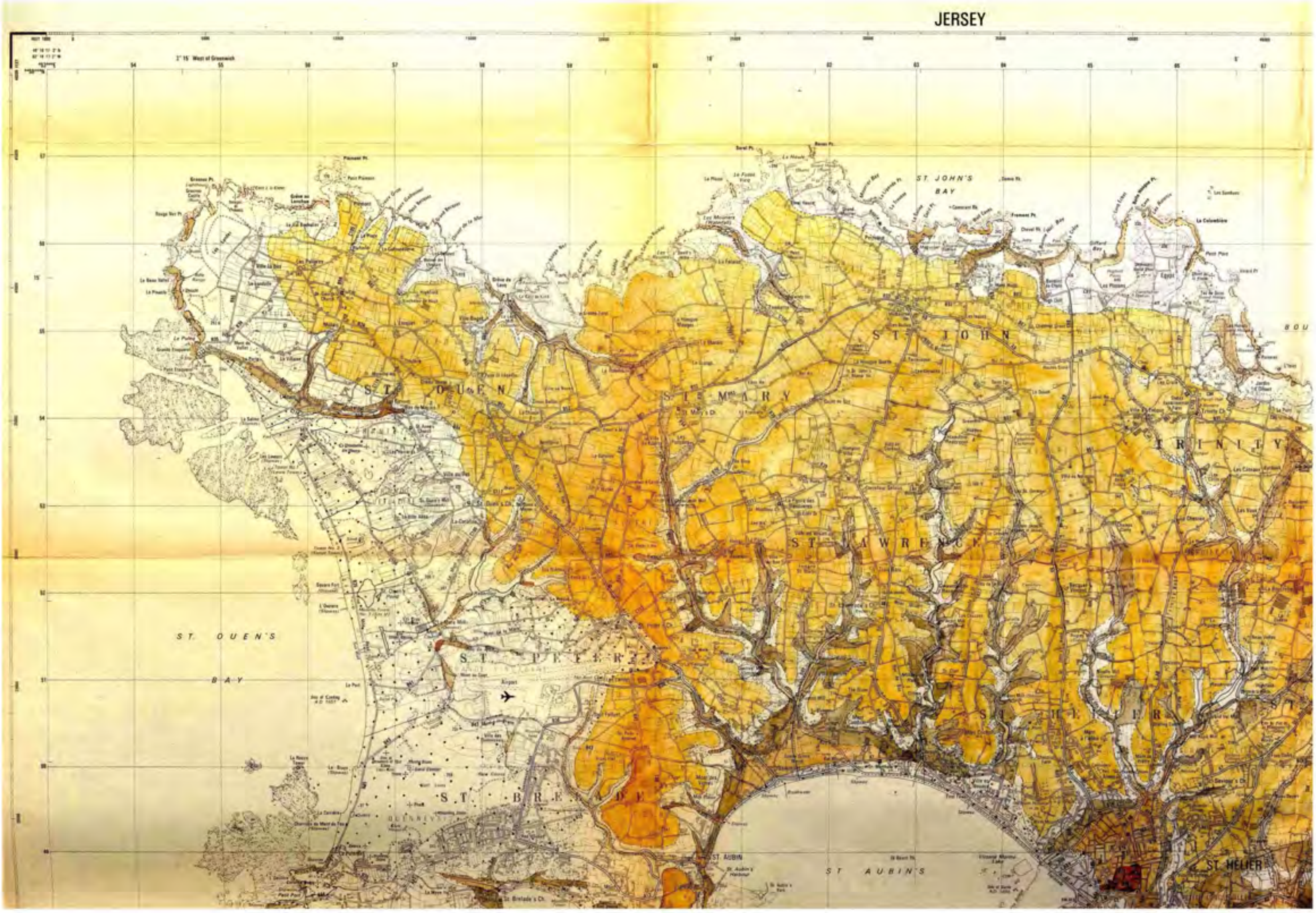

CHERBOURG
DE FLAMANVILLE
0 15 30 Miles
0 24 48 Kilometres
CARTERET
CAP DE CARTERET
MAITRE ILE
10


FORT LE MARCHANT
LA JAONNEUSE
BEAUCETTE
L'ANCRESSE BAY
OMPTOLLE
CHOUET
MONT CUET
LA ROCHELLE
LA MOYE
MIELLETTE
PARADIS
NOIRMONT
HOMMET PARADIS
ROUSSE
VALE MILL
PULAIS POINT
VALE CHURCH
LES VARDES
LA PASSEE
PORT INFER
CAILLOTERIE
PLEINHEAUME
ST. SAMPSON'S CHURCH
PORT SOIF
GRANDES ROQUES
LES CAPELLES
DELANCEY PARK
SPUR POINT
0 1 2 miles
0 1 2 3 kilometres
ANNEVILLE
Abandoned cliff line
Abandoned cliff of the 30m beach
LA FEUGRE
LA RAMEE
BLANC BOIS
KING GEORGE'S FIELDS
FORT HOMMET
LE VILLOCQ
ST. GERMAIN
VAZON BAY
ST. PETER PORT
FORT LE CROCQ
CÂTEL CHURCH
FORT RICHMOND
KING'S MILLS
N
LIHOU ISLAND
LE CATIOROC
MONT SAINT
RUE DE LA ROCQUE
LES ROUVETS
MIRUS BATTERY
L'EREE
ST. ANDREW'S CHURCH
ST. MARTIN'S CHURCH
LES ADAMS
FERMAIN POINT
ST.SAVIOUR'S CHURCH
LA HOUGETTE
LA LONGUE
LA VILLETE
ROCQUAINE BAY
LA POMARE
ROCQUE
DIVETTE
JERBOURG
ST. PETER IN THE WOOD CHURCH
MOULIN HUET
ST MARTIN'S POINT
FOREST CHURCH
LES FOSSES
LA JAONNET
SAINT'S RIGHT BATTERY
TABLE DES PIONS
TORTEVAL CHURCH
LES SOMMEILLEUSE
PLEINMONT POINT
CORBIERE POINT


LA COTTE À LA CHÈVRE
PLEMONT POINT
GRANDE BECQUET
CANE DE LA RIVERE
ILE AGOIS
LA SALINE
BONNE NUIT BAY
GIFFARD BAY
LES ROUAUX
LES PLATONS
N
LE PINACLE
ST. JOHN'S CHURCH
BOULEY BAY
LES SAUCHET
SAIE HARBOUR
ST. MARY'S CHURCH
HANDOIS RESERVOIR
TRINITY CHURCH
ST. OUEN'S CHURCH
ST CATHERINE'S
BELVAL COVE
GIBRALTAR
ST. OUEN'S POND
VAL DE LA MARE RESERVOIR
ST. OUEN'S BAY
DANNEMARCHE RESERVOIR
ST. MARTIN'S CHURCH
ST. PETER'S CHURCH
ST. LAWRENCE CHURCH
MONT JUBILEE
MILLBROOK RESERVOIR
GRAND VAUX RESERVOIR
LA HOUGUE BIE
FIVE OAKS
BEAUMONT
GOREY
ST. SAVIOUR'S CHURCH
QUENNEVAIS
GROUVILLE MARAIS
LE BOURG
ST. HELIER'S CHURCH
GROUVILLE CHURCH
ST. BRELADE CHURCH
ST. AUBIN'S FORT
LA CORBIERE
BOUILLY PORT
SNOW HILL
GROUVILLE MILL
OUAISNE POND
BELCROUTE BAY
ELIZABETH. CASTLE
SOUTH HILL
VERCLUT
BEAUPORT
LA COTTE DE ST BRELADE
ST. CLEMENT'S CHURCH
L'INDUSTRIE
PORTELET BAY
PONTAC
0
1
2 Miles
0
1
2
3 Kilometres
NOIRMONT POINT
ILE AU GUERDAIN
Abandoned Cliff
LA MOTTE
SEYMOUR TOWER


N
WIGTON
EASINGTON
DALTON-IN-FURNESS
SPEETON
SEWERBY
LEEDS
HESSLE
KIRMINGTON
AUSTERFIELD
RED WHARF BAY
MORSTON
BEESTON
MUNDESLEY
BEETLEY
SWANTON MORLEY
HILTON TERRACE
NAR VALLEY
BIRSTALL
WRETTON
MARCH
TRYSULL
NECHELLS
WORTWELL
ST.CROSS
NENE 3rd TERRACE
HOXNE
ICKLINGHAM
ATHELINGTON
HISTON RD.
BARRINGTON GRAVELS
AVON 3rd TERRACE
IPSWICH
STUTTON
STRETTON-ON-FOSSE
HITCHEN
MARK'S TEY
COPFORD
HOLLAND
HANBOROUGH TERRACE
KELVEDON
CLACTON
HATFIELD
SUMMERTOWN - RADLEY TERRACE
ANGLE
STOKE NEWINGTON
ILFORD
HORNCHURCH
MIDDLE THAMES 100 ft TERRACE
TRAFALGAR SQ.
AVELEY
GRAYS
GOWER
DURDHAM DOWN
TAPLOW
BRENTFORD
CRAYFORD
TWICKENHAM
HALLING
NORTHFLEET
FURZE PLATT
SWANSCOMBE
CLEVEDON
SAVERNAKE
WESTON-SUPER-MARE
FARNHAM TERRACE
AYLESFORD
STOUR TERRACE

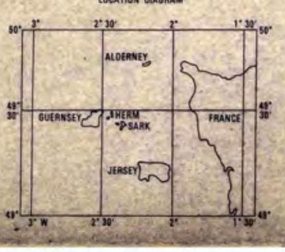

WESTON-SUPER-MARE
BURTLE BEDS
SAUNTON
CROYDE
WESTWARD HO
FREMINGTON
TREBETHERICK
MOUSEHOLE
TRESCO
ST.MARTIN'S R.B.
PLYMOUTH
JOINT MITNOR CAVE
KENT'S CAVERN
HOPE'S NOSE
HONITON
AXMINSTER
PORTLAND
RINGWOOD
BOURNEMOUTH
HIGHCLIFF
MILFORD
PENNINGTON
STONE
NEWTOWN
W.WITTERING
BEMBRIDGE
SELSEY
ARUN TERRACE
SLINDON
BRIGHTON
FARNHAM TERRACE
AYLESFORD
STOUR TERRACE
IPSWICHIAN
○ Pollen
△ 8m beach and terrace
□ Fauna
★ 18m BEACH & TAPLOW TERRACE
HOXNIAN
● Pollen
▲ 30m beach and terrace
■ Fauna
◆ Hand axes
0 10 20 30 40 50 Miles
0 10 20 30 40 50 Kilometres


JERSEY
2°15' West of Greenwich
ST. JOHN'S BAY
ST. OUEN
ST. MARY
ST. JOHN
TRINITY
ST. LAWRENCE
ST. PETER
ST. BRELADE
ST. OUEN'S BAY
ST. AUBIN
ST. AUBIN'S
ST. HELIER
Airport
BOU

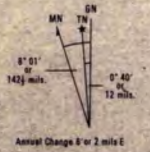

50000
55000
60000
65000
68000 FEET
49° 16′ 09·5″ N
01° 58′ 58·2″ W
15000 METRES
68
69
70
71
72
2° 8′
73
⁶74⁰⁰⁰E
⁵⁴58⁰⁰⁰N
57
14000
56
13000
15′
55
12000
54
11000
53
10000
52
9000
51
8000
50
7000
49
6000
BOULEY BAY
Tour de Rozel
Le Saucher
Nez du Guet
Beauvallet
Le Catel Earthwork
Le Catel
L'Etaquerel
La Tete des Hougues
Fort (Disused)
Cotes du Nord
Islet
ROZEL BAY
Jetty
Douet de la Mer
Le Couperon
Saie Harbour
ROZEL
La Ferme
La Coupe Pt.
Brayes Rk.
La Fosse
Pot du Rocher
ROZEL
Ville Brée
Rozel Mill (Disused)
Ville es Nouaux
La Poudretterie
FLIQUET BAY
Slipway
Telegraph Tower
Cem.
Rozel Manor
Chap.
L'Auge
Les Champs
Verclut Pt.
Breakwater
Slipway
Le Villot
Quarry
St. Catherine's Light
Dielament Manor
Pièce Mauger
Clos du Buisson
Maufant Manor
ST. MARTIN
L'EGLISE
Croix au Maître
Belval Cove
Reservoir
Gibraltar
Slipway
Martello Tower (White)
Chapel
Parish Hall
Rectory
St. Martin's Ch.
La Perrelle
ST. CATHERINE'S BAY
Hall
R.C. Church
Sch.
FIEF DE LA REINE
Ville es Gaudins
QUERUÉE
Remains of Dolmen
La Fara (Beacon)
Quarry
Chap.
Archirondel Tower (Red)
Havre de Fer
La Crête Pt.
MAUFANT
Maufant
Chouquetterie
Quarry
Anne Port
Slipway
Anneville
FALDOUET
St. Maurice
Grands Chemins
Chap.
SOUS LA HOUGUE
Hambye
Faldouet
Jeffrey's Leap
Dolmen de Faldouet
Victoria Tower
Petit Portelet
ST. SAVIOUR
Carrefour au Clercq
St. Saviour's Hospital
School
Teighmore
GOREY
Mont Orgueil Castle
Slip
PIGNEAUX
La Ferrière
La Hougue Bie (Tumulus)
Prince's Tower Rd.
Ville es Philippes
Moulin de Haut
Gorey Harbour
Lighthouse
Equerriere Rk. (Beacon)
Oaks
Gorey Village
Slipway
Highstead
Franchevilie
LA RUE
Fort William
Du Desert
Catillon
Queen's Valley
Maîtrises
GROUVILLE
Gorey Common
Rouen Ho.
Le Boulivot
Maison de Haut
Moulin des Bas
Ville es Renauds
Golf
La Bourg
Links
Chapel
Taponnerie
Vallée
Fort Henry (Disused)
Hotel
Club House
ROYAL BAY OF GROUVILLE
Hospital
Grouville Ch.
La Fontaine
Rue Jutize
Horn Rk. (Beacon)
A6
A3
B28
B29
B30
B31
B37
B38
B39
B46
B91
B92
C93
C94
C108
C109
C110


Blown Sand
Alluvium
Peat
Flandrian
Holocene
Loess
Solifluction Deposits
Devensian
Blown Sand
25 ft. (8 m.) Raised Beach
60 ft. (18m.) Raised Beach
Ipswichian
Pleistocene
100 ft. (30 m.) Raised Beach
Hoxnian
ST. AUBIN
ST AUBIN'S BAY
ST. HELIER
St. Brelade's Ch.
ST. BRELADE'S BAY
PORTELET BAY
Pt. le Fret
Noirmont Pt.
Corbière Pt.
Pt. la Moye
7° 15' West of Greenwich
SCALE 1: 25,000
or about 2½ inches to 1 mile

LOCATION DIAGRAM



MAGNETIC INFORMATION 1970
for centre of sheet



Annual Change 6′ or 2 mils E

GRID DATA
Universal Transverse Mercator Grid
Zone 30

Projection :– Transverse Mercator
Spheroid :– International
Origin :– Long 3°W Lat. Equator
Scale factor at origin :– 0.9996
False co-ordinates of origin :–
500,000 mE 0mN
Datum :– European

1000 METRE UNIVERSAL TRANSVERSE MERCATOR GRID