THE RAISED BEACHES AND STRANDLINES OF SOUTH DEVON

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CONTENTS

I. INTRODUCTION .. 109

II. THE PROCESSES .. 110

III. THE RAISED WAVE-CUT BENCHES .. 114
(1) Datum .. 114
(2) Structure and Morphology .. 114
(3) The 65 foot Strandline .. 116
(4) The 24 foot and 14 foot Strandlines .. 116
(i) Limestone Area .. 116
(ii) Slate Area .. 116
(iii) Schist Area .. 118

IV. THE RAISED AND DEGRADED CLIFFLINE .. 120
(i) Limestone Cliffs .. 120
(ii) Slate Cliffs .. 120
(iii) Schist Cliffs .. 120

V. THE RAISED BEACH DEPOSITS .. 122
(1) Morphology and Composition .. 122
(i) Limestone Area .. 122
(ii) Slate Area .. 123
(iii) Schist Area .. 123
(2) Fauna .. 123

VI. THE HEAD .. 124
(1) Form .. 124
(2) Composition .. 125

VII. THE PEARTREE STAGE—POST-GLACIAL RAISED BEACH .. 125

VIII. CORRELATION AND CONCLUSIONS .. 128
(1) The 65 foot Strandline .. 128
(2) The 24 foot Strandline .. 128
(3) The 14 foot Strandline .. 128
(4) Post-Glacial .. 130

REFERENCES .. 130

I. INTRODUCTION

REMNANTS of raised wave-cut benches, often partially covered by old beach deposits and lying beyond the normal reach of marine processes, occur at several places along the South Devon Coast between Plymouth Hoe and Hope's Nose. These raised beaches, strandlines and old seacliffs are evidence of the effect of

marine erosion and subaerial denudation at a time when the sea stood at a higher level relative to the land, and during its subsequent fall. They reflect the complex interrelation of geomorphic process, climatic change and movement of sea level during late Pleistocene times. There is, however, comparatively little reliable local evidence upon which to establish an exact chronology of events. Morphological analysis of the terrain will establish a broad sequence of changes and study of the superficial deposits may contribute additional data. Fossils within the raised beach deposits may be invaluable indices of age and environmental conditions, but they are not often preserved.

Possibly the oldest rocks of South Devon are the resistant metamorphics, the schists of various kinds, which occur between Start Point and Bolt Tail. Elsewhere the coast is made of Devonian strata, notably slates, grits and limestones, and associated igneous rocks. These were compressed into a number of complex major flexures with a general east-west trend by the Armorican mountain-building movements. The overlying New Red Sandstone formations have accumulated from the wearing down of these fold mountains (Fig. 1).

The more resistant rocks often reach the coast as high plateaux fronted by steep cliffs. Limestone plateaux occur on the flanks of the Torquay peninsula, in the Brixham area and above the northern shores of Plymouth Sound. Their surfaces cut across the slates on either side of the mouth of the Dart and rise to 450 ft. or 500 ft. above sea level, whilst on the Revelstoke and Wembury coasts the plateaux lie at about 350 ft. In the metamorphic area, the plateau developed across the quartz-mica schist is between 400 ft. and 450 ft. high. On the seaward edges of these plateaux the raised beaches are best preserved, and we may distinguish three former strandlines, often accompanied by beach deposits, at 65 ft., 24 ft., and 14 ft., above sea level.

As early as 1839, De la Beche commented on the work of Hennah who had noticed the Plymouth Hoe raised beach in 1817, and Godwin-Austen's previous description of the features at Hope's Nose and Thatcher Rock. Our present knowledge owes, in addition, much to the detailed observations of Pengelly and Hunt, recorded in the *Transactions of the Devonshire Association* during the latter half of the nineteenth century. Their research was supplemented by the work of Pidgeon, Prestwich, Jukes-Browne, Shannon and others. Ussher (1904) considered the available material and made many additional observations which appear, together with a bibliography of previously published work, in the Memoirs of the Geological Survey. Lloyd subsequently incorporated some new ideas in a second edition of the Torquay Memoir (1933); more recently Green (1949) and Zeuner (1953) have elaborated upon former theories.

To avoid repetition of recorded work relating to individual sites, certain principles of geomorphology and stratigraphical geology are applied to the raised beach problem generally in the following account. The student may thus appreciate the principles involved and seek more detailed information about each feature whilst in the field.

II. THE PROCESSES

The initiation of the shoreline cycle depends on sea level remaining stationary relative to a newly-emergent or newly-submergent landmass sufficiently long for agents of marine erosion and deposition to operate successfully on the new

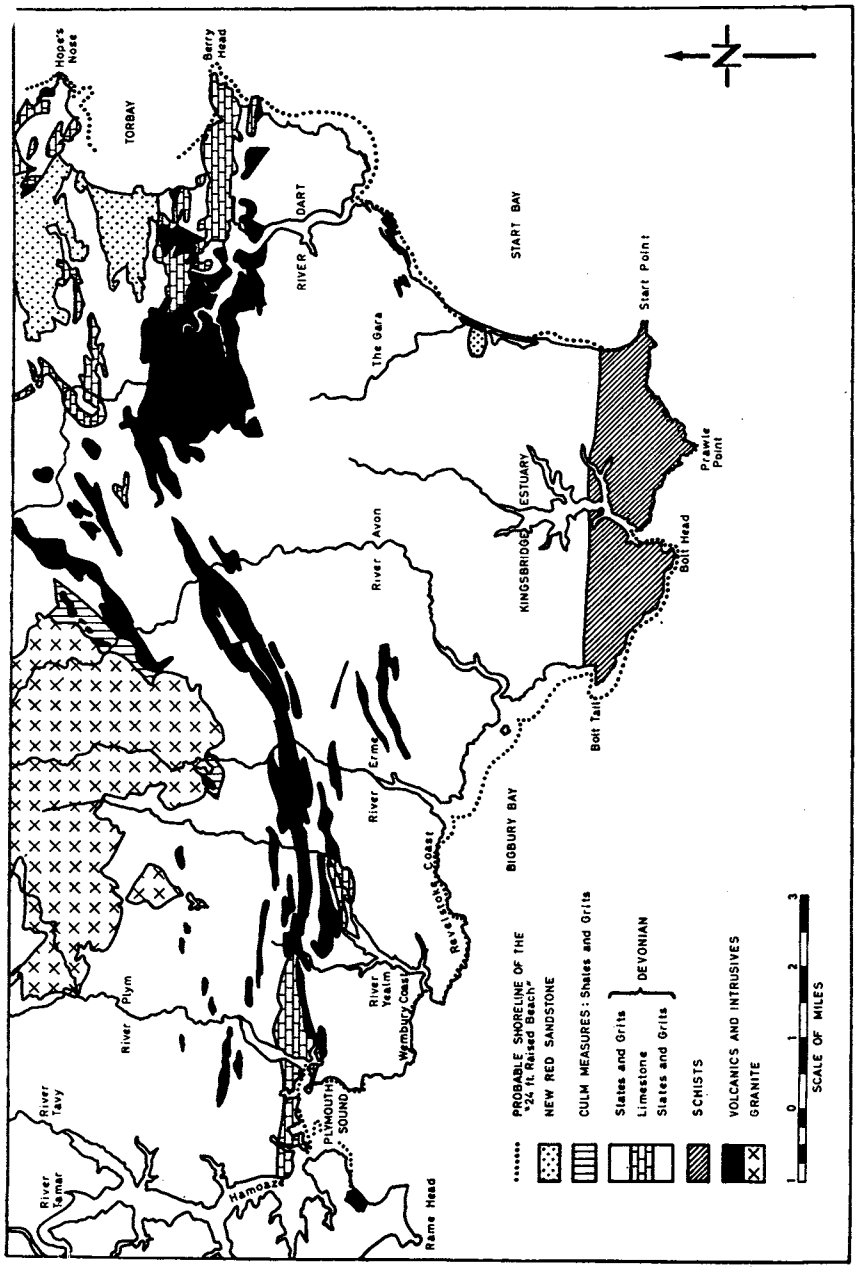


FIG. 1.
Geology of South Devon.

coastline. Erosion is at first limited. Once an adequate supply of rock debris becomes available for corrasion and attrition however, erosion, aided in certain rocks by corrosion, is accelerated (Figs. 2*a* and *b*). The continued recession of newly formed cliffs causes a progressive widening of the wave-cut bench below high water mark. Abrasion of both cliff and bench supplies debris for the seaward extension of the wave-built terrace (Fig. 2*c*). The wave-cut bench, the upper part of which is exposed at low water, usually has a slope seaward of from 2 to 4 degrees. It may contain patches of beach material in depressions and fissures, supplemented at the notch by debris derived from the retreating cliff. This debris results in part from wave undercutting, and in part from subaerial denudation, which during periglacial phases is considerably intensified.

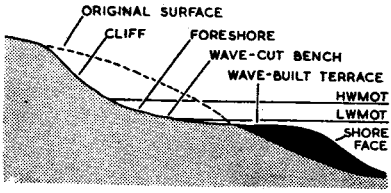
During youth, erosion and deposition smooth out the initial irregularities by moving debris from headlands towards bayhead beaches. As the cliffs recede, wave energy at their base is often partly dissipated in crossing the shallow waters of the widening bench. Maturity occurs when the (initial) salients have retreated to a line beyond the initial bayheads. During late maturity and old age the whole cliffline may be reduced to a uniformly low altitude.

Shoreline development is a far slower process in massive and resistant rocks, such as the limestones, slates and schists of South Devon, than in less resistant shales. A coast varied in relief and geology will exhibit different phases of development at any one time. Individual elements produced by marine processes remain evident longer in resistant rocks should an accident or interruption occur in the shoreline cycle.

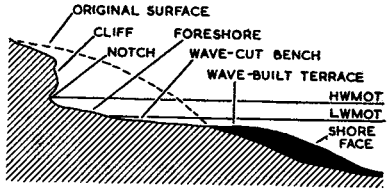
Emergence, in which seacliffs, wave-cut benches and beach deposits are raised beyond the normal range of marine activity (Fig. 2*e*), may result from a eustatic lowering of the sea or from isostatic warping of a landmass. Earth-movements involving either localized folding and faulting, or widespread elevation of the surface of a continent may have similar results. Relative lowering of sea level may, of course, be produced by a combination of any of these processes.

Before, during and after the several glaciations experienced by the British Isles in the Pleistocene epoch, the relative level of land and sea fluctuated greatly. This was in part due to the growth and decay of ice sheets which drew off large volumes of water, and in part to the degree of isostatic readjustment which landmasses undergo when alternately subjected to, and released from, the pressure of continental ice caps. South Devon seems to have been unaffected by orogenic earth-movements since Miocene times, during which period the Alpine orogeny had only limited effect. Furthermore, the area lay well beyond the southernmost limits of the great ice sheets of the Pleistocene. One may assume, therefore, that movements of sea level relative to the land between Plymouth and Torquay have everywhere been uniform. Such movements are attributed to the abstraction of water from the oceans and its transfer to continental ice sheets, and to its liberation at a later date.

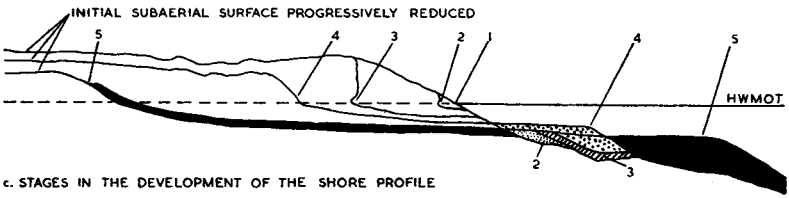
On a coastline which has experienced only eustatic shifts, raised beaches and strandlines occurring at or near the same height in different localities are contemporaneous. Small variations of level between several wave-cut benches are attributed to their formation at different inlets or headlands along the



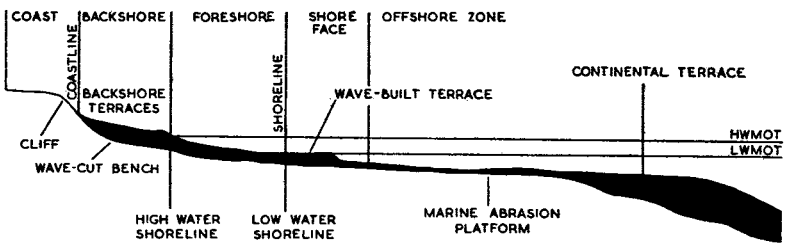
a. EARLY STAGE OF SHORE DEVELOPMENT IN UNCONSOLIDATED ROCK MATERIAL



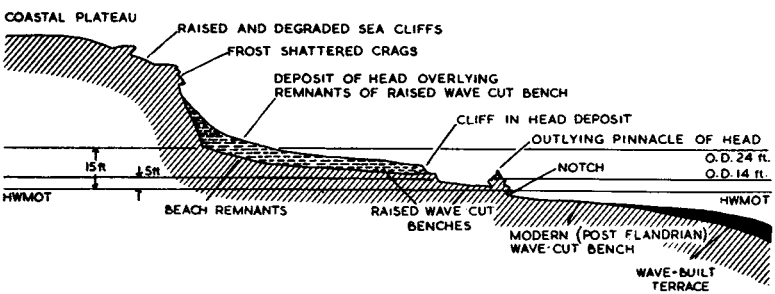
b. EARLY STAGE OF SHORE DEVELOPMENT IN CONSOLIDATED ROCK



c. STAGES IN THE DEVELOPMENT OF THE SHORE PROFILE



d. ELEMENTS OF THE SHORE ZONE DURING AN ADVANCED STAGE OF DEVELOPMENT (SEDIMENT SHOWN BY SOLID BLACK)



e. ELEMENTS OF THE RAISED BEACHES AND STRAND LINES OF SOUTH DEVON

FIG. 2.

Shore zones and shoreline development.

former coast. Exposure, storm seas, tidal range and local variations in shore and submarine relief and geology may affect the seaward slope of the bench and the supply of beach-forming materials. Large scale height differences, however, imply a time lapse between the formation of two distinct benches.

III. THE RAISED WAVE-CUT BENCHES

(1) *Datum*

The datum to which raised strandlines are usually referred is high water mark of Spring tides (H.W.M.S.T.) for this represents the upper limit of effective marine processes. Storm waves throw beach material above this level, but their erosive powers in solid rock are negligible. However, as other features of the landscape are invariably referred to mean sea level at Newlyn (O.D.), it is advisable to relate the raised beaches also to this height. This takes into account the tidal range which varies from 16 ft. at Plymouth to 13 ft. at Torquay.

Old beach material, although often cemented into a fairly compact mass may suffer subaerial denudation and the periodic depredations of storm seas. Preferably therefore, the wave-cut notch in the solid rock at the base of the old cliff should be used as it coincides with the former high water level. The extent of the emergence can be fixed by measuring the height of the raised notch above present high water mark. However, a considerable part of the old cliff and bench are often obscured by debris, in which case the position of the notch can only be conjectured. A major problem in correlation thus depends on whether heights are measured above H.W.M. or above O.D., and on whether they refer to the visible part of a raised bench, its average height or its high water mark. In referring to the 65 ft., 24 ft., and 14 ft., strandlines, the heights relate to the average elevation of the former notches above present O.D. Owing to the limited exposures of its notch, the upper limit of what is termed the 24 ft., bench could be higher in several places.

(2) *Structure and Morphology*

The wave-cut bench is an erosional feature. Although its formation may be facilitated in less resistant rocks, neither its surface, nor that of the adjacent cliff is governed wholly by beds of exceptional durability. Marine planation cuts across steeply inclined slates, limestone, dolerites and schists alike. There are few remnants of benches in less resistant Devonian shales or New Red Sandstone formations.

The raised benches have on average a 3 degree seaward slope, similar to that of the modern, or Post-Flandrian, platform. In both cases however, the profile may become irregularly concave towards the base of the cliff. These features are well displayed on the shores of Lannacombe Bay (Fig. 7). In areas of considerable tidal range the height range of the bench may vary, but this does not necessarily affect the ultimate slope or the upper limit. Following uplift, the rate of subaerial denudation and marine undercutting differs from place to place. One part of a raised bench may suffer little; elsewhere it may retreat to the verge of annihilation, in which case the modern coastline eventually reaches, destroys, and retreats beyond, the former cliffs. The amount, attitude, and direction of cleavage, bedding and jointing in the rocks affects the degradation

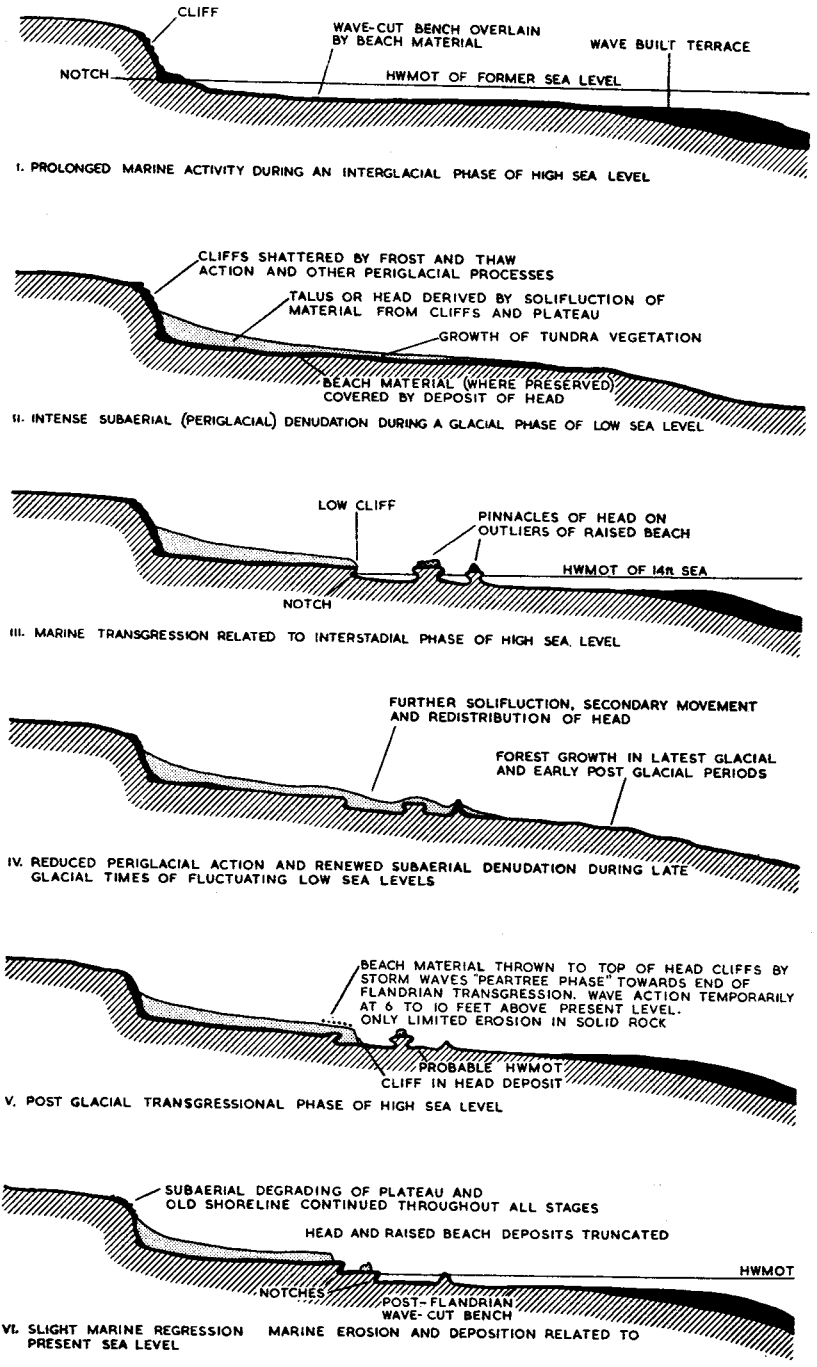


FIG. 3.

Stages in the evolution of the coastal zone of southernmost Devon.

of the bench before and after emergence. Thus the height of the seaward exposure of the old beach plane where it appears from beneath a mantle of beach or cliff debris, may vary considerably within a limited stretch of coast. Inequality of height of the visible part of a raised bench is not sufficient proof that former strandlines are of different age, or are related to different sea levels. In South Devon planes of cleavage and of jointing, and to a lesser extent bedding planes, have influenced the directions in which the beach or marine platform has developed most rapidly, but not the amount of relief it possesses.

(3) *The 65 foot Strandline*

The limestone shelf containing the higher and more westerly of the two raised beaches of Plymouth Hoe is now hidden by a retaining wall. It is believed to slope upwards from a seaward edge some 30 ft. above high water to 50-55 ft. at its rear. This bench, 40-65 ft. above O.D., is an isolated example related to a former sea level above that to which any other raised strandline in South Devon is referred. The Geological Survey (Ussher 1907) has traced the higher beach up the sloping platform beneath the head as seen in local temporary excavations. Traces of raised beach at corresponding heights on head-covered platforms on the Cornish coast west of Plymouth Sound, and also on the Rickham and Revelstoke coasts, may yet be revealed in a similar way.

(4) *The 24 foot and 14 foot Strandlines*

(i) *Limestone Area.* The benches supporting raised beach deposits in the Torbay area are cut entirely across Middle Devonian limestone (Fig. 4). At the south-east corner of Hope's Nose the platform extends 40 yards north-east before ending in a wave-cut gully. Its irregular surface lies at approximately 24 ft. above H.W.M.S.T. The tidal range is normally 13 ft., so the bench lies at 30 to 35 ft. above O.D. Further north a limestone pavement contains unconsolidated beach debris thrown up by modern storms.

On the north and east sides of Thatcher Rock, less than half a mile south-west of Hope's Nose, a limestone shelf occurs at 15 to 17 ft. above H.W.M.S.T. The irregular platform on the southern headland of Churston Cove, and the well-marked bench between Shoalstone Point and the Berry Head Quarries are 15 to 18 ft. above high water. The seaward edge of the latter bench reaches the modern cliff.

On the northern shore of Sharkham Point a limestone bench extends 100 yards into St. Mary's Bay at 15 ft. above H.W.M.S.T. The notch is obscured by head and tippings from old iron workings. Cut across steeply dipping limestones, the shelf is divided by a deep cleft running north-east to south-west, into a well-developed northern bench, and a southern shelf buried beneath iron ore debris. To the east of the 65 ft. bench below Plymouth Hoe, a lower platform at 13 ft. above high water is related to the 24 ft. strandline.

(ii) *Slate Area.* At Blackstone Point, in Western Combe Cove and on the Revelstoke and Wembury coasts, the raised benches cut across contorted Dartmouth Slates. On the south side of the Dart estuary between Blackstone Point and Compass Cove, the bench projects up to 100 ft. seawards from beneath head and beach debris. It extends for 300 yards along the coast at 12 to 16 ft.

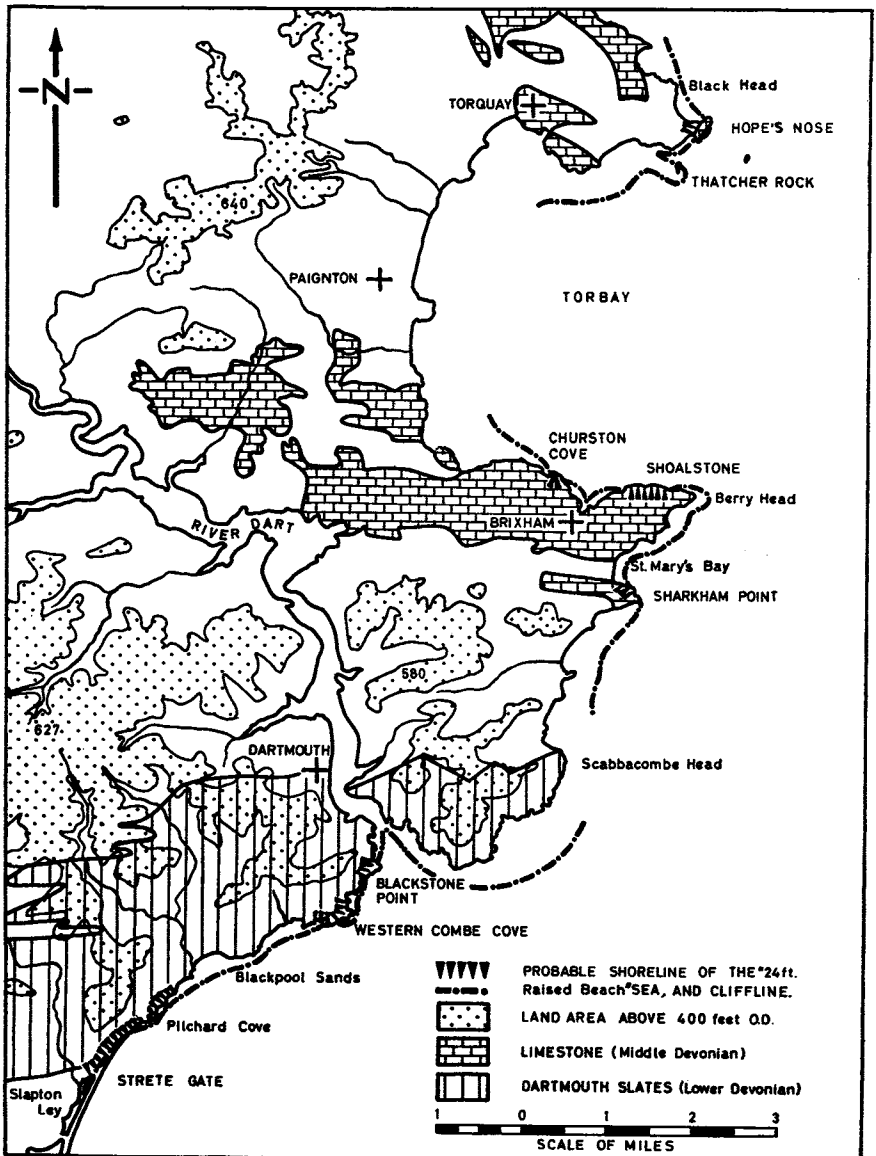


FIG. 4.
The coast of the Torbay and Dartmouth area (Black Head to Strete Gate).

above high water. There is a grass and samphire-clad bench 3 or 4 ft. above a barren shelf at 12 ft. The slates dip seawards at 50° and owe their jagged appearance to the differential weathering of upturned hard and soft strata. The platform is trenched by the sea and deeply fissured.

Beyond Combe Point a slate bench, flush with the modern cliff at its edge 15 ft. above high water, occurs in a coast locally protected by resistant dolerite bastions. A few yards offshore an isolated remnant of the same platform occurs.

Between the mouth of the Erme and Plymouth Sound, where the raised strandline appears at 8 to 10 ft. above high water, the notch and a greater part of the shelf are obscured by head. The surface of the visible bench however, reflects the inequalities of the rock and the power of marine processes in breaching the slates along the cleavage strike and cutting gullies along dominant joint systems.

(iii) *Schist Area.* Remnants of raised benches are well preserved in the resistant schists between Hallsands and Splat Cove (Fig. 5). There are three distinct levels of wave erosion: the modern, Post-Flandrian platform and two benches raised to 5 ft. and 15 ft. approximately above high water. The juxtaposition of these features is well shown on the shores of Lannacombe Bay.

The relation of the 15 ft. bench to the 5 ft. bench must remain doubtful. The lower may be a local development during or soon after the cutting of the higher bench. Alternatively it may be of much later date, representing a short-lived marine transgression the traces of which have since been removed everywhere except between Peartree Point and the mouth of the Estuary.

The destroyed village of Hallsands was built upon a quartz-mica schist bench at 14 ft. above high water. Remnants of this bench may be traced at the base of the cliffs to Start Point and beyond to Peartree Point. Owing to subsequent erosion or to the mantle of head, its occurrence is limited between Peartree and Langerstone Point. The 24 ft. bench continues intermittently along the Rickham Coast between Prawle Point and Splat Cove on the western flank of the Estuary, often cutting across both the quartz-mica schist and the hornblende-chlorite schist in the Prawle and Rickham areas without regard to geological structure.

The 14 ft. bench is well developed at Great Matchcombe Sand and borders the shores of Lannacombe Bay to beyond Langerstone Point (Fig. 8). Further west it appears from beneath 80 ft. of head at Rickham Sand, distinct from the higher 24 ft. bench to either side. It has been suggested that both this and the modern post-Flandrian benches are contemporaneous, the higher bench being the product of marine erosion at high water by modern seas. At Rickham Sand and Great Matchcombe however, the 14 ft. bench projects from beneath undisturbed head deposits which would be removed long before the cutting of any platform at their base. The bench thus predates the last major phase of solifluction.

The destruction of both the raised strandlines by modern seas has been aided by structural weaknesses in otherwise resistant schists. Gullies and fissures follow predominant north-easterly and north-westerly trends (Fig. 7, foreground). An ironstone seam separating quartz-mica schist from hornblende-chlorite schist at Rickham Sand permits erosion along NW-SE lines. There are other directions of weakness, but in most cases the joint pattern often serves to isolate remnants of raised beach reefs, and accelerate their removal.

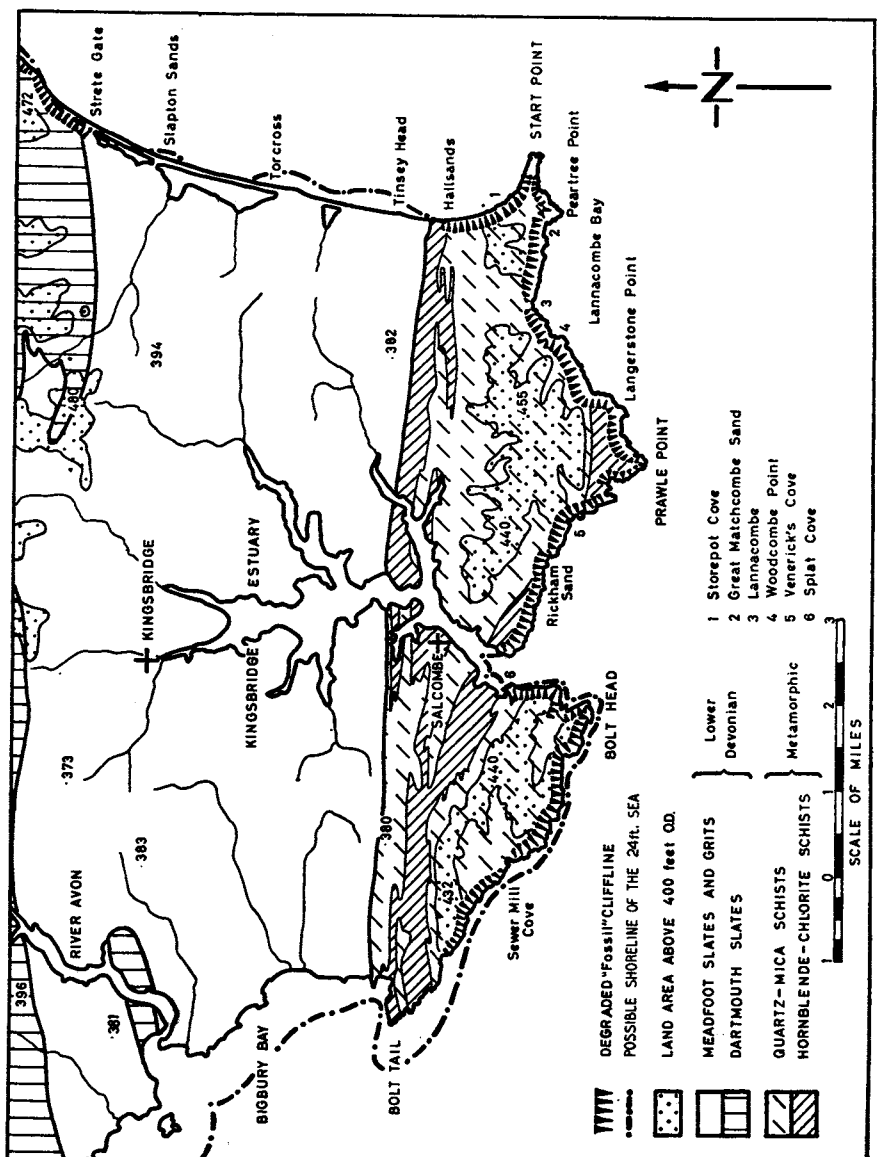


FIG. 5.

The coast of the Kingsbridge area (Strete Gate to the mouth of the Avon).

IV. THE RAISED AND DEGRADED CLIFFLINE

Whilst the wave-cut notch at the rear of the raised bench is the most accurate measure of old sea level, it is rarely visible. The ancient cliff therefore, provides the surest means of tracing the extension of the former coastline, and sea cliffs normally remain evident longer in the emergent landscape where cut into resistant rocks. Cliff form varies with many factors—the original relief, structure and lithology, and the effectiveness of marine processes dependent on exposure, wave fetch, width of wave-cut bench and the nature and amount of eroding debris. Weathering, wasting and slumping simultaneously act on the cliff top. The lateral extent of a cliff depends further on the number and size of gullies, hanging valleys and through-valleys whose streams need not be related to the same base level.

An elevated "fossil" cliffline also varies considerably. Its sharpened cliff-top profile is due to the rigours of subsequent subaerial degradation. The extended stream systems of the elevated landscape are not aligned to remove the waste derived from the crumbling older cliffs. These rapidly degenerate into inconspicuous and irregular slopes, locally interrupted by bare rock. With the accumulation of scree or head at the base of raised cliffs, an irregular concave profile ultimately results (Figs. 2*e* and 3). Subsequent wave action at lower levels causes more recent cliffs to truncate, intersect and retreat beyond the concave profile of the "fossil" cliffline.

(i) *Limestone Cliffs*. Cliffs related to the Torbay raised beaches are nowhere pronounced. At Hope's Nose, Thatcher Rock and Sharkham Point a low inclined cliff fronts a steeper rise. At Churston Cove and Shoalstone raised cliffs exist at no great distance from the present cliffs, leading onto the base of the 200 ft. coastal plateau (Fig. 4).

(ii) *Slate Cliffs*. At Blackstone Point and Western Combe Cove the raised clifflines are either largely obscured by head, or are being destroyed by subsequent wave action. The characteristic concave profile occurs between Pilchard Cove and Strete Gate. There is no apparent wave-cut bench and the modern shingle beach lies against a low cliff of head-mantled slate. However, the feature clearly differs in form from that of adjacent modern cliffs, and most probably is the "fossil" cliffline related to the "24 ft. sea".

Along the Revelstoke and Wembury coasts the degraded cliffs form the southern edge to elevated plateaux on either side of the Yealm Estuary. The edges of the two 350 ft. plateaux are bevelled by subaerial weathering, below which a pronounced break of slope, accompanied by jagged slate crags, occurs at between 200 and 300 ft. O.D. (Fig. 6).

(iii) *Schist Cliffs*. Between Hallsands and the Kingsbridge Estuary the "fossil" cliffline is the well-marked seaward limit to the 450 ft. coastal plateau. On the Prawle and Rickham Sections it fronts a lower bench cut across hornblende-chlorite schists. West of the Estuary the cliff occurs intermittently from Splat Cove to beyond Sewer Mill Cove. It is absent, as also are any traces of raised bench, within the present Estuary. Certain river gravels and head deposits both here and in the South Sands Valley are related to stream sections and attendant valley slopes graded to the 24 ft. strandline (Fig. 5).

The upper parts of the old cliffs often exceed 30 degrees in slope, but as the detrital head thickens towards their base, so gradient lessens. The "fossil"

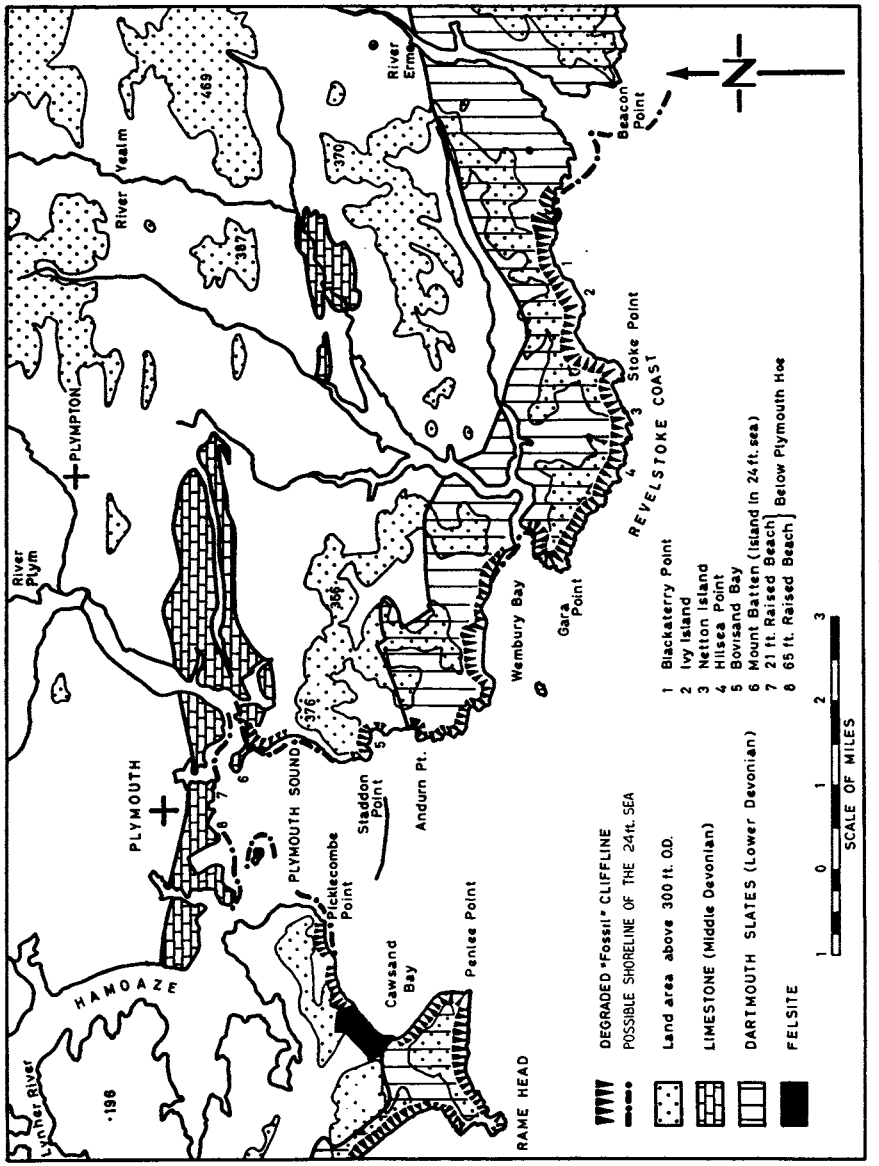


FIG. 6.

The coast of the Plymouth area (Beacon Point to Rame Head).

cliffline, despite a protective vegetation cover, has suffered a variable amount of subsequent erosion; in several places it disappears completely, whilst elsewhere the concave profile is well developed. The rugged schist crags cresting the Start Point arête have resulted from the retreat of former sea cliffs towards one another, both before and since their emergence, accompanied by subaerial denudation.

V. THE RAISED BEACH DEPOSITS

(1) *Morphology and Composition*

Raised beaches are not everywhere apparent. They may have suffered subsequent erosion and the intermittent attacks of storm seas, or they may have been overwhelmed by and incorporated in the head. Their very origin precludes any great extension. During the sea's withdrawal from the wave-cut bench, much beach material, if it existed at all, would be removed by backwash and undertow, or by subaerial denudation. Alternatively, raised beaches may, owing to their permeability which allows percolation, escape destruction by sheetwash and gully erosion, and be preserved beneath talus derived from wasting cliffs. Cliffs cut in the head by erosion at subsequent lower levels reveal occasional raised beach deposits at their base.

The deposits are not necessarily the same age as the wave-cut bench on which they lie. They may represent beach debris thrown up by the storms of a retreating sea level. They may be thrown up during later transgressional phases, such as those associated with the cutting of the 14 ft. bench on the Lannacombe Coast, or of the Post-Flandrian platform. In such cases the head which may cover beach material will have resulted from a later movement of debris, not always easily distinguished. However, where the beach is well cemented and occurs beneath primary deposits of head, it was most probably formed during the cutting of the underlying bench.

(i) *Limestone Area.* A fine raised beach rests on the wave-cut bench at 24 ft. above H.W.M.S.T. at Hope's Nose (Fig. 9). The basement bed is 12-16 inches thick; it is composed of locally derived limestone and slate debris varying from small gravels to boulders and angular blocks up to 18 inches long. Above, a current-bedded coarse sand, becoming progressively finer upwards, is cemented by carbonate of lime into a fairly resistant, often overhanging mass up to 12 ft. thick. The sand is of flint, limestone, slate, dolerite, quartz and sandstone debris, with comminuted shell fragments. The anomalous flints, which occur in other raised beaches of South Devon, originate in Cretaceous and Eocene beds. The Hope's Nose flints are probably derived from Eocene gravels on the Haldon Hills or Newton Abbot area to the north, which represent insoluble remnants of a former Chalk cover, or alternatively are from deposits existing in "raised beach" times, and subsequently wholly removed. South of Torbay, however, flints in modern and "fossil" beaches may be derived from proven thicknesses of Chalk occurring at no great depth or distance offshore.

The coarse nature of the Hope's Nose deposit, whose constituents show a predominant northern origin—dolerite from Black Head, sandstone from Teignmouth, the estuary-loving fauna on Thatcher Rock, and the somewhat higher occurrence at 33 ft. O.D., imply that the beach was formed on an

exposed shore near an estuary. This was possibly where the ancient Ilsham Stream entered the sea. Above the consolidated sand lies 2-3 ft. of loose blown sand, overlaid by soil wash and limestone debris at the base of a gentle grassy slope.

Lithologically similar, the Thatcher Rock beach contains more material derived from the sandstone around Torbay. It has been suggested from evidence of different assemblages of heavy minerals, that it may be of later date than the Hope's Nose beach (see Shannon, 1927). The greater amount of epidote and sphene in the Thatcher Rock deposit could indicate a later stage in coastal erosion when the Black Head dolerite was more exposed. Furthermore, whilst kyanite is large confined to Hope's Nose, the Thatcher Rock minerals are more akin to those in modern beaches. However, dolerite has recently been recognized in the Hope's Nose deposit.

Below limestone debris at Shoalstone, wave-worn pebbles of flint, limestone, chert, quartz, sandstone from fissures in the local limestone, and tourmaline are cemented into a thin beach deposit. At Sharkham Point a strip of cemented coarse sand with quartz, flint and limestone pebbles is all but obscured by head and mine debris.

The 21 ft. Hoe beach comprises up to 5 ft. of limestone fragments and coarse sand cemented by calcium carbonate. The constituents of the 65 ft. Hoe beach differ from those of the lower deposit, for in addition to limestone debris, they include pebbles and sands derived from Staddon Grit and Cawsand felsite on the Cornish side of Plymouth Sound.

(ii) *Slate Area.* Beach deposits at Blackstone Point and Western Combe Cove have been resorted and incorporated in the head. The rounded, subangular and angular materials consist of flint, and of local quartz, slate, grit, limestone and dolerite. Similar deposits occur on the Revelstoke coast east of Carsewell Cove, west of Wembury church, at Bovisand and elsewhere. West of Erme mouth pebbles of granite and other rocks from the Dartmoor area occur in raised and modern beaches.

(iii) *Schist Area.* The 24 ft. bench between Hallsands and Start Point contains large isolated quartz boulders, whilst at Storepot Cove brown sand and quartz, grit and flint pebbles, up to 30 inches thick within a head matrix, occur at 23 ft. O.D. (see Ussher, 1904).

At Great Matchcombe Sand, a cemented beach deposit, red to black in colour, contains small quartz, flint and quartzite pebbles, larger quartz boulders and angular fragments of schist and quartz protruding from beneath a slumped mass of head at 5 ft. above high water. This deposit was left by a temporary high post-Glacial or, at least, late sea level, as also were two boulders on a raised bench near Malcombe Point. A raised beach related to the 24 ft. strandline occurs in Splat Cove. Deposits in an ENE-WSW gully on the east side of Lannacombe Beach and also at Lannacombe Mill were stranded by the 14 ft. sea. Elsewhere old beach sands become so confused with the admixture of head as to be almost indistinguishable from sandier beds in the later deposit.

(2) *Fauna*

Few raised beach deposits in Britain contain dateable remnants of contemporary marine life. However, the fauna of the Torbay beaches is invaluable.

Ussher (1903) found parts of crab and 17 species of marine mollusca at Hope's Nose. Comminuted shell occurs throughout the deposit, whilst well-preserved specimens are found towards the base of the coarse sand. Most common are oyster (*Ostrea edulis*), mussel (*Mytilus edulis*), limpet (*Patella vulgata*) and decayed examples of the cockle (*Cardium edule*).

Hunt (1888) examined 43 species from the Thatcher Rock beach. Whilst not containing the commonest cockles now found within Torbay, there were 106 fragments of the rarer form *Cardium echinatum*, and 36 of *Cardium edule*, a cockle now absent from Torbay. *Trophon truncatus* and *Pleurotoma turricula*, whose present range is more northerly portray a somewhat colder climate. However, *Pinna rubis*, *Adeorbis subcarinatus* and *Fusus jeffreysianus* which today occur from Aberdeen to the Mediterranean show that there was no intense cold. The number of estuary-frequenting forms is the result of a former extension of the proto-Ilsham stream between Hope's Nose and Thatcher Rock and which entered the sea not far from the extended Exe-Teign Estuary.

Shell fragments occur at Churston Cove and Sharkham Point, whilst *Littorina obtusata* and *Cardium echinatum* are preserved at Shoalstone. Comminuted shells in confused sandy matrices occur beneath a later estuarine deposit some 12 ft. above H.W.M. at Splat Cove. The 21 ft. Hoe beach contains broken shells, possibly limpets. Elsewhere the raised beaches contain few identifiable fossils.

The 24 ft. shoreline thus bordered a sea only slightly colder than at present. Numerous molluscs of that period still exist in the vicinity, although relative proportions vary. The 24 ft. raised beaches are of Pleistocene age; there are no Pliocene or older species amongst the fossils present.

VI. THE HEAD

Head is a solifluctional scree or talus, owing its special characteristics to the rigours of the frost climate under which it was formed. Not confined to the coasts, it overlies river gravels and occupies basin-shaped valley heads inland. It postdates the elevation of the beach planes on which it lies for otherwise it would have been removed by wave action. However, the head cannot be divorced from the raised beach problem for it overwhelms both the beach deposit and the underlying bench.

(1) *Form*

The head within the present region is the debris weathered mechanically, largely as a result of alternate freezing and thawing, from the raised cliffs. It accumulated as a semi-frozen sludge of snow, ice and rock waste which moved downslope during seasonal thaws. Originally it extended further seaward than at present, but has been truncated by more recent seas. This undercutting provides several fine sections between Great Matchcombe Sands and Prawle Point in head cliffs up to 100 ft. high. In many places slumping of the head cliff face has covered beach material of more recent age than the underlying bench.

The height of the head cliff depends on the thickness of the original deposit and on the distance to which it has been eroded back towards the "fossil" cliff. Where the "fossil" cliffline more closely approximates to the present shoreline

the head bench is limited in width, its surface is steeply sloping, and it presents a high cliff seawards. Above Great Matchcombe Sand a narrow bench of head ends abruptly in a cliff rising 80 ft. above the 14 ft. bench. At Langerstone Point, however, the irregularly concave debris slope flattens considerably into a gently sloping platform extending 200 yards beyond 200 ft. "fossil" cliffs of hornblende-chlorite schist. At its outer edge the head deposit is only 4 ft. thick (Fig. 7).

Pinnacles and partially detached masses of head, overlying remnants of old beach reefs, have been isolated by recent marine and subaerial erosion at Great Matchcombe (Fig. 8), Netton and Ivy Islands on the Revelstoke coast, near Staddon Point and elsewhere. Gullies and valleys running seawards through the "fossil" cliffline are also lined with this type of deposit.

(2) *Composition*

In the Torbay and Plymouth areas the head consists mainly of limestone fragments with some quartz and sandstone shards. Bordering the schist upland, it is composed of quartz-mica or hornblende-chlorite schist, often both; elsewhere slate, shale, grit, quartz-veins and local igneous rocks provide the debris. Larger fragments of schist, slate or limestone have their long axes aligned downslope, the whole incorporated in an ochreous to red-brown matrix. This matrix, however, varies in colour from light grey and yellow to sepia and black, and in texture from a coarse grit, through sandy loams to occasional lenticular masses of clay. These differences reflect minor adjustments of processes to variations in the climate and slope during the formation of the head. During deposition, contemporaneous erosion within the head differed over small distances, which largely accounts for present inequalities. Two masses of head occurring at similar heights above the wave-cut bench need therefore not be of the same age.

The very nature of the head precludes the finding of recognizable fauna within the deposit. It represents a period or periods of variable solifluction associated with intense frost-shattering and gully and sheet-erosion when the local climate was far more extreme than today, and when the sea stood at a lower level.

VII. The peartree stage—post-glacial raised beach

At Peartree Point and Langerstone Point old storm beach material containing the modern limpet, *Patella vulgata*, overlies the head bench near its seaward edge. At Peartree Point the pebble stratum, composed mainly of vein quartz and flint, is up to 9 to 12 inches thick, and lies at a depth of 6 to 9 inches below the soil surface. It lies at 15 to 20 ft. above high water and extends 500 ft. along the upper edge of the head cliff. These pebble deposits are possibly remnants of a short-lived phase of marine erosion, related to a post-Glacial sea level which rose 6 to 10 ft. above the present level. This transgression cut the cliffs in the head deposits overlying the 24 ft. and 14 ft. benches throughout the South Devon coast. These cliffs are now beyond the range of storm seas and have become degenerate. Furthermore, at Matchcombe Sand and elsewhere a distinct bench, only 3 to 4 ft. above present high water, is observable over short distances, cut into the higher benches.

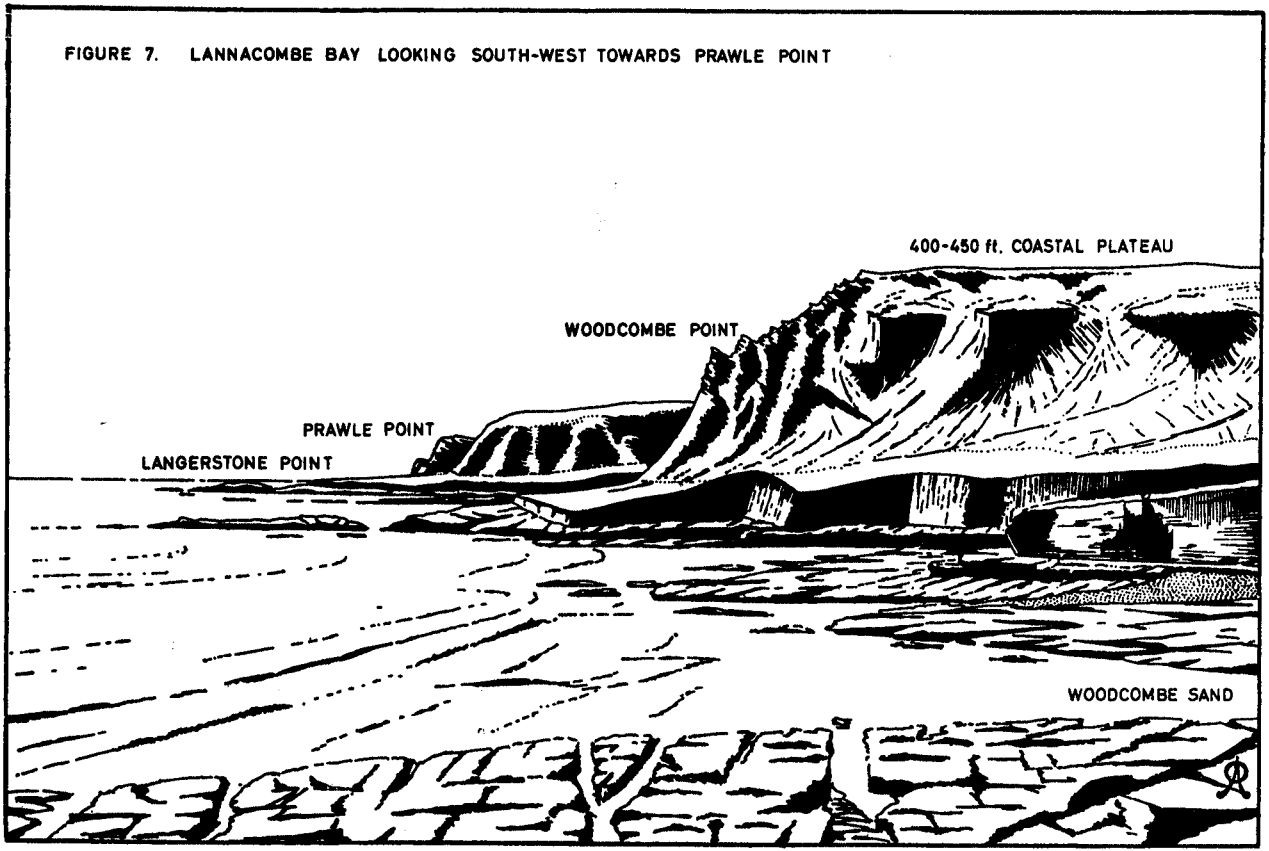


FIG. 7.
Lannacombe Bay, looking south-west towards Prawle Point.

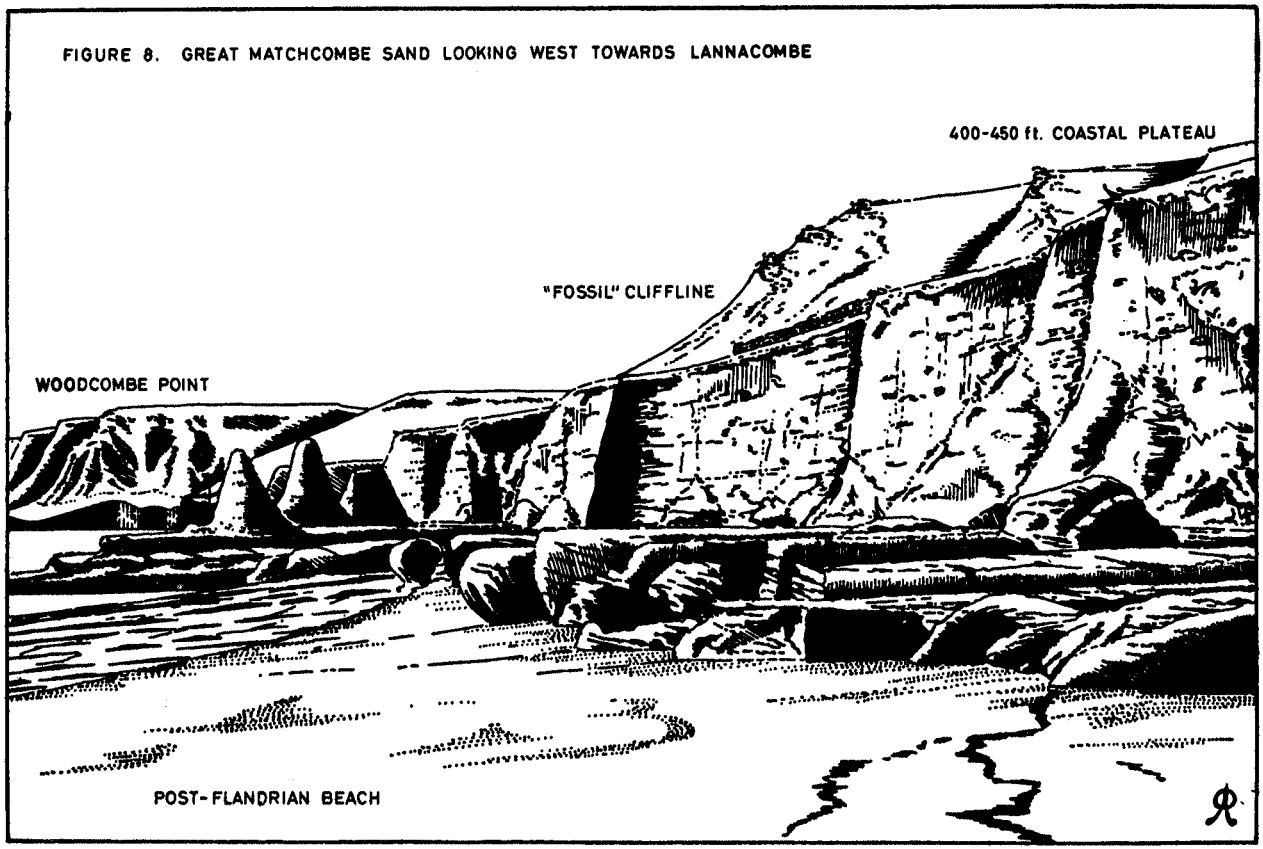


FIG. 8.
Great Matchcombe Sand, looking west towards Lannacombe.

VIII. CORRELATION AND CONCLUSIONS

Changes of sea level bring about a readjustment of stream profiles and slope forms to the altered base level, provided that this remains relatively stationary for some time.

In broad outline, the periods of high sea level and raised beach formation correspond to interglacial phases of climatic amelioration during which the melting of former continental ice sheets liberated large volumes of water into the oceans. Alternatively, the periods of low sea level and intense solifluction correspond to glacial phases of climatic deterioration, the transfer of volumes of water to the ice masses, with periglacial activity in zones, such as South Devon, just beyond the limits of the ice-front.

(1) *The 65 foot Strandline*

To judge from their similar heights above present day level, the higher Hoe beach seems contemporaneous with a beach at 65 ft. near Mousehole in Cornwall. It was formed before the overdeepening of the Tamar Estuary hindered the movement of Cawsand felsite across Plymouth Sound. The 65 ft. strandline is related to a stillstand during the last Interglacial phase (Zeuner, 1953) evidence of which has since been removed by erosion, or buried beneath solifluction deposits.

(2) *The 24 foot Strandline*

This shoreline was less irregular than the present submergent coast. It can be traced with some accuracy between Hope's Nose and Plymouth Hoe (Fig. 1), it disappears in Bigbury Bay and again between Hallsands and Strete Gate where less resistant Meadfoot Beds reach the shore. Torbay also owes its present form to erosion subsequent to the period of the 24 ft. sea. Elsewhere the strandline was either just landward of the present coast, where the raised benches occur, or just seawards as shown by truncated remnants of the "fossil" cliffline. Plymouth Sound existed in much the same shape as today. The Mount Batten limestone knoll stood as an island in the 24 ft. sea, the isthmus which connects it with the mainland having been cut across, and since elevated and covered by head (Fig. 6). The present estuaries of the Tamar, Plym, Yealm, Erme, Avon, the Kingsbridge inlet, Gara and Dart were at this time major river valleys, the lower stretches of their streams grading to the 24 ft. sea. Their overdeepening followed a withdrawal of the sea during late Glacial times, and they were subsequently drowned during the Flandrian transgression.

The 24 ft. strandline dates from a late stage in the last Interglacial, followed by colder climate, fall of sea level and solifluction which rapidly wore down the emergent coast (Fig. 3, II).

(3) *The 14 foot Strandline*

This strandline notched the seaward slope of the higher bench and is well preserved on the shores of Lannacombe Bay. It was cut at the close of the marine transgression related to an interstadial phase of the last glaciation, a temporary waning of the continental ice sheets (Fig. 3, III).

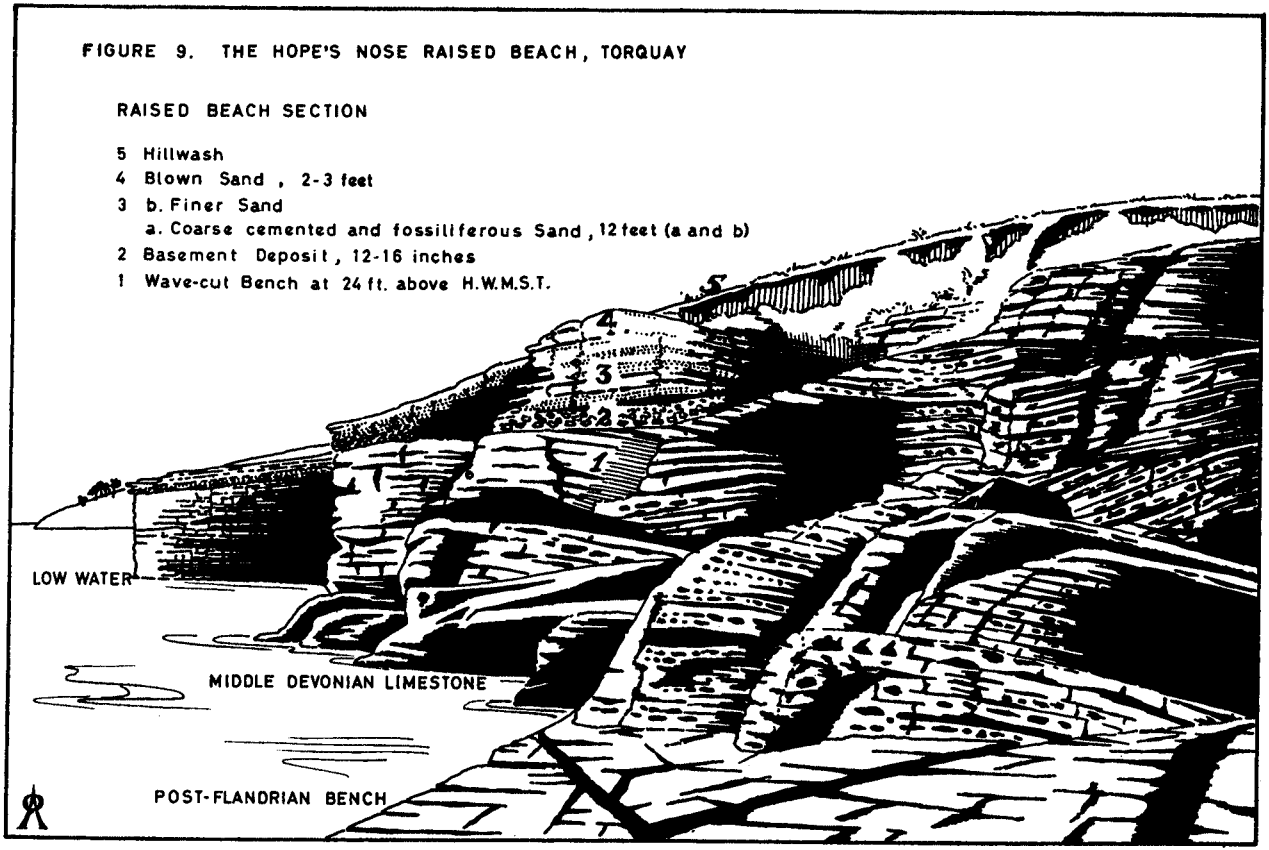


FIG. 9.
The Hope's Nose raised beach, Torquay.

During late Glacial times sea level again fell to well below the present. Renewed, though less intense, solifluction gave way slowly to normal geomorphic processes operating in a cool temperate regime. Forests replaced the tundra of the frost climate (Fig. 3, IV).

(4) *Post-Glacial*

The post-Glacial sea temporarily rose some 6 to 10 ft. above the present level (Fig. 3, V). In doing so it drowned valleys graded to late Glacial seas, submerged much forest land, and reintroduced marine processes to the coastal zones of former times (Fig. 3, VI).

The Post-Flandrian bench and beach deposits, and the modern cliffs and shingle bars of Start Bay and Bigbury Bay are the latest stages in coastal evolution. The present shoreline cycle has reached submaturity in a submergent coast, adjacent to which lie the raised beaches and strandlines, relics of former part-completed cycles interrupted by emergence.

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