DENUDATION CHRONOLOGY OF PARTS OF SOUTH-WESTERN ENGLAND

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INTRODUCTION

THE South West Peninsula is the only unglaciated highland region in Britain. Its importance therefore in the elucidation of the events of late Tertiary and Quaternary time in terms of landform evolution is considerable. Unfortunately, the stratigraphical record is incomplete since the greater part of the surface is developed on Palaeozoic rocks. Even in the east of the region, where newer rocks are exposed, deposits which postdate the mid-Tertiary (Alpine) earth movements, i.e. deposits of undoubted late Tertiary or Pleistocene age, are rare. Wooldridge (1950) has spoken of "this great lost interval in the geological story" and of the "leapfrog antic from the topographical expression of ancient structures to the story of glaciation". In these circumstances morphometric studies can help to fill the gap.

Erosion surfaces of wide extent have been recognized throughout the Peninsula. From the early papers of Jukes-Browne (1907), Barrow (1908) and Davis (1909) to the more recent writings of Green (1941, 1949), Balchin (1952), Wooldridge (1954), Waters (1960a, b,) and Brown (1961), discussion of their extent and origin has continued. Platforms at heights ranging from the summit levels of Exmoor and Dartmoor to below sea level have been described. Argument over their genesis has ranged through every possible erosional process. Discussion is now largely concerned with the relative importance of "normal" sub-aerial and marine agencies, the origin and evolution of the drainage pattern, and the chronology of events. The work of Jukes-Browne (1904), Clayden (1906), Green (1949) and Wooldridge (1954) deserves special mention in this context.

The present paper is a collection of the recent results of four geomorphologists who have been working, independently, in adjacent areas of south-west

England. Inevitably there is overlap between these areas—and thus repetition in the written accounts. This has been edited to a minimum in the text, retained only where it would otherwise destroy the sense. The story begins on Dartmoor and is continued into the lower parts of the Dart and Avon basins and finally the Exe Valley, thus straddling the Highland/Lowland Zone boundary and providing a close link with the more thoroughly worked landscapes of south-eastern England.

The opinions expressed in each section are entirely those of the individual authors. Their conclusions show a wide measure of agreement and it is hoped that they will serve as a basis for future work in the area.

I. DARTMOOR AND ADJACENT AREAS ABOVE THE 700-FOOT CONTOUR

R. S. Waters

(1) *Planation Surfaces*

Extensive remnants of three surfaces have been mapped on Dartmoor (Fig. 1).

(i) *Upper Surface (1,900–1,500 feet)*. The central parts of the high plateaux on the north and south of the Dart Basin exhibit gently undulating tor-free summit plains with relief of the order of 100 to 200 feet. The summit plain of northern Dartmoor lies between 1,700 and 1,900 feet O.D. and is surmounted by three unconsumed residuals; that of the southern plateau is well developed over a wide area between 1,500 and 1,650 feet and carries one residual. That these plains are surviving portions of a single, southward-sloping surface is suggested by their morphological similarities, their present elevations and the height of the North Hessary Tor whaleback (1,675 feet) on the Dart-Walkham divide. The top of the Hamel Down ridge (1,550–1,730 feet) is an outlying part of this surface and the isolated Rippon Tor summit (1,564 feet) may give some indication of its elevation in the Haytor area.

(ii) *Middle Surface (1,350–1,050 feet)*. Surviving portions of the Middle Surface are separated from the Upper Surface by a zone of variable width with steeper, tor-topped slopes and other isolated and more or less reduced fragments of the higher surface. The surface is particularly well developed in the Dart Basin and about the headstreams of the North and South Teign Rivers, is represented by the higher parts of the granite plateau east of Moretonhampstead, and is present elsewhere around the upland on both granite and altered country rocks. It is by no means plane or even of identical morphological character throughout its wide extent; and the range of height within which its flatter portions occur is considerable.

(iii) *Lower Surface (950–750 feet)*. This surface has been traced all around Dartmoor. It is conspicuous on the floor of the Bovey-Chagford depression north-west of Lustleigh, on the top of the eastern plateau and, beyond the Teign Valley, on the Haldon Hills. On the west of the Moor, it is present on Sourton Down (G.R.SX545918) whence it is traceable north-westwards for eight miles along the Tamar-Torridge divide, around Lydford where the spectacular gorge exhibits a two-tier incision into it, and farther south where it flanks the westerly projection of the Middle Surface between Lydford and Tavistock. The

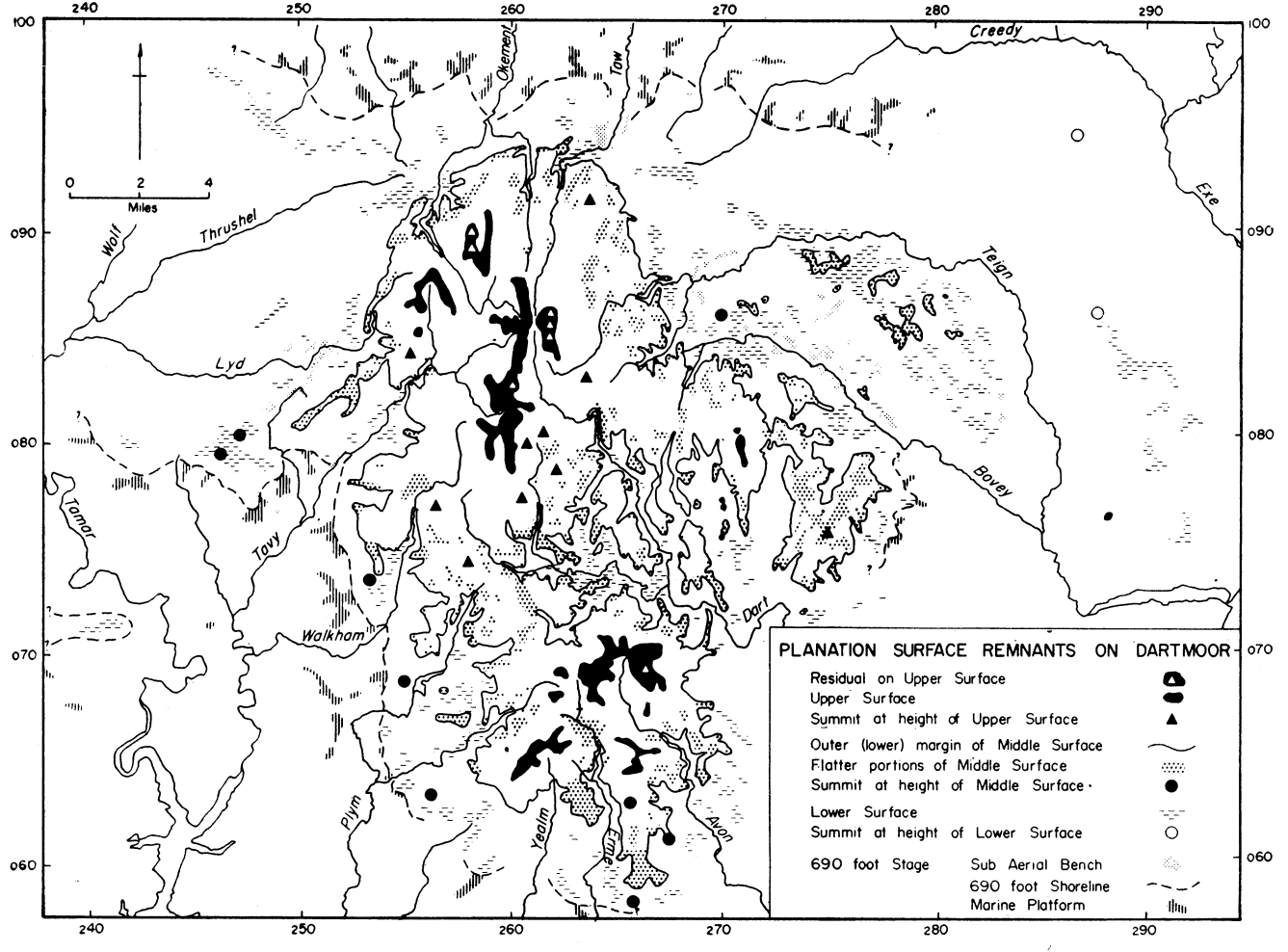

FIG. 1.

Planation surface remnants on Dartmoor.

top of Hingston Down links remnants mapped in south-west Devon with wide areas of the surface on Bodmin Moor. On Dartmoor itself, the Lower Surface is represented by valley-side benches and river terraces which may occur at various levels between 750 and 1,000 feet O.D. Tors are absent from this surface and although some subsequent adjustment to structure is apparent, e.g., north-west of Hennock where the surface is grooved by shallow N.W.–S.E. valleys parallel to the Bovey-Chagford depression, it is not so well developed as on the Middle Surface.

(2) *Correlations and Chronology*

The *Lower Surface* is part of a widely developed planation surface which maintains a constant height (750–950 feet O.D.) from Cornwall to Kent. It appears to be sub-aerial in origin: wherever it has been identified on permeable formations, as on the Haldon Hills, in east Devon, or further east in Wessex and the Weald, it carries a weathering mantle of clay-with-flints and chert; moreover, it is represented in the higher parts of Dartmoor by a series of valley-side benches or terraces which when followed downvalley grade imperceptibly into the broad, flatter portions of the surface on the moorland periphery. Although up to four related terraces between 750 and 1,000 feet have been recognized in the major Dartmoor valleys they are not indicative of a like number of base-level changes. They are attributable rather to structural variations in the granite and Palaeozoic sediments, which were revealed during the incision of the streams, and arise from the multiplication of knickpoints associated with the rejuvenation to which the creation of the *Lower Surface* is due. The terraces reflect the immaturity of development of the surface on the more resistant bedrock. By contrast, on less resistant and relatively homogenous Mesozoic formations in east Devon, planation was more nearly perfect and is represented by a surface which extends without a break from 750 to 950 feet above sea-level.

The age of the surface can be fixed with some precision. As it is unwarped it must post-date the earth movements which in south Devon created the Bovey Basin in which Middle Oligocene sands and clays were deposited. But its formation also pre-dates the Pleistocene changes of base level; the (?Early Pleistocene) sea transgressed and trimmed its lower parts (*c.* 690 feet) e.g., on Roborough (G.R.SX515667), Whitchurch (G.R.SX502737) and Plaster Downs (G.R.SX514729). Thus on Dartmoor, as in south-east England, the 750–950 foot surface may be regarded as a sub-aerial product of late Tertiary (Mio-Pliocene) age.

Although in the absence of associated deposits it is impossible to give a precise geological date to either the *Middle Surface* or the *Upper Surface*, it is possible to suggest a chronology of denudation stages based on the morphological characteristics and relations of the three planation surfaces and on what is known of the Tertiary geological history of the West Country.

On the eastern plateau of Dartmoor there is an interdigitation of the higher parts of the *Lower Surface* with rounded spurs extending south-eastwards from more or less isolated and degraded remnants of the *Middle Surface*, and elsewhere on the margins of the upland a similar morphological relation suggests that the higher of the two surfaces is the older. Likewise, the apparent development

of the *Middle Surface* at the expense of the *Upper Surface* suggests that the highest surface is the oldest of the three.

From the distribution of its remnants it appears that the *Middle Surface*, like the younger *Lower Surface*, developed sub-aerially in relation to a pattern of streams which was practically identical with the existing drainage pattern on the upland. But the headstreams of this pattern which have cut back into the high northern and southern plateaux cannot be interpreted as descendants of streams responsible for fashioning the *Upper Surface*. They are much too closely spaced and lack the expectable integration. As both Jukes-Browne (1904) and Green (1949) perceived, the prevalence of southward-trending tributary streams suggests that the existing pattern developed under the influence of a southerly slope which resulted from a southward tilt of a formerly eastward-draining land surface. The west-east Dart trunk and the upper Teign are substantial relics of the earlier drainage pattern. Thus it is not inconceivable that the southward-sloping *Upper Surface*—if it is a sub-aerial product—was fashioned in relation to easterly-flowing rivers and that the initiation of the *Middle Surface* succeeded its tilting to the south.

Geological evidence corroborates these suggestions. Ball-clays in Dorset attest to the conveyance eastwards of kaolinitic waste from Dartmoor during the Eocene; but by the Middle Oligocene earth movements had disrupted this transport and the products of Dartmoor denudation were being deposited locally in the newly-created Bovey Basin. It is not unreasonable to suppose that the early Tertiary denudation produced the *Upper Surface*—largely sub-aerially—and that the *Middle Surface*—at best an imperfect and partial "pene-plain"—developed *pari passu* with the sinking and filling of the Bovey Basin during the mid-Tertiary (Middle Oligocene).

Table 1. *Planation Surfaces of Dartmoor*

Lower Surface	950–750 feet	Late Tertiary (Mio-Pliocene)	sub-aerial
Middle Surface	?1,350–1,050 feet	Middle Tertiary (Oligocene)	sub-aerial
Upper Surface	Northern Dartmoor 1,900–1,700 feet Southern Dartmoor 1,650–1,500 feet	Early Tertiary (Eocene)	predominantly sub-aerial

(3) *Pleistocene Modifications*

During the Pleistocene a distinctive series of minor features was produced which reflects the alternation of cold and mild climatic phases and the erosional processes associated with them. Mass transfer of waste exposed summit tors, moulded slopes and plastered valley floors with rubble-drift; frost weathering disrupted exposed masses of bedrock and produced "clitters" of boulders and sharp-edged blocks; but none of these ubiquitous features has chronological significance. No base-levelled surfaces were created on the upland. To complete the record of denudation during the last million years we must look to the strand-flats and river terraces of the lower plateau country of south Devon.

II. THE DART BASIN

D. Brunsden

This study of the River Dart was undertaken with the intention of critically re-examining, revising and extending the work of the late J. F. N. Green (1949). Detailed field mapping of the erosion surfaces was carried out on a 6 inch to the mile scale and heights were determined using a 5 inch surveying aneroid barometer and the methods outlined by B. W. Sparks (1953). Seventeen stages have been recognized, and are given in Table 2. The distribution of the major surfaces is shown in Fig. 2.

(1) *The Surfaces*

The highest surface has been mapped on the summits and interfluves of northern Dartmoor at 1,900–1,700 feet, and south of the Dart at 1,650–1,500 feet O.D. The form of the surface is that of a base-levelled sub-aerial peneplain that possesses considerable relief related to the structure of the granite, and has a 40 feet per mile slope to the south and south-east. This slope has been interpreted by Green (1949) and Waters (1960a, b, and above) as the result of tilting.

Table 2. *Planation Surfaces of Dart Basin*

Feet O.D.	Comments
1,900–1,700	Northern Dartmoor } sub-aerial summit plain
1,650–1,500	Southern Dartmoor }
1,300–1,100	Extensive, sub-aerial erosion surface
1,000	River terraces on the moorland Dart
920	
800	
750	
690	Highest marine shoreline identified
590	River terraces, shorelines and marine platforms identified in most cases
480–475?	
445–430	
325	
270	
230	
180	
150	
110–100?	
50	
25	
10	

NOTE: The altitudinal sequence shown in this table does not, necessarily, imply a chronological sequence.

The 1,900–1,500 foot summit plain is separated from the surfaces between 1,300–750 feet O.D. by a youthful fringe of isolated hills, interfluve bluffs, and knickpoints on the streams, which represent the limit of the extension of the lower surfaces into the summit plain.

The 1,300–1,100 foot surface is composed of valley-side benches and flood-

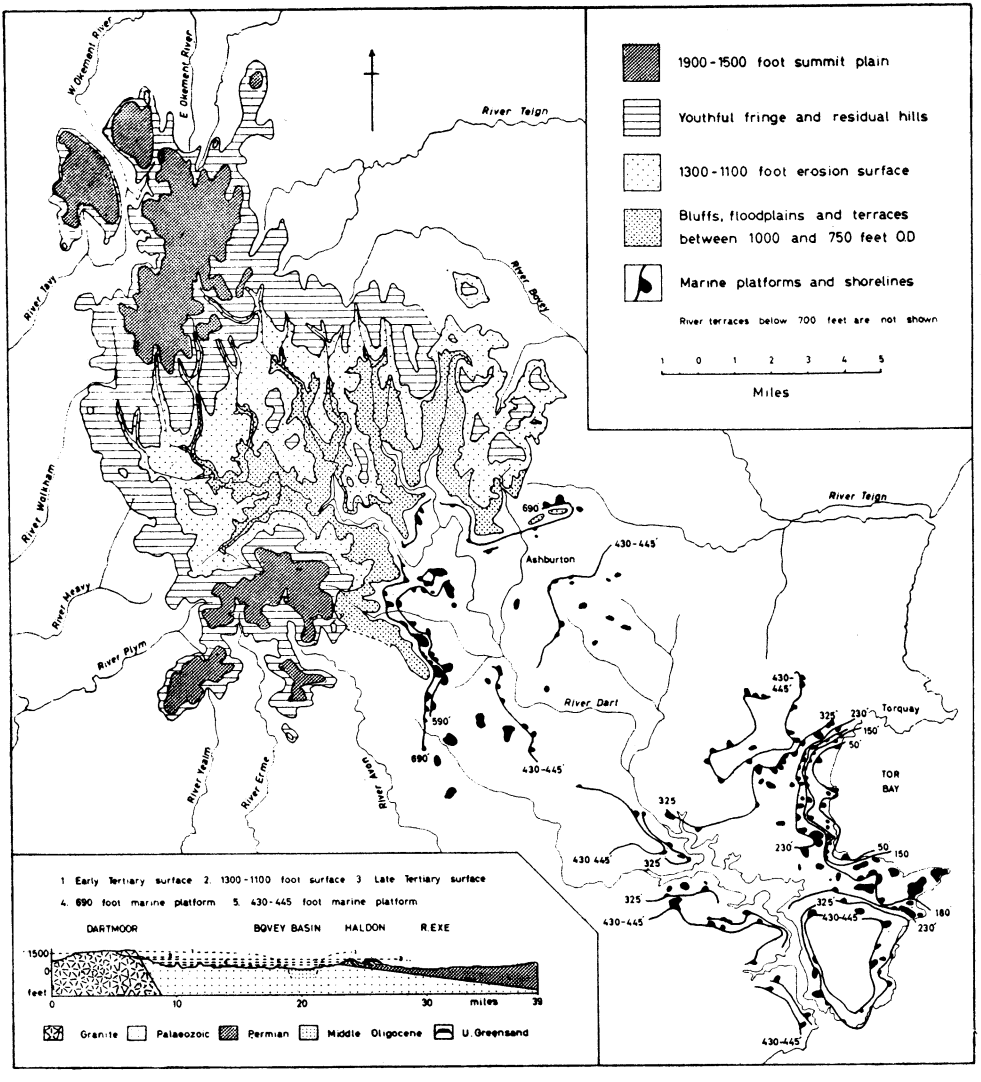

FIG 2

Erosion surfaces, terrace sequence and former shore lines in the Dart Basin.

plains which interdigitate with the summit plain along the narrow, steeply descending valleys of the south-flowing tributaries; broad basin-like areas on the west and east Dart that are interpreted as locally base-levelled areas of old age; and finally, isolated hills, ridges and tors which are part of the residual relief of the surface and are in a mature stage of development.

The levels at 1,000, 920, 800 and 750 feet O.D. are preserved by terrace fragments and floodplains within the valley of the moorland Dart. These terraces are believed to be entirely of sub-aerial origin. No evidence of marine base levels has been found at these heights and it is therefore impossible to confirm Green's recording of wave-cut benches at 1,000, 920, and 800 feet O.D. The heights given for these terraces do not represent base levels but are the heights of the lowest terrace fragments in the sequence.

Below 700 feet, however, strong evidence has been found for marine benches and associated river terraces at eleven heights between 690 feet and present sea level. (Table 2).

The evidence in the field is of four kinds:

(1) A series of flats bevelled across spurs.
(2) Well marked bluffs at the back of the spur flattenings.
(3) Bevelled hilltops.
(4) Valley-side benches and floodplains.

The first three categories fall into marked altitudinal groups which maintain a constant horizontal level throughout the area and are interpreted as evidence of marine planation. The surfaces that fall in the fourth category form part of a well marked terrace sequence.

The most important of the stages are those at 690, 325, 230 and 25 feet O.D. The base levels identified largely agree with those established by Green (1949) but in many cases the flats assigned to each base level have been revised. The recognition of the wider inland extension of the 690 foot shoreline is a major addition to his findings.

(Traces of two further levels at approximately 480–475 feet and 110–100 feet O.D. have been mapped but the evidence is insufficient to allow them equal status with the rest.)

(2) *The Drainage Pattern*

The earliest drainage pattern on Dartmoor was probably eastward and was responsible for the production of the summit plain. The extension of the south-flowing tributaries of the Dart took place during the 1,300–1,100 foot stage and it is significant that there was no comparable development of the north-flowing streams. It is possible that this pattern reflects the influence of the southerly tilt postulated by Green and Waters. A simple hypothesis is that the 1,300–1,100 foot stage was initiated by the uplift and tilting of the summit plain.

The trunk drainage on the Moor continued eastward throughout the 1,000-750 foot stages but was interrupted by the transgression of the 690 foot sea in the region of the Holne embayment. Following the retreat of the 690 foot sea, the lower Dart was superimposed across the Palaeozoic rocks of south Devon as a discordant, south-eastward flowing stream, and developed sub-parallel

tributaries. This whole development took place in a number of stages that were related to a spasmodically falling sea level. These stages are represented on the rivers by the extensive valley-side benches, floodplains and knickpoints.

(3) *Conclusions*

The surfaces below 1,300 feet show no evidence of warping and it is suggested that they postdate the mid-Tertiary earth movements which have been responsible for the extensive faulting of south-west England and the tilting of the early Tertiary wave-trimmed surfaces of east Devon (Waters, 1960a).

The 690 foot marine bench may reasonably be correlated with a similar feature that is preserved in south-eastern England where it is believed to be of early Pleistocene (Calabrian) age.

It is suggested that the surfaces below 690 feet represent stages in the retreat of the sea during the Pleistocene Period. Insufficient evidence is available, however, to give a more accurate correlation.

III. The South Hams and Southern Dartmoor

A. R. Orme

The South Hams, broadly speaking, lie between Dartmoor and the English Channel. To the east lies the Dart valley, and to the west the catchment area of the river Yealm. The South Hams, together with that part of southern Dartmoor draining to the Avon and Erme rivers, constitute an area of approximately 180 square miles of considerable geomorphological interest.

The South Hams comprise a tract of dissected plateau country, between 400 and 500 feet above sea level and scored by numerous deeply entrenched stream valleys draining to the Avon and Erme rivers, the Kingsbridge Estuary, the Gara and directly to the coast between these lines. The influence of the Armorican orogeny is demonstrated in the correlation between the complex folding of the underlying schists and Devonian slates, grits and volcanics and the general east-west trend of the principal morphological units.

The area has not hitherto been subjected to intensive geomorphic analysis. Previously published research has been confined largely to the solid geology with brief accounts of superficial deposits and coastal phenomena but only passing mention made of landforms. The present summary of the denudation chronology is based upon evidence supplied by detailed morphological mapping at the 6 inch to 1 mile scale throughout the entire area. The precise dating of the complex sequence of events thus recognized is, however, rendered virtually impossible by the local scarcity of recent deposits. Nevertheless, the most important stages have been correlated, not without reservation, with major events already placed on the Tertiary and Quaternary time scale elsewhere.

(1) *Southern Dartmoor*

Although the larger granite-complexes of south-west England were probably exposed in part during Lower Cretaceous times, there is strong evidence to suggest that Dartmoor was for a period wholly submerged beneath Upper

Cretaceous seas (Smith, 1961). Prior to the close of Cretaceous times, however, the seas withdrew and drainage was initiated on the emergent marine surface.

Peneplanation during early Tertiary times removed the Cretaceous cover and shaped an extensive surface on Dartmoor which, tilted southwards by the mid-Tertiary earth movements, now lies at 1,620–1,520 feet on southern Dartmoor (Fig. 3). Only Ryder's Hill (1,690 feet) rises appreciably above this general level. The summit plain is flanked by a less extensive 1,375-1,300 foot surface whilst outlying summits descend to 1,050 feet.

Two apparently unwarped sub-aerial surfaces, probably of late Tertiary age, are preserved on the granite and aureolar rocks of the Dartmoor periphery near South Brent and Ivybridge at 930–875 feet and 820–730 feet. The latter is a remnant of a broad land surface, related to a base level not lower than 400 feet, which probably extended southwards across the South Hams towards the close of Tertiary times.

(2) *The South Hams*

The late Tertiary surface was largely drowned by a marine transgression rising to approximately 700 feet at the onset of Pleistocene times. Its form nevertheless influenced the subsequent emergence and is reflected in certain relief elements at present between 400 and 700 feet. In the north-east, the South Hams drained eastwards towards a proto-Harbourne River, whilst in the western sector drainage was directed towards the Erme and Yealm rivers. Elsewhere, however, streams drained radially southwards away from a watershed stretching from Blackdown (720520) to beyond Hemborough.

The 690–700 foot strandline, whose shore-platform is well-developed at Roborough and Plaster Downs (outside the present area, north of Plymouth) is, south of Dartmoor, defined by relatively few benches. Further south, however, Blackdown (648 feet) and the central grit uplands from Horner Down (679 feet) to beyond Hemborough (627 feet) are wave-trimmed remnants of the late Tertiary watershed, dominated by the unsubmerged Stanborough Brake (775517, 706 feet).

The subsequent Pleistocene regression was punctuated by numerous still-stands of which those at 600, 550, 460, 327, 150, and 25 feet were most important (Table 3). Furthermore, it is evident that transgressive seas interrupted the general fall of sea level, not only in the present coastal zone but also at the 150 foot stage and at possibly higher levels, and may have significantly influenced the developing relief and drainage pattern.

The 600 and 550 foot strandlines are well-preserved south of Stanborough Brake. The 460 foot stage, conspicuous near Cole's Cross witnessed the final planation of the 400–455 foot coastal plateaux around Start, Prawle and Bolberry. During the 430, 400 and 375 foot stillstands, seas similarly trimmed the extensive Kingston, Bigbury, Churchstow and Coleridge (795439) plateaux. Such trimmings would have been less effective, however, had not the landscape been previously lowered to near base level during late Tertiary and possibly early Pleistocene times.

In the Kingsbridge area, and around the shores of Bigbury and Start Bays, a veritable staircase of shore-platforms backed by low-angle "cliffs" is related to

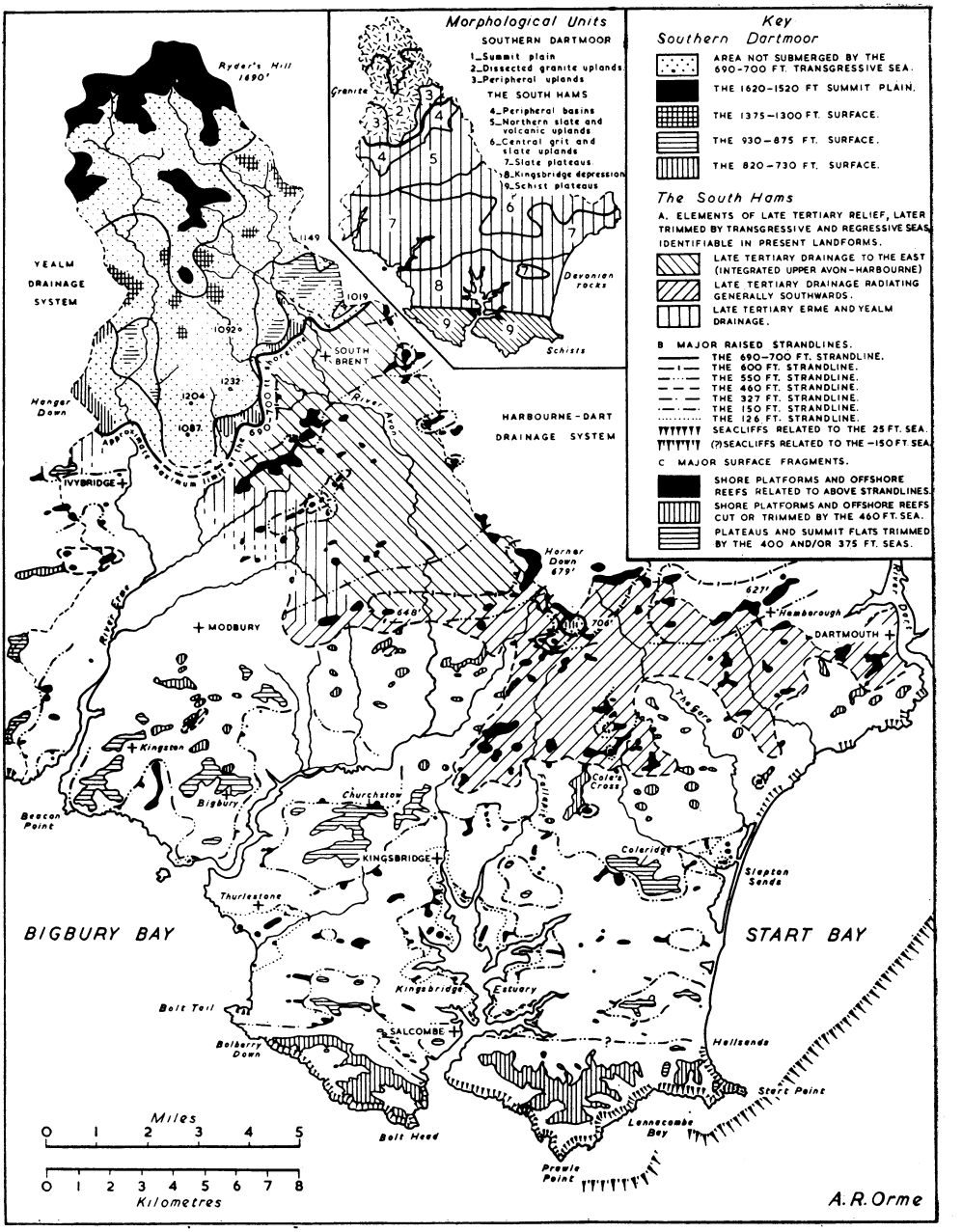

FIG. 3.

The denudation chronology of the South Hams and southern Dartmoor.

stillstands at 400, 375, 327, 300 and 280 feet. Strandlines at 150 and 126 feet may be traced around the Kingsbridge Estuary and the Slapton and Thurlestone basins, and the transgressive nature of the 150 foot sea convincingly demonstrated. Significantly, erosion during New Red Sandstone times probably blocked out the rough outline of southernmost Devon and thus influenced the Pleistocene development of these same three areas.

Table 3. *Planation Surfaces of the South Hams and southern Dartmoor*

Stages in feet O.D.	Comments
1620–1520	The summit plain of southern Dartmoor
1375–1300	
930–875	
820–730	Probable extension to 500 feet
700–690*	Possible stillstands at 650 and 626 feet
600*	
550*	Extensive surface between 530 and 480 feet
475	
460*	
430	
400	
375*	
350	
327*	
300	
280	Confused sequence with possible stillstands at 240, 225, 214, 200 and 175 feet
150*	
126	
25*	
14	
0*	
−36 to −50	
−140 to −150*	

NOTE: Stages given in italic figures relate to the precise fragments of sub-aerial surfaces whose base level is doubtful.
Stages below 700 feet refer to marine stillstands, the most important of which are marked with an asterisk*. Each is fronted by a shore-platform below the height mentioned.
This table is based on altitude alone and does not imply a chronological sequence.

The shore-zone is characterized by the clearly distinct 25 foot, 14 foot and Post-Flandrian strandlines (Orme, 1960). The 25 foot shore-platform is backed by old seacliffs, which in the schists are 400 feet high but which are locally truncated by cliffs cut by the 14 foot sea (Orme, 1962). In the less resistant rocks of Start Bay and Bigbury Bay, the composite elements of the former shore-zones are being effectively devoured by present day marine erosion.

Offshore, the Start Bay floor is a broad rock shelf, between 36 and 50 feet *below* present sea level, whose outer edge is defined by the crest of a 100 foot high submarine cliff (Robinson, 1961). This cliff was probably shaped during a prolonged stillstand, approximately 140–150 feet *below* present sea level, to which level important sections of the submerged rock floors of the Erme (McFarlane, 1955) and Dart estuaries apparently grade.

The re-developing Pleistocene drainage pattern was in places modified by stream piracy, although the Gara and the Fallapit streams re-occupied much older valleys. The incised nature of the stream courses and the strongly convex valley sides, whose general smoothness of outline is broken principally by terracettes and non-paired benches rather than by extensive terraces, suggest that the emergence was relatively rapid and that little lateral planation was accomplished. In addition to normal weathering, the landscape was also subjected periodically to periglacial activity, reflected mainly in frost-shattered crags and solifluction deposits. In short, the present physique has been produced by a variety of processes acting upon rocks which show varying resistance to erosion.

(3) *Correlation and Conclusions*

The principal phases of planation in south Devon may therefore be assigned a tentative position on the Tertiary timescale as it is at present recognized (Waters, 1960b; Brown, 1961). Furthermore, current evidence suggests that the 690–700 foot strandline may be of early Pleistocene age, and, as Kidson (1962) has suggested, a correlation with the Calabrian of the Mediterranean is not unreasonable. However, whilst it may be possible to equate some of the lower strandlines with similar Mediterranean sea levels, their precise placing in the Pleistocene sequence of north-west Europe remains problematical.

The sequence is undoubtedly complicated by the evidence within the South Hams for transgressive as well as regressive seas. For example, it is probable that Middle and Upper Pleistocene times were characterized by complex eustatic oscillations ranging from 150 feet *above* to at least 150 feet *below* present sea level. The problem of correlation is particularly pertinent in relation to the 25 foot strandline which is often equated with the Monastirian II level of the Mediterranean. There is clear evidence for a marine transgression in the English Channel during the Ipswichian (Eemian) Interglacial (West and Sparks, 1960), to which some authors assign the 25 foot strandline. It may be argued cogently, however, that this transgression was responsible, in the more resistant rocks of western Britain, for the trimming of a much older coastal zone which may trace its origins to Hoxnian, or possibly earlier, times. Considerable evidence outside the area, for instance the deeply weathered drifts which overlie the raised shore-platform along the south and east coasts of Ireland, suggests that the 25 foot strandline was cut principally during the Hoxnian (Holstein) Interglacial or possibly earlier, on a coast which had been blocked out initially during local preglacial times. The 14 foot strandline may, however, belong to the Ipswichian Interglacial.

In conclusion, three essential points are emphasized which possess relevance regardless of actual correlation. First, it is possible in south Devon to reconstruct in part the approximate shape of that section of the late Tertiary surface below 700 feet whose planation was arrested by the subsequent rise of sea level. This suggests that parts of the present drainage pattern predate this temporary submergence, and that the broader elements of the relief were resurrected and trimmed, rather than initiated, during the Pleistocene emergence.

Secondly, there is strong evidence for multiple strandlines of varying importance below approximately 700 feet. Their direct contribution to the present

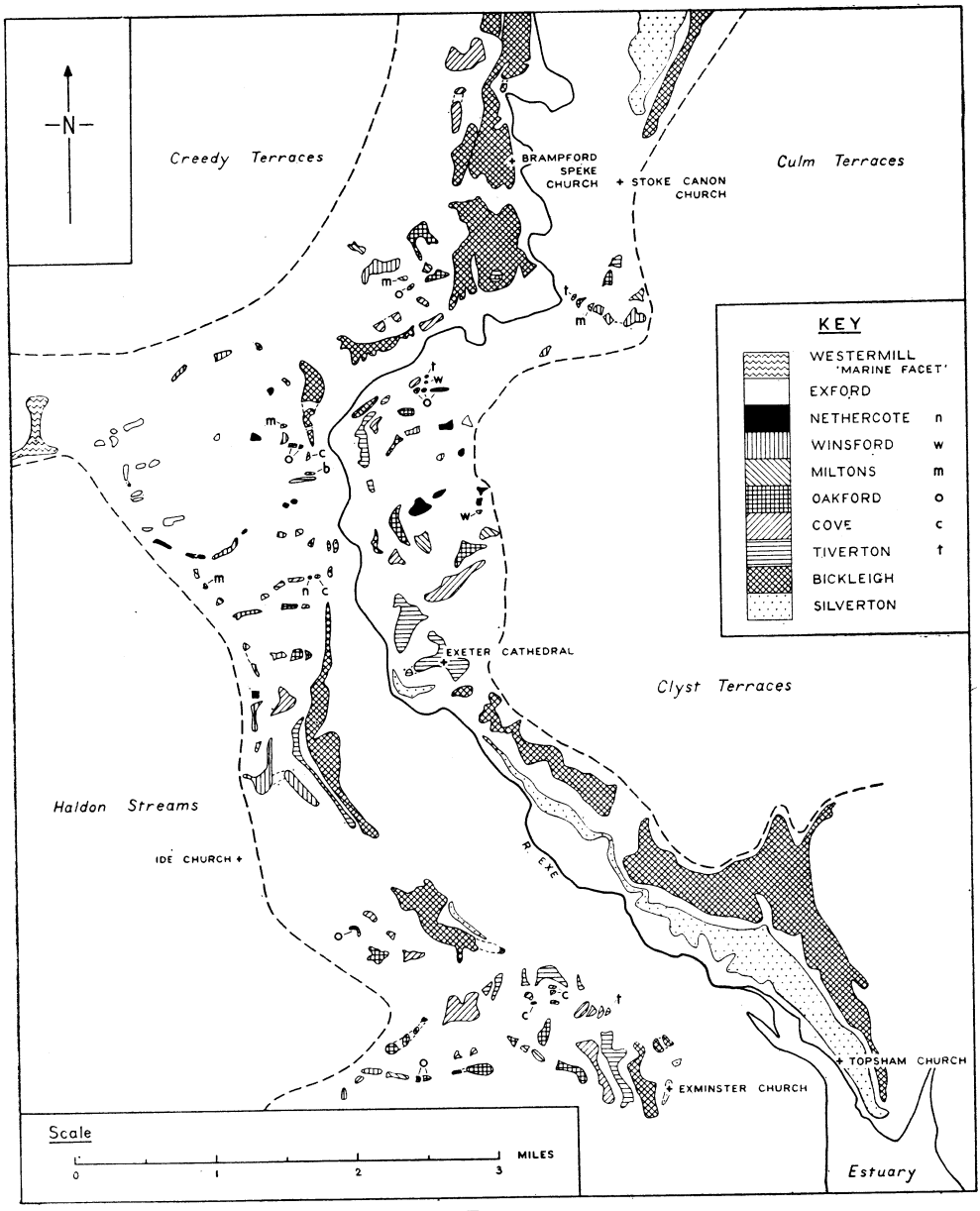

FIG. 4

River terraces and valley benches of the River Exe in the Exeter area.

physique, however, is small compared with that made by the impressive, composite shore-zone blocked out principally during the 25 foot, 14 foot and Post-Flandrian stillstands.

Thirdly, there is in the South Hams considerable evidence for a series of minor transgressions superimposed upon the overall lowering of Pleistocene sea level.

IV. The river exe

C. Kidson

The detailed study of the thalweg of the River Exe (Kidson 1962) and of the benches and terraces to be found in its valley, which is summarized here, provides one key to the denudation chronology of the South West peninsula. It was planned initially to serve as a link between Balchin's work (1952) in Exmoor and Green's studies (1941 and 1949) in south and east Devon, in the hope that a comprehensive picture of events in the region as a whole would emerge.

Precise levelling of the long profile of the River Exe and of its tributary the River Barle was followed by the fitting of mathematical curves to the profile segments thus revealed. The extrapolation of these curves gave approximate positions of the valley floor at a series of stages in the recent history of the river. Detailed mapping of valley-side benches confirmed the reality of these major stages and made it possible to determine the base levels to which they relate. These stages are given in the first column of Table 4. The distribution of river terraces and valley benches of the Exe in the Exeter region are shown in Fig. 4.

Table 4. *Planation Surfaces of River Exe correlated with those recorded on Exmoor and in south and east Devon*

River Exe		Exmoor (Balchin) 1952		S. & E. Devon (Green 1941 and 1949)	
Stage	Base Level Feet	Stage	Base Level Feet	Stage	Base Level Feet
		Lynton	1225		
					1150
Prayway	?	Molland	925	Bodmin Moor	920
Warren	?	Anstey	825		820–825
Westermill (Calabrian?)	690–686	Buckland	675		690
					595
					630
					505
Exford	424	Georgeham	425		430
Nethercote	334–330			Sicilian	338
Winsford	287–283	Instow	280	Upper Ambersham	236
Milton's	232–230			Ambersham	187
Oakford	185			Boyn Hill	134
Cove	127–122				
Tiverton	91–85 terrace			Iver	82
Bickleigh	50–48 evidence			Taplow	59
Silverton	30 only				

The results of Balchin's work on Exmoor and of Green's in east Devon and on the River Dart are given in Table 4 side by side with the results from the Exe. They are arranged on a purely altitudinal basis.

The polycyclic nature of the Exe profile together with the matching suite of terraces and valley-side benches is evidence of a spasmodically changing base level. This in itself does nothing to confirm the sequence of events proposed for adjacent areas. In the Exe profile no real evidence remains which can either support or refute the very highest surfaces described by Green and Balchin, ranging from the sub-aerial peneplains of the summits of Exmoor and Dartmoor down to the "1,150 foot terrace". Headward erosion has removed any evidence which may have existed.

Above the Westermill (690 feet) stage, the Exe does not provide support for stillstands at or about 925 and 825 feet. At the Prayway stage the Barle profile agrees with Balchin's Molland surface but this is not confirmed on the Exe. At the Warren stage neither Exe nor Barle provide confirmation of the Anstey surface or of Green's equivalent. At these higher levels the fluvial evidence is inconclusive but such signs as are available would suggest that, if sea level ever stood above 690 feet, the transgression (and subsequent regression) were separate from and not directly related to later events.

At the Westermill stage the picture changes dramatically. There is strong evidence for a marine transgressive phase culminating in a stillstand at 690 feet. The later stages in the development of the valley would seem to be phases in the regression of the sea from this transgression. A remarkable series of valley benches backed by breaks of slope at or near 690 feet can be traced from south of Dulverton to the latitude of Exeter where they pass outside the confines of the present study. Their arrangement, first close to the river and then progressively divergent, has led to their interpretation as remnants of a marine abrasion platform passing into estuarine flats in the Cove area. If this interpretation is correct, the coastline at this stage crossed the present valley between Tiverton and Cove.

This is in broad agreement with Green and Balchin but Green's division of this surface into a higher phase, related to a 690 foot base level, and a more strongly marked phase at 595 feet does not accord with the Exe results. Similarly, while there are suggestions in the Exe terraces of minor sub-stages between the Westermill and the Exford (424 feet) stages, there is no evidence of stillstands, as suggested by Green, at 530 and 505 feet. So far as these stages are concerned, the results of the Exe study support Waters' (1960a) reappraisal of Green's east Devon terraces as "river cut" rather than as marine flats.

One of the most surprising outcomes of the Exe study is the relative insignificance of the Exford stage related to a base level at 424 feet. In view of the widespread recognition of the "430 foot platform" in Cornwall and other parts of the South West, it was to be expected that the Exe valley would bear evidence of a marked stillstand at this level. The fact that it does not is probably due to the duration of the succeeding Nethercote stage with a base level at 334–330 feet. The evidence for this stage is particularly strong in the Thorverton—Silverton—Stoke Canon area. It may be that the Stoke Canon depression was largely produced during this stage. This could have been made possible by the "trimming" and destruction of a broad platform cut in the relatively non-

resistant New Red rocks at the earlier stage. Whatever the reason, the Nethercote stage is, after the Westermill, or 690 foot stage, easily dominant in the Exe valley. Balchin has no surface at this stage but Green's "Sicilian" is a strongly marked equivalent phase.

The lower stages of the Exe, including three based on terrace evidence only, agree broadly with the sequence recorded by Green and for which he used the terminology of the Thames terraces. It should be emphasized that the study of the Exe reported here was concerned primarily with the higher stages. A much more detailed examination of the lower Exe and its terraces must be carried out before this apparent correlation can be confirmed or a full sequence, down to the lowest levels, can be established.

Conclusions

The evidence from the River Exe throws little light on the origin of surfaces above 690 feet. It does however suggest a major marine transgression to this height. The surfaces related to this stage can be correlated with the early Pleistocene (formerly Pliocene) bench of southern England, and a Calabrian age is suggested for it. A spasmodic regression from this Westermill transgression with a major stillstand at about 330 feet is suggested. While the stages from 690 feet downwards must be Pleistocene in age, detailed correlation is not yet possible and an absolute chronology cannot be presented. The lower Exe awaits detailed study. Points of agreement between the Exe and Exmoor, East Devon and the Dart have been established but major disagreements still exist.

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