Royal Geological Society of Cornwall

ABSTRACTS

OF THE PROCEEDINGS

OF THE THIRD CONFERENCE

OF

GEOLOGISTS AND GEOMORPHOLOGISTS

WORKING IN

THE SOUTH-WEST OF ENGLAND

BRISTOL, 1960

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J. Robson

assisted by S. Simpson

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ABSTRACTS OF THE PROCEEDINGS OF THE THIRD CONFERENCE OF GEOLOGISTS AND GEOMORPHOLOGISTS WORKING IN THE SOUTH-WEST OF ENGLAND. BRISTOL, 1960.

Below is given the programme carried out by the Conference held at the University of Bristol in January 1960. It will serve as an index to the abstracts of papers delivered to the Conference which follow. For a variety of reasons abstracts have not been provided for certain of the papers. The abstracts printed here are numbered and the numbers appear against the names of the authors in the programme. In addition three abstracts of papers (numbers 18, 19 and 20) delivered to the Second Conference (Exeter 1958) which were omitted from the published extracts of that Conference are included here. The Conference wishes to express its gratitude to the Royal Geological Society of Cornwall and particularly to its Honorary Editor, Mr. J. Robson, for arranging the publication of this pamphlet.

PROGRAMME OF THIRD CONFERENCE

14 January

Morning session.

1. Professor Yves Milon (University of Rennes). Guest speaker: "Same Problems of the Geology of Brittany."
2. Dr. M. R. House: " The Devonian Succession of the Padstow Area, North Cornwall."
3. Mr. N. E. Butcher :"The Carboniferous Goniatite Zones in Devon and Cornwall."[1]

[1] See also N. E. Butcher and F. Hodson, 1960. A review of the Carboniferous Goniatite Zones in Devon and Cornwall. **Palaeontology** 3, (1).

Afternoon session.

4. Dr. **J. E.** Prentice and Mr. J. M. Thomas :" The Carboniferous Goniatites of North Devon."
5. Dr. W. R. Dearman :" The Structure and Stratigraphy of the Lower_ Culm Measures between Bridestowe and Lewtrenchard, Devon."
6. Mr. P. T. Carr :" The Treleague Quartzite and its associations."
7. Dr. R. Goldring :" Sedimentology of the Baggy Beds in North Devon."

15 January

Morning session.

Professor W. F. Whittard :" Geological results from the Western Approaches of the English Channel."

Mr. J. L. M. Lambert :" Minor Structures in the Gramscatho Beds ."[22]

Mr. M. Lucas: "The Structure of the Dulverton area."

Dr. E. B. Selwood : " Some observations on the stratigraphy of the Tintagel area."

Afternoon session.

8. Dr. D. L. Dineley :" A sandy facies in the Dartmouth slates." Dr. E. M. L. Hendriks :" Evidence of large scale northward -directed thrusting in South Cornwall."
9. Mr. M. Stone: " The Tregonning - Godolphin Granite."
10. Mr. G. Subbarao :" A study of the Godolphin Granite."

16 January

Morning session.

11. Mr. M. R. Weller :" Geomorphology of Bodmin Moor."
12. Mr. M. J. Bradshaw :" Geomorphology of the Culm area of Central Devonshire."
13. Mr. C. E. Everard :" Streams and Structure in West Cornwall."

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[2] See J. L. M. Lambert, 1959 Cross-folding in the Gramscatho Beds at Helford River, Cornwall. **Geol. Mag.** 96, (6).

14. Mr. A. R. Orme :" The Geomorphology of the South Hams area."

Afternoon session.

15. Mr. R. A. G. Savigear :" The Seaward slopes and cliffs at Porth Nanven (West Penwith)."
16. Mr. B. Clayden and Mr. D. C. Findlay :" Mendip derived gravels and their relation to combes."
17. Mr. R. A. Neilson and Mr. J. Palmer :" Origin of the Dartmoor Tors."

SECOND CONFERENCE

Abstracts of three papers delivered in the Geomorphology Section, Exeter 1958.

18. Mr. R. S. Waters. "The bearing of superficial deposits on the age and origin of the upland plain of East Devon."
19. Mr. R. S. Waters. " Erosion surfaces on Dartmoor and adjacent areas."
20. Mr. C. Kidson. " The Shingle Complexes of Bridgwater Bay."

1. Some Problems of the Geology of Brittany : by Y. Milon.

The Brioverian. This consists predominantly of shales or slates of dark colour, with a wide distribution throughout the Armorican peninsula. Near Lamballe beds of carbonaceous shale and thin graphitic micro-quartzite (phtanite) occur. The only Brioverian fossils come from these phtanites. Originally described as Radiolaria by Cayeux in 1894 they have been compared with hystrichospheres by Deflandre. Thick magnesian limestones with beds of coarse oolite occur at Saint-Lo (=Briovera). At Granville is a conglomerate with granitic pebbles which is now supposed to be a tillite.

The Cambrian. Unfossiliferous red grits with conglomerates and some shales are supposed to be of Cambrian age. They are very difficult to separate from the Brioverian, but a separation has been effected by J. J. Chauvel south of Rennes where the problem is complicated by the presence of some intraformational conglomerate within the Brioverian.

The red rocks of Cap Fréhel and Erquy. A series of red sandstones, conglomerates and quartzites without fossils in North Brittany which lies unfolded on the Brioverian. A late Carboniferous or Permian age has been suggested. Direct evidence of age has not yet been found.

The Tertiary. Marine deposits occur in distinct basins in eastern Brittany. An interesting feature is evidence of subsidence and faulting affecting these basins as recently as the Pliocene. Tertiary mineralization is proved by the occurrence of bornite, chalcopyrite, malachite and azurite in a Miocene crag near Rennes. Outside the basins and to the west of them Tertiary weathering has given rise to laterite and caused the kaolinization of a variety of bed-rocks. The widespread deep weathering "maladie tertiare" is at present being studied in relation to the geomorphology.

The Pleistocene. The shores of Brittany provide evidence of severe periglacial conditions following the retreat of the sea after the Tyrrhenian transgression. Low level granite tors are found mantled in head and loess (limon). The sea has subsequently (Flandrian transgression) returned to its earlier limits. There is little evidence of extensive marine erosion during the later Pleistocene.

2. **The Devonian succession of the Padstow area, North Cornwall :** by M. R. House.

The east-west axis of the St. Minver synclinorium passes two miles north of Padstow, North Cornwall. Rocks of Upper Devonian age crop out in the core of the synclinorium and Middle Devonian rocks crop out in the northern limb around Portquin, and in the southern limb along a broad belt between Wadebridge, Padstow, Trevone-, Constantine Bay and Trevose Head. The following succession has been established : -

7. Purple and green slates (unnamed) ; at least 400 ft. in thickness, with common *Richterina* and some trilobite-bearing horizons. The goniatites *Ponticeras* and *Manticoceras,* of middle Frasnian type, occur near the base of the series.

6. Merope Island Beds ; a series of banded dark grey slates, at least 150 ft. in thickness, well exposed on the western side of Merope

Island and at several places in the Padstow Estuary. Containing *Archoceras, Manticoceras, Aulatornoceras* and *Tornoceras* of middle Frasnian type.

5. Gravel Caverns Conglomerate ; a conglomerate bed five to six feet in thickness with the Frasnian type goniatites *Manticoceras, Aulatornoceras and Tornoceras* in the matrix. Seen only in the northern limb of the synclinorium.

4b. Pentire Point Pillow Lavas ; at least 200 ft. in thickness, only occurring in the northern limb of the synclinorium.

4a. Longcarrow Cove Tuff Beds ; grey slate with beds of tuff and agglomerate, 80 ft. in thickness. Seen only on the southern limb and thought to be the equivalents of the Pentire Point Pillow Lavas and possibly of the Gravel Caverns Conglomerate.

3. Gray slate (unnamed) ; at least 800 ft. thick in the southern limb. The Pentonwarra Point goniatite bed occurs near the base, which contains the following Upper Givetian type goniatites, *Maenioceras, Sobolewia, Agoniatites, Wedekindella, Werneroceras, Tornoceras, Aulatornoceras* and *Protornoceras*. The same horizon crops out in the northern limb at Portquin.

2. Marble Cliff Beds ; 200 ft. of alternating slate and limestone bands, seen only in the southern limb. The Givetian goniatites *Wedekindella* and *Agoniatites* have been found associated with these beds on Trevose Head.

1. Light grey, finely banded slate (unnamed) ; at least 600 ft. in thickness, with common *Styliolina* and some goniatites. Includes the fossiliferous locality of Cant Hill which is probably of Couvinian age.

It is, probable that there are gaps between some of the units of this succession. No indubitable Famennian fossils have been found but it is thought probable that the Frasnian/Famennian boundary lies within the purple and green slates of unit 7. For convenience the Middle/Upper Devonian boundary is taken at the base of the Pentire Pillow Lavas in the northern limb and at the base of the Longcarrow Cove Tuff Beds in the southern limb. Further fossil collecting may modify this. The Couvinian/Givetian boundary apparently falls within the light grey slate of unit 1.

3. Carboniferous Goniatite Zones and Stratigraphy in Devon and Cornwall : by N. E. Butcher.

The results of a re-examination of existing museum collections of goniatites from Devon and Cornwall were presented, the identifications having kindly been made by Professor F. Hodson.

This study shows that most of the Carboniferous goniatite zones and subzones are represented in this region. Indeed, the only zones for which there is at present no evidence are the *Eumorphoceras* and Lower *Gastrioceras* Zones.

Sedimentation appears to have been continuous throughout the Lower Carboniferous in both the north and south Devon successions. In north Devon (Barnstaple area) the junction between the Pilton Beds and the Lower Culm Measures lies within the *Pericyclus* Zone. In south Devon (north-west Dartmoor area) the stratigraphical horizon of the junction between the Transition Series and the Lower Culm Measures is unknown, but it is thought to occur within the Tournaisian. The present evidence suggests that the Upper Culm Measures may succeed the Lower Culm with an essentially non-angular unconformity. In north Devon (Barnstaple area) an Upper Culm succession of R_1 to G_2 age succeeds Lower Culm Beds of P_2 age, whilst in south Devon (Exeter area) an Upper Culm succession, H_1 to R_2 in age, succeeds P_2 Lower Culm Measures.

4. The Carboniferous Goniatites of North Devon : by J. E. Prentice and J. M. Thomas.

New occurrences of Carboniferous goniatites found during fieldwork in north-west and north-east Devon were described, and stratigraphical inferences drawn.

Zone I of the German zonal scheme is represented by *Gattendorfia* and *Imitoceras,* species recorded by Goldring (1955) from the Pilton Beds of north-west Devon, and *Protocanites* cf. *lyoni* in the Hamling Collection from Mount Sandford, near Barnstaple.

Zone II is shown to be present at Tawstock and Codden Hill by the occurrence of *Ammonellipsites* cf. *kayseri* associated with *Prolecanites* cf. *similis.* Similarly sutured prolecanites have also been found in the middle part of the Bampton Limestone group.

Zone IIIa (thought to be partly equivalent to B_2 on trilobite evidence) contains *Prolecanites discoides* associated with a doubtful *Beyrichoceras ;* and also the *Goniatites hudsoni-antiquatus* group. These have been found in the Westleigh Limestones.

The Bampton Limestones have yielded *Prolecanites mixolobus* showing the zone to be represented in the north-east.

Zone P_1a is represented in the Westleigh Limestones by *Goniatites crenistria,*

Zone P_1b has yielded *Goniatites falcatus* at Fremington in the chert group, and at Westleigh in the limestones.

Zone P_1c is present in the Westleigh Limestones, giving specimens of *Hibernicoceras carraunse* with *Sudeticeras crenistriatus* and a doubtful *Goniatites sphaericostriatus.*

Zone P_1d is shown to be near the top of the Westleigh Limestones by *Neoglyphioceras spirale* associated with *Sudeticeras splendens. N. spirale* is associated with a form cf. *G. granosum* in both the Fremington and Tawstock facies in the north-west; and above the Bampton Limestones where the same goniatites are associated with *Dimorphoceras kathleeni* and *Sudeticeras splendens.*

Zone P_2a is shown to be present above *N. spirale* near the top of the Westleigh Limestones where *G. granosum* was found associated with *Sudeticeras splendens.*

The E Zone has been found for the first time in Devon and is represented by a species of *Cravenoceras* intermediate between *C. leion* and *malhamense,* from the black shales above the Bampton Limestones.

The H zone has not yet been proved with certainty, but poorly preserved straight-ribbed goniatites from the black shales above the Bampton Limestones suggest that this zone is present.

The R_1 subzone is present in the Limekiln Beds at Fremington, where *Reticuloceras reticulatum* has been recorded, and in equivalent shales east of Bampton where doubtful *Homoceras beyrichianum* and *Reticuloceras pulchellum* have been found.

R_2a has been proved to be present in the Limekiln Beds at Fremington and Tawstock by E. W. J. Moore's collection and identification of *Reticuloceras gracile.*

R_2c is present south and east of Bampton, where *R. superbilingue* has been found in a greywacke series.

A number of goniatite horizons have been found representing various parts of the Gastrioceras zone.

G. carbonarium (F. & C.) with *Homoceratoides divaricatum* and *G. listeri (F.* & C. non Sowerby) are found in the Instow Beds, and the last fossil has been found south-east of Bampton.

G. subcrenatum (Wright; non C. Schimdt) has been found in the Cockington Grits, and in the greywackes of north-east Devon.

G. retrorsum and *normalis* occur in the Clovelly Marine Band, *G. langenbrahmi* at an horizon in the greywackes in north-east Devon.

Thus in north-west Devon the sequence starts with Pilton Beds of I age, followed by a chert series in which II and possibly IIIa is represented, these cherts terminating at a P_1d horizon. Then follow the shaly series containing fossils of stage R, whilst greywackes begin after R_2a and include G_2 horizons. In north-east Devon, the Bampton Limestones and Westleigh Limestones include representations of IIIa and P_1a-d. E and H are probably represented by a shaly facies, whilst R_2c and G_2 are represented within the greywacke sequence.

5. The structure and stratigraphy of the Lower Culm Measures between Bridestowe and Lewtrenchard, Devon : by W. R. Dearman.

The most southerly chert horizon at Meldon can be traced continuously into the prominent whale-back ridge rising above the south bank of the River Lew at Lewtrenchard. There is a second ridge of chert on the north bank of the Lew which is more continuous than- is shown on the Geological Survey map. On the southern slopes of both chert ridges there are limestone and slate quarries, and the valleys are floored with the Slate-with-Lenticles Group, the oldest beds in the succession. Structures are best displayed in quarries along the south ridge. A recumbent fold closing to the south is exposed in Lower Culm cherts in Kersford Quarry (497868)[13]; drag folds show that there has been normal faulting down the bedding in both limbs, and the fold is partly broken by a normal fault along the bedding. At Hedge Cross Quarry (488860) two sets of cleavage planes are developed sub-parallel to the two bedding plane attitudes in the recumbent fold. Coryton Slate Quarry (465849) provides discontinuous exposures of a recumbent fold which closes to the north. Slaty cleavage dips uniformly to the south, and it can be demonstrated that normal faulting movements have taken place

[3] All National Grid reference numbers occur within the 100 kilometre square 20 (SX)

along the cleavage planes. The slates are interbedded with limestones, and at a lower level on the hillside there is an overgrown quarry (469848) in Lower Culm limestones.

Along the northern chert ridge there is a recumbent fold closing to the north in cherts exposed in a roadside quarry (4698-65), half a mile south-east of Lobhillcross. Lew Quarry (464862), half a mile to the west, is reminiscent of Coryton Slate Quarry but was worked for limestones. Limestones and slates are overlain by cherts. Here bedding dips evenly to the north and is crossed by a southerly dipping shear cleavage. There is another typical Lower Culm limestone quarry (459859) near Lew House.

The problem was to decide whether the minor structures described above reflected the major structure of the area. Rather surprisingly, in this complex country, an analysis of the Survey map of the southern chert ridge provided the answer. A north-west to south-east vertical section was constructed by projecting along the strike the margins of the chert outcrop at successive levels. The northern margin of the chert outcrop plotted as a recumbent fold, closing to the north, with a limb length of just over 1,000 feet. On the southern margin the Coryton Slate Quarry fold turned abruptly downwards into a northerly dipping plane which was parallel to one fold limb on the north side of the chert outcrop. This was interpreted as a faulted boundary. Details of the northern chert ridge were plotted in the same way, but the results were not so revealing.

The results of this manipulation suggest that the successive chert ridges were once parts of a connected pile of recumbent folds. This pile has been disjointed and spread out to the north and south by normal faulting movements along the two bedding attitudes in the folds.

The stratigraphical succession is similar to that at Meldon, but the southern chert outcrop on the Survey map includes representatives of the Calcareous Group and the Slate-and-Quartzite Group, with volcanic horizon, of the Lower Culm Measures. The limestone and slate facies of Coryton Slate Quarry and Lew Quarry are unusual and cannot yet be correlated with certainty with the carbonaceous limestones and shales so typically associated with the Lower Culm cherts.

6. The Treleague Quartzite and its Associations : by P. T. Carr.

The Treleague outcrop is more extensive than previously recorded, extending to within $^1/_4$ mile of the sea at Porthoustock, where it is truncated by a north-south fault, presumably related to others in the quarries further to the east. The northern boundary is the Porthoustock Fault, a major dislocation, with a zone of brecciation and often intense iron-staining. Black dykes are unrecorded north of this line, and gabbro only as a dyke at Porthallow. Except when associated with serpentine around that village, the hornblendeschists and other older schists, from the coast westwards towards Traboe, possess an east-west structure with a plunge to the west. South of the fault, there is insufficient evidence to prove a similar tilting of the Quartzite. The southern margin of the Treleague rock extends from south of Treloyan due west to a point south-west of Trembraze, and thence north-westward, displaying little relation to the topography. The Quartzite exposure nearest this line shows brecciation and an abnormal northward dip.

The Quartzite ranges from a pale grey quartz-cemented feldspathic grit to a foliated quartz-hornblende schist in which only the larger elastic grains are preserved. This latter variety occurs south of Trenoweth, where it is intruded by a gabbroic sill about 125 ft. thick which grows finer-grained towards the base. Parallel to it are several smaller sills with contact planes demonstrably in concordance with the typical southward dip of the invaded Quartzite. West of Trenoweth, the main sill is faulted to the north before continuing towards Treleague, whilst eastwards it extends to the limit of the outcrop at Treloyan.

Intrusive greenstone at Trembraze may represent another smaller sill. Probably most of these greenstones and micro-gabbros originated as quicker-cooled gabbro, rather than having a common origin with the black dykes.

The absence of these dykes and any massive gabbro north of the Porthoustock Fault indicates that the highly metamorphosed older schists of the region are on its downthrow side. The minor dislocation forming the southern Quartzite margin appears to have moved in the same sense, thus preserving a portion of the roof of the gabbro invaded by sills derived from it. This would be possible provided that movements prior to the main thrusting and associated serpentine emplacement had produced an inversion of the younger Quartzite and older schists. The latter include the two hornblende-schists `types' which, in this area, appear to differ only in their relationships with the serpentine. The Treleague Quartzite is never found in association with either variety, and is almost certainly younger than any hornblende-schist, though older than the serpentine.

The quartzite from the black lenticles at Turwell Point in the Meneage has a close affinity with that of Treleague, apart from the characteristic amphibole of the latter. Both contain a significant number of clastic feldspars and seem to lack the minor constituent tourmaline. The `paler' Meneage quartzites,. and those of Veryan, differ in both respects.

7. **The Sedimentology of the Baggy Beds :** by R. Goldring.

The Baggy Beds of North Devon are fully exposed along the coast section at Baggy Point. The fauna, which is essentially of thick-shelled lamellibranchs and gastropods, cannot be used to determine accurately the age of the beds. However, because they immediately underlie the Pilton Beds *(Wocklumeria* Stage), they may be correlated, at least in part, with the *Clymenia* Stage (Famennian). Below the Baggy Beds (1,400 feet) lies the Pickwell Down Sandstone of Old Red Sandstone facies. The upper 800 feet of the Pickwell Down Sandstone is of cleaved siltstones and claystones and may be distinguished as a separate member, the Upcott Beds (Hull, 1880). The base of the Baggy Beds is sharp, without upward passage from the Upcott Beds, whilst the boundary with the Pilton Beds is gradational.

The Baggy Beds are constituted of three randomly repeated types of strata.

(i) Thick groups of sandstones. These are the most conspicuous type, though they account for only about 30 per cent of the rock, and occur mainly north of Baggy Point. Current-bedded sandstones are associated with lenses of intraformational conglomerate, and lenses of micaceous shale. Washouts are common and occur either as distinct channels or as larger structures only one side of which is exposed. The elongation of the channels and the dip direction of the current-bedding indicates a derivation from the north and northeast. Slumping on various scales occurs frequently.

(ii) About 15 per cent. of the Baggy Beds consist of thin, alternating laminations of sandstone and shale which occur as regular and irregular layers, and as organically formed distinct and indistinct patches. Ripple-drift bedding in the regular sandstones indicates a general south-easterly current.

(iii) Eighty per cent of the beds south of Baggy Point, and almost half of the beds north of the Point, are sandstones, siltstones and shales in which the typical laminae are thin, and grow finer upwards from a sharp base. Organically formed burrows are limited to intercalations of regular and irregular sandstone laminae. There are numerous boulder beds, ranging to seven feet in thickness, apparently the result of differential loading and the fragmentation of regular layers during downward movement.

Groups (i) and (ii) are very similar to the channel, and high and low tidal-flat deposits of the Wadden Sea (Netherlands and North Germany). There is no described, present parallel to the graded laminae of group (iii), but it is possible that they were deposited in a rather deeper-water, lagoonal environment.

8. A sandy facies in the Dartmouth Slates : by D. L. Dineley.

Two distinct facies seem to occur within the Lower Devonian Dartmouth Slates in the south Devon coastal sections. A thick division characterised by dark - even black - slates with thin, rare and impersistent sandy bands is widespread and has been regarded as "typical" Dartmouth Slate. In the cliffs between Revelstoke and Wembury, however, the slates are intercalated with thicker sandstones, grits and conglomeratic pellet beds so that the lithologies alternate rapidly in vertical sequence. The (non-arenaceous) slate beds are thicker than the sandy beds and, allowing for compaction, must have been proportionately even thicker prior to the Armorican earth-movements and metamorphism. This sandy facies shows, despite the effects of metamorphism, many sedimentary features which, like the rapid alternation of argillaceous and arenaceous units, may be compared closely with those of the Lower Old Red Sandstone of the Welsh Borderland and South Wales.

The sandstones show cross-bedding, scour-and-fill structures, sandstone pipes, possible ripple-markings and other features known in the deposits of the Anglo-Welsh cuvette. They are often somewhat graded and overlie conglomeratic bands and lenses which contain flattened rounded blebs of shale, siltstone and calcareous material - assemblages of intraclasts typically found in the cornstones of the Old Red Sandstone. Quartz pebbles occur but are not numerous. In beds of this conglomeratic type and in the sandstones fish remains, including those of pteraspids, have been found. Their preservation is generally poor but some of the fossils retain sufficient detail to suggest that they belong to forms as yet undescribed and quite different from the other pteraspids of the Dartmouth Slates. The mode of occurrence of these vertebrates is again similar to that in the Old Red Sandstone, with the fossils often gathered into local segregations of large fragments. So far, the only invertebrates found associated with the fish remains are large isolated pelecy pod valves. preserved as distorted casts and moulds. They have not been determined but are larger than the pelecy pods known in the Downtonian and Dittonian.

It is suggested that this group of sandstones and conglomeratic layers, interbedded with slates that must have once been clays or marls, shows signs of having been laid down under conditions similar to those of the Lower Old Red Sandstone known north of the Bristol Channel. It seems to be a continental phase preceding the spread of Lower Devonian marine sedimentation. The exact relationship of the sandy facies to the non-arenaceous Dartmouth Slates known elsewhere is not yet determined but on general stratigraphical, and possibly also on structural, grounds it seems probable that the beds described above occur low in the Dartmouth Slates. Pteraspid fragments found near Revelstoke also suggest an horizon lower than the *leachi* and *dunensis* beds of Newquay (which are black and grey Dartmouth Slates with very few sandy bands).

9. The Tregonning-Godolphin Granite : by M. Stone.

It has been 'established by Mr. Subbarao (Birkbeck College, London) and the writer that the Godolphin granite is a composite mass which consists of two major units :

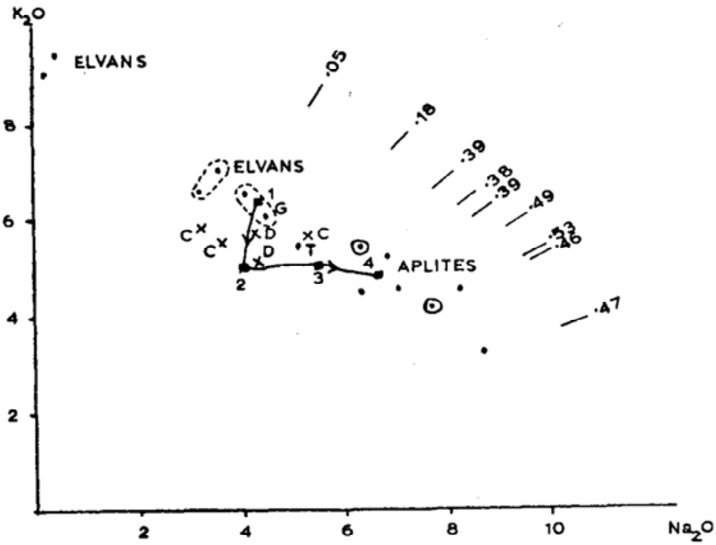
1. The Godolphin granite ; exposed on Godolphin Warren. This is a porphyritic granite containing quartz, potash feldspar, oligoclase, biotite, tourmaline and small amounts of pinite and andalusite.

2. The Tregonning granite : exposed on Tregonning Hill, where it is largely kaolinized and greisened, and on the coast between Praa Sands and Tremearne. It is nonporphyritic and contains quartz potash, feldspar, albite, lithium-bearing mica, topaz and tourmaline.

Overlying this granite forming a roof zone in the cliffs and a series of sheets at Tremearne, is a third unit-the aplite-pegmatite complex. This consists of banded aplites, aplogranites, pegmatites and greisens together with granites resembling the normal Tregonning type. This unit is mineralogically and chemically related to the Tregonning granite.

Petrogenesis.

The mol. ratio K_2O: Na_2O of analysed specimens together with data from other granites of the South-West is shown in fig. 1.



Molecular quotients (x 100) of Na_2O plotted against K_2O in rocks from the Godolphin area (dots) together with some data from the big-feldspar granites of Dartmoor (D) and Carnmenellis (C). T-Tregonning granite, G-Godolphin granite ; numbers 1-4 show the trend in the St. Austell granite (from earliest to latest). The numbers preceded by dashed lines show the wt. per cent Li_2O in the analysed rocks of the Tregonning-Godolphin granite.

The magmatic trend of soda enrichment in the St. Austell granite (Exley, 1959) is indicated. That magmatic differentiation is responsible for such a trend is supported by the general increase in Li_2O (and Li_2O/MgO) with the increase in Na_2O. However, there is good evidence to show that any former trends, magmatic or otherwise, have been overshadowed by later potash metasomatism and recrystallization. Also, the analyses shown by ringed dots in fig. 1, come from adjacent bands in a single hand specimen of banded aplite. The " magmatic " relation between K_2O/Na_2O and Li_2O is preserved, yet it is most unlikely that one band could be derived from the other by magmatic differentiation. Textural evidence indicates that there has been late-stage enrichment in potash in the band having the higher potash content.

The metasomatizing agent is believed to have been a fluid phase acting from within the rock itself. Evidence is provided by the occurrence of pegmatites beneath structural traps, drusy cavities, baffles (Hosking, 1954), and the association with volatile elements. It is believed that this fluid phase has transformed rocks which were formerly aplitic into coarser aplites, granites and pegmatites.

Similar conclusions can be reached regarding the big-feldspar granites of south-west England.

References:

EXLEY, C. S. 1959. Magmatic differentiation and alteration in the St. Austell granite. **Quart. Journ. Geol. Soc., 114,** 197-230.

HOSKING, K. F. G. 1954. The pegmatites of Trolvis Quarry, Carnmenellis, Cornwall. **Geol. Mag., 91,** 273-285.

10. A Study of the Godolphin Granite, with special reference to its Structure : by G. Subbarao (communited by Dr. A. T. J. Dollar).

The Godolphin Granite, formerly regarded as a single unit is now found to be composite, consisting of three distinct granites 'G_1'- a biotite-muscovite granite ;'G_2'- a lithionite granite and 'G_3'- a leucogranite with aplitic and pegmatitic facies, which were injected, in that order, into the Mylor Slates. Petrographic evidence shows that these granites are decidedly sodi-potassic and probably represent late differentiates of a single original parent magma.

In the aureole about the mass are several distinct kinds of thermally-altered rocks, but where there has been a concentration of volatiles at granite-slate junctions, metasomatism has been superimposed on earlier contact metamorphism to produce additional special rock-types.

There is a close relationship between alteration and jointing in these granites. Tourmalinisation and muscovitisation are dominant in 'G_1' while greisening and kaolinisation are prevalent in 'G_2'. By contrast, chloritisation is very limited in 'G_1' and 'G_2', while sericitisation, though common in all the granites, is intense only locally.

The relations between joints, veins and flow structures have been studied in detail. Following the Cloos notation, the E.N.E. W.S.W. joints appear to be ‘Q’ joints, N.N.W. - S.S.E. joints seem to be ‘S’ joints and the horizontal joints appear to be ‘L’ joints, while Mohr's diagonal joints have been noted at several localities. In the country rocks, strike joints, dip joints and oblique joints have been noted. Field evidence suggests that many original cooling joints in the granites have been accentuated by regional stresses.

Linear flow is shown by parallelism of feldspar phenocrysts in ‘G_1’, at Godolphin Warren. On the other hand, there is little evidence for planar flow in this granite, and no clear manifestation of either linear or planar flow in ‘G_2’ or ‘G_3’.

Inland, all contacts between the granites and their country rocks are obscured, but along the coast the eastern and western contacts between ‘G_2’ and killas, and ‘G_3’ and killas are well exposed. Both eastern contacts are steep and sharp while the corresponding western contacts are concordant and dip at lower angles. At these surfaces there is neither a migmatic zone, nor are there any killas xenoliths, but abundant evidence for the former trapping of volatiles. The inferred junction between ‘G_1’ and ‘G_2’ runs approximately parallel to the road between Godolphin Hill and Tregonning Hill. The contact between ‘G_2’ and ‘G_3’ is visible in places, where it tends to be irregular and sometimes stepped.

Acid dykes, sills and veins are frequent along the coast. In some of the thicker sheets there are regular alternations of pegmatitic and aplitic bands. It is believed that these resulted from volatile-rich residual fluids which penetrated along cleavage planes in the country rocks, thereby occasionally enclosing thin plates of killas. Where these latter are nearly horizontal it is inferred that concentrations of volatiles below them gave rise to pegmatites, while the residual fluid produced aplites.

Assuming that regional stresses, operating in a N.N.W. - S.S.E. direction at the time of the Hercynian orogeny, produced the Land's End anticline in the Mylor slates, it is into the central part of this major structure that the magmas of the Godolphin mass were intruded. These magmas appear to have risen on the southern flank of this anticline and to have advanced in an essentially north western direction.

11. The Geomorphology of Bodmin Moor : by M. R. Weller.

The landforms of Bodmin Moor have been mapped morphologically on six-inch to the mile base maps and the Fowey and Camel river profiles surveyed. Analysis of the two and a half inch to the mile Morphological Maps, subsequently produced, revealed major erosion surfaces. The marine origin of the 1,000 foot summit surface is supported. The form and pattern of the 750-800 foot surface suggests a sub-aerial origin ; this conflicts with earlier views. Fragments of an intervening 850-950 foot stage also appear to be of sub-aerial origin. Terraces and stream segments reveal an initial dissection of the 750-800 foot surface by streams graded to a feature which cuts across the structure along the southern margin of Bodmin Moor, and which maintains a constant height at about 675 feet. This feature is interpreted as a former shoreline and the relation to the 750-800 foot partial-peneplain suggests a transgression on to the latter. This shoreline is thought to be equivalent of the 6-700 foot, early Pleistocene, (Red Crag), shoreline of S.E. England, since neither area shows any sign of deformation at or below this stage. The 750-800 foot surface may be the equivalent of the 800 foot summit peneplain of S.E. England, of Mio-Pliocene age. In the absence of deposits no dates can be suggested for the earlier and higher surfaces of Bodmin Moor. The 1,000 foot surface may be gently warped.

12. Geomorphology of the Culm Area of Central Devonshire : by M. J. Bradshaw.

The area comprises the Taw, Torridge, and Upper Tamar Basins on the outcrop of Culm rocks. It has been called the `dissected plateau of central Devonshire'. Diversification is provided by the various rock types. The Pilton Beds coincide with a subsequent depression running south-south-east of Barnstaple ; the Lower Culm cherts and limestones give a series of hogs-back ridges: the thicker shales in the Middle Culm have permitted differentiation of east-west strike ridges and vales ; the Upper Culm is a massive greywacke formation.

The present survey, covering a large area (1,100 square miles), has been selective in the mapping of relief facets, those on the tops of interfluves, but also thorough on a six-inch to one mile scale. A surveyor's aneroid and Abney level were used for measurement of height and slope.

Along the west-facing coast between Hartland and Bude, and seawards of the watershed of the short coastal streams with the Torridge and Tamar Basins, a succession of old shorelines has been established. The massive Upper Culm beds have preserved the record of a close-spaced series of still-stands of a regressing sea. Major levels are at 570 ft., 520 ft., 480 ft., 430 ft. (not so dominant as when recorded by other workers), 350 ft., 290 ft., and 230 ft. All these levels have a definite rise at 5-7° landwards of a flat of less than 1°, and are found at consistent heights for over 20 miles. Similar features are found around Bideford, and in both these areas the streams run normal to the inferred shorelines, and were probably consequently extended across them. It is noticeable that the shorelines were very close to the present, though more sinuous.

Above the 600 ft. level evidence is not so convincing, but there is a shoreline round the north of Dartmoor at 670-690 ft. Higher up `stepping' of summit levels is present here, and on the Taw-Exe watershed, but a confident interpretation of their origin is impossible.

A number of stages recorded on the coasts are reflected in the valleys of the major rivers, and especially in that of the Lower Torridge. The tops of the interfluves on either side of the river are gently sloping `moors' at 630-650 ft., beneath which are steeper (5°) slopes, flattening somewhat at 300-350 ft. This old valley floor had a very low gradient, and meanders developed on it. Subsequent rapid incision resulted in the preservation of these forms within very steep walls. On the slip-off slopes of these meander cores there is another stage in the down-cutting history. It is also recorded on the west bank of the Taw valley in terraces south of Kings Nympton Station and north of Umberleigh.

The Petrockstow Basin, in the great elbow of the River Torridge, is filled with sands and Ball Clay deposits of supposed Oligo-Miocene age. These are faulted down, and many of the spurs of the western side of the Basin are faceted, as if the fault-line is being exhumed. It seems that the excavation of the clays was a very recent event, associated with the abandonment of the uppermost of the Torridge meanders. This took place in glacial times, and may have given rise to the Fremington Clays, which contain erratic blocks, if the Taw-Torridge estuary was blocked by ice.

Thus the relief of this area has been determined by a falling sea level, and that below 600 ft. at least is of very recent origin. It is an area of great interest to the geomorphologist, and many of the problems have not been touched here.

13. Valley and Structural Trends in West Cornwall : by C. E. Everard.

A field-survey of erosion surfaces in Cornwall west of a line from Padstow to Fowey has shown that the region intermittently emerged from beneath a transgressive sea during the Pleistocene and that the upstanding areas are flanked by roughly concentric rings of erosion surfaces, the dominant levels being as follows :

600 ft. 530 ft.	Upper Plateaux
400 ft. 345 ft. 300 ft. 240 ft.	Lower Plateaux

There is evidence that the submergence did not extend beyond 650-700 ft. A drainage pattern evolving under these conditions might be expected to be one of radial consequents, progressively extended as each marine platform was emerged. In many places this is not the case, there being marked contrasts between the transverse slope of the marine platforms and the trends of the valleys dissecting them. The valley trends are very close to those of joints and faults, and the high degree of adjustment to structure so revealed led to a detailed analysis of the valley alignments.

The basis of the analysis was the 1:25,000 Ordnance Survey Map, and the areal unit chosen for study was the quarter-sheet. Valley bearings and lengths were measured in each kilometer square, the bearings being classified in 15° groups. A rose-diagram was then constructed for each quarter-sheet showing the percentage of its total valley length which lay within each 15° group. These diagrams revealed the dominance of N.W. - S.E. and N.E. - S.W. trends over much of the region, apart from the extreme east, where an E.-W. trend is much more marked. Similar diagrams were made for the granite areas, the

Lizard and the " killas ", and the dominant trends could be found on them all.

The controlling factors behind such persistent valley trends must be structural, and a similar analysis of joint, fault and mineral vein trends shows approximately the same favoured orientations.

The widespread nature of this adaptation to structure would seem to be highly significant for it is found on all rock types and on the three kinds of surfaces of different ages, noted above, viz. unsubmerged, high and low plateaux. In the case of the lower plateaux time for such close adaptation to structure would appear much too short.

The explanation of these facts is now the object of further research, with particular reference to the following views :

(1) this is an area of very rapid adjustment to structure, much faster than normally supposed ;

(2) the valley trends were imposed by stream action on a land surface *before* the initial submergence, and erosion during the latter and the subsequent emergent phases was insufficient to completely destroy these early valleys, which were "resurrected" and to-day leave their imprint on the morphology of the peninsula.

14. Morphological Mapping and Geomorphic Analysis in the South Hams : by A. R. Orme.

Highest astride the N.E. watershed with the Dart Basin, all that remains of a regional slope inclined S. and S.W., are a number of irregular uplands isolated by dissection and differential erosion, draining principally to the Avon, Erme, Kingsbridge Estuary and Gara. Master streams display a marked non-adjustment to the structure of Devonian and metamorphic rocks. Whilst valleys open out in less-resistant slate and shale lithologies, streams are confined to narrow incisions through schists, grits and volcanics. Tributary development is better adjusted to the predominant E. - W. or EN.E. - W.S.W. strike. Steeply incised stream courses, considerable relative relief over short distances, and overwhelming convexity typify the morphology. The anomalous drainage pattern, only in small part explained by river capture, reflects the irregularities of the Tertiary surface and the extension and partial superimposition of consequent and tributary streams during the Pleistocene emergence.

Field analysis discloses a physiographic stairway of gently-inclined benches, separated by shallow buffs, distributed irregularly along and across major and minor waterpartings. Assuming Post-Alpine tectonic stability and lack of warping, the notable height correspondence of the concavities basal to the many bluffs implies a common origin for many of the erosion surfaces-as wave-cut benches backed by low sea-cliffs. A 2-3° slope typifies the remnant benches, and whilst the base of the degraded cliff may be masked by subsequent hillwash or eroded by run-off, the height of the former notch, actual or inferred, varies no more than plus or minus three feet. The problem is complicated by river and estuarine benches and by structural and lithological differences.

Remnants of the Mio-Pliocene partial peneplain occur on aureole and granite rocks of the Dartmoor periphery, between 720-940 ft., extending into the moor along major river valleys and southwards to include Stanborough Brake (708 ft.). Residuals, such as the Beara Common igneous mass (1,017 ft.) rise above this surface.

The late Pliocene transgression drowned an extensive area of moderate relief, but whilst those hills which rose above sea level were reduced by marine and sub-aerial erosion, the submerged valleys and depressions remained to influence the form of later shorelines. Shoreline remnants at 700 ft. related to the maximum transgression and often accompanied by a further change of slope at 675 ft. occur on the north, the west and south-west of Dartmoor, associated with extensive wave-trimmed surfaces- Roborough and Plaster Downs, Henlake Down 696 ft., Horner Down 680 ft., and Bickleigh Brake 665 ft.

The Pleistocene emergence of 850 ft., an intermittent succession of rapid and irregular eustatic shifts separating lengthier periods of stillstand, preceded a Late- and Post-Glacial submergence of 150 ft. Whilst independent of structure, wave-cut surfaces are better preserved in more resistant rock.

Thus the extensive quartz-mica schist plateau between Start Point and Bolt Tail is related to the 460 ft. shoreline and bench well developed inland across Dartmouth slates.

Mid-Pleistocene and later erosion further accentuated the poor resistance of the Meadfoot shales in the Kingsbridge area, a factor originally emphasised by Permo-Triassic desert processing of Armorican structures. The absence of sizeable floodplains except in association with the alluvial infill post-dating the Flandrian transgression, and the polycyclic nature of both the valley cross-sections and longitudinal stream and terrace profiles, emphasise the intermittent downcutting which accompanied but did not keep pace with the retreating Pleistocene base-levels.

The coastal zone furnishes evidence of four distinct stillstands within a limited height range. The 24 ft. and 14 ft. raised beaches, related to a late stage in the Last Interglacial and to an interstadial during the Last Glaciation respectively, were both followed by periods of intense solifluxion and lower sea level. A short phase of high sea level, 6-10 ft. above the present and well displayed on the Lannacombe Coast, predated the formation of the Post-Flandrian bench. Structural weaknesses facilitate erosion along predominant N.E. - S.W. and N.W. - S.E. lines.

Maritime periglacial processes induced coastal and inland solifluxion, frost-shattered slate and schist outcrops and clitter slopes ; and whilst modifying basin-shaped valley heads, accentuated lithological differences. Excessive run-off over frozen subsoil accelerated slope development, enlarging valleys to a size disproportionate to the present volume of their streams, which became littered with solifluxional and stream-borne debris.

15. The seaward and valley slopes and cliffs at Porth Nanven, West Penwith : by Ronald Savigear.

As part of an extended programme of work on the forms and evolution of the seaward and valley slopes of West Penwith. an attempt is being made to establish a denudation chronology for the area. The Admiralty Charts reveal a drowned polycyclic valley system, and The Brisons off Cape Cornwall may be interpreted as the remnant of a sub-aerial spur separating a formerly longer Nanquidno valley from the coast, or from a "Whitesand Bay " valley, to the south-west. Four narrow and fragmentary benches have been identified below the cliffs between Porth Nanven and South Carn Gloose, the uppermost, with an approximate maximum height of 28 feet above mean sea level, is mantled with marine cobbles which at the bay head, are piled as a storm beach to about 48 feet above mean sea level. About the 28-foot bench, and behind the cobbles, is a low vertical cliff, though in places all these features are absent and sub-aerial spurs lead down to sea level. Both cliffs and spurs terminate upwards in a distinct bevel with an average inclination of 50 degrees. The bench, the beach, the cliffs, the spurs and the bevel all antedate the whole or part of the last glaciation since they are, or have been, blanketed by head which accumulated to a height of about 100 feet above Ordnance Datum.

Three morphological units, at mean inclinations of 32, 27 and 6 degrees respectively, are the main constitutents of the seaward slopes above the 50 degree bevel, and below the relatively smooth convexity which leads upwards to the interfluve platform at 330 feet. It is suggested that they originated in four phases of river or marine erosion, but that they have been modified during the production and accumulation of head. Cliffs and rocky eminences occur both at the junctions of the 32 and 27 degree, and at those of the 27 and 6 degree, units. The former are free faces initiated by corrasion, the latter are tors revealed by the stripping of rock waste, from the interfluves and their peripheral slopes, during the last glaciation. The 32 degree unit, when traced laterally into the Porth Nanven valley declines in inclination and becomes concave as it extends outwards on to the surface of the head terrace which is not yet destroyed. The forms and angles of this concave unit, which is composed of plane facets and curved elements adjoining in angular intersections, are repeated both on the seaward slopes, where current marine cliffing has not yet removed the head, and on the slopes of the Zennor valley at approximately 400 feet. The facets and elements adjoining in angular intersections resemble the forms described by W. Penck. The repetition of similar back slope forms, both where there is an extensive foot slope, as in the Zennor valley at 400 feet (which probably originated in the Pliocene), and where it is hardly developed, as in the Porth Nanven valley (which originated in the Pleistocene), lends some support to the concept of slope evolution defined by L. C. King.

16. Mendip derived gravels and their relationship to combes : by B. Clayden and D. C. Findlay.

In the course of detailed soil mapping for the Soil Survey of England and Wales in North Somerset, the distribution of gravels around the Mendip Hills has been mapped in some detail. The gravels are sub-angular, ill-sorted and unstratified, and vary in thickness from a mere stony wash less than 1 ft. thick to deposits of 15 ft. or more. The composition of the gravel depends on the particular site

; in the Churchill and Winscombe localities it is composed dominantly of Old Red Sandstone and at West Harptree of chert, while south of Mendip the gravels are largely of Carboniferous Limestone. The deposits are only found opposite the mouths of gorges and combes leading from the Mendip plateau. The bulk of the gravels occur on gently sloping platforms cut in the Keuper Marl at 250-200 ft., 150-100 ft. and at about 50 ft. West of Cheddar gorge some gravels also occur on the lower slopes below 200 ft. of broad embayments into which lead a series of small combes, and in the Wells area trains of gravel follow the courses of the Axe. Sheppey and its tributary draining from Wells.

Associated with the Old Red Sandstone gravels around Churchill is a variable thickness of stone-free, red, sandy loam which has been incorporated into the upper layers of gravel by frost heaving. This sandy loam has been compared with sandy deposits mapped on lower slopes around the western end of the Mendips (Findlay and Clayden, 1958) and with blown sand from beneath the upper breccia at Brean Down described by Palmer (1934). On the basis of particle size and mineralogical analyses, the sandy material from the three sites is similar, which suggests that it is derived from a common source. Almost certainly it accumulated under aeolian conditions and resembles the coarser and locally derived parts of the main European loess spreads, for which the Dutch use the term coversands.

The gravel material was produced by intense frost shattering of the Mendip rocks under periglacial conditions in Pleistocene times and was moved out to the vales by periodic torrents of water flowing along the gorges. Water must have moved along the length of the dry valleys above Cheddar gorge to bring the small amounts of sandstone found in the Cheddar limestone gravels from the distant outcrops of Old Red rocks. The proportion of sandstone in the Mendip gravels is related to the distance between the gorges and the sandstone outcrops so that where these are separated by a long dry valley, the gravels are dominantly limestone.

The vales bordering the Mendips have a polycyclic form and the chronology of the gravel deposits can only be inferred by relating them to the old valley floors. Although gravels occur at elevations up to 400 ft. in the Litton area, they are most commonly found on platforms at 150-100 ft. or at about 50 ft. At Churchill and Langford they extend from the 100 ft. platform near the mouths of the gorges at Churchill Rocks and Burrington down on to the younger valley floor at little above 50 ft., and at Cheddar the gravels rest on an extensive platform at 50 ft. It is concluded that the gravels were formed in a cold phase during the Last Interglacial when valley floors were graded to a sea level at about 50 ft. but when unreduced remnants of older valley floors were still preserved extensively in the vales. The gravels are of the same age as Palmer's phase of breccia-formation and as the lower taele fans and fan deltas described by Tomlinson (1940) on the Cotswolds Sub-Edge Plain.

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17. The origin of tors on Dartmoor :by J. Palmer and R. A. Nielson.

The granite tors on Dartmoor are residual projections of bedrock left behind during the lowering of a hilltop or the recession of a valley side and are produced by congelifraction acting on a well-jointed but otherwise very resistant rock exposed by solifluction. The clitter around them consists of frost-riven material moved downslope and sorted by solifluction. Deep sections of rotten granite, such as at Two Bridges, are associated with tourmaline stringers and are the product of pneumatolysis. Substantial preglacial weakening of granite by deep subsurface chemical weathering along joints is rejected as a contributory cause of for formation owing to the lack of rotten granite in the joints of tors and the fact that the primary form of tors and clitter is angular. Rounding of the clitter is minor except when melanacratic granites occur, while rounding of tors is greatest in places most exposed to the weather and least in sheltered parts. Pneumatolitically altered granites are located mostly in topographic lows, and many valleys and cols appear to have been eroded along joints around which the granite has been weakened by ascending solutions. Where altered granites occur on topographic highs, tors are virtually absent. The detailed form of individual tors has much to do with the pattern of joints, including L joints, and also with slope, and the smallest detail is the product of post-glacial chemical weathering.

The existence of a recent periglacial phase is independently attested by other lines of evidence, and in view of the position of Dartmoor, just south of the line of maximum advance of the British ice-sheet, several periglacial phases may be expected to have occurred in this the highest portion of unglaciated Highland Britain. It is contended that the effects of such periglacial processes will have modified all but the flattest slopes, and tors of inselberg origin could not have survived from Tertiary times. The theory here put forward for the origin of Dartmoor tors has been found to explain other important groups of British tors in areas glaciated in early pleistocene times and at heights below the plio/pleistocene surface of S.E. England.

It is not intended to suggest that tors in humid tropical or semi-arid areas are formed in an identical way, but the factor common to all tors is thought to be strongly differential resistance of bedrock to atmosphere weathering where soil is removed faster than it can be built up by weathering. Tors are thus a feature of youthful or rejuvenated landscapes and in Britain are found best developed where situation in respect of ice margins, topographic situation and lithology were all favourable.

18. The bearing of superficial deposits on the age and origin of the upland plain of East Devon : by R. S. Waters.

The composite erosion surface (Green, 1941)) which is developed discordantly across the Upper Greensand and Chalk that build the plateau of east Devon, south Somerset and west Dorset may be subdivided on the basis of the character of superficial deposits associated with it. West of a line from Leigh Hill (31/190170) to Raymond's Hill (30/326964) the superficial mantle comprises chert rubble in a sandy matrix on the Blackdown Hills, angular flint and chert in a sandy clay on the Culm/Otter interfluve and typical clay with flints south of the Otter valley. Puddingstone boulders are locally very common, particularly in the south, and sarsen blocks are also present. The bulk of the fine argillaceous matrix would seem to have been derived from a former Eocene cover, which may also have furnished the sands and silica cement for the sarsens and the silica for the puddingstone matrix. But the larger constituents of flint and chert and the angular flint chips in the puddingstone represent the indissoluble weathering residue of the subjacent Chalk and Upper Greensand. The weathering out of the flint and chert from the Cretaceous formations, which may have begun beneath the presumably thin Eocene cover, the cementation of flint chips to form puddingstone and the differential induration of surface layers of the sands to form the sarsen boulders are all indicative of sub-aerial denudation under hot and at least seasonally humid conditions. It is suggested that the later phases of this subaerial denudation saw the production of the remarkably flat and tectonically undisturbed erosion surface (below 920 ft.) with which the residual deposits are associated.

On the plateau east of Leigh Hill-Raymond's Hill line there occur, in addition to the material present in the western area, numerous, widely separated patches of well rounded gravels in a sandy matrix. At eleven localities within the quadrilateral defined by the summits of Leigh Hill, Windwhistle Hill (31/380095), Beaminster Down (31 /494034) and Raymond's Hill thin spreads of flint, quartz, tourmalinised rock, greywacke and other palaeozoic pebbles with longer dimensions of from 0.5 to 10 cms. have been mapped at various heights between 725 and 960 ft. O.D. Although these gravels include a few whole or broken flint cobbles the most convincing evidence for their identification as shingle is provided by the extensive spread of beach material (cobbles of flint, chert, puddingstone and sarsen with diameters of from 5 to 10 cms. and rarely up to 25 cms.) present at the twelfth locality, Staple Hill (970-1,035 ft.). The gravels on the interfluves which diverge from Staple Hill represent material which has moved downslope from that elevated exposure under periglacial conditions. But the morphological setting of the other exposures suggests that the marine-trimmed surface upon which the late- or post-Eocene shingle was deposited has been warped.

The upland plain above 700 ft. is therefore interpreted as a polygenetic surface comprising two elements : (1) the "1,000 ft. platform" on Staple Hill, the most elevated portion of a marine erosion surface which was deformed by the mid-Tertiary earth movements, and (2) the 750-920 ft. surface which was developed sub-aerially subsequent to those earth movements. The latter surface is best preserved on the western parts of the plateau where it was cut solely on the Cretaceous rocks ; farther east where it was also developed across the Tertiary deposits its preservation is less perfect owing to the subsequent removal of the bulk of those deposits and the consequent exhumation of the deformed early-Tertiary marine plain.

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19. Erosion surfaces on Dartmoor and adjacent areas : by R. S. Waters.

Widely distributed and locally extensive erosion surfaces indicative of three phases of base-levelling subsequent to the formation of the southward sloping summit plain of Dartmoor (1,900 to 1,700 ft. in the north, 1,650 to 1,500 ft. in the south) are conspicuous elements in the morphology of the country between the lower Exe and the Tamar.

The uppermost of the three surfaces is represented on granite and altered country rocks by piedmont benches of varying width peripheral to the upland and, on the upland, by related valley-side benches and valley-floor segments which in some valleys (e.g. Dart. Teign) extend laterally as broad basin floors. Flatter portions of this surface which has suffered much dissection on western Dartmoor and considerable differential weathering and erosion (expressed in the landscape by such structurally adapted forms as tor-crowned ridges and elongate, basin-like depressions) lie between c. 1,300 and 1,050 ft.

Breaks of slope in the valleys and on the interfluves separate this upper group of facets from the most extensive base-levelled areas in west Devon which lie between c. 950 and 750 ft. Developed across many different outcrops this surface (Green's "Bodmin Moor platform") is also represented on Dartmoor by river terraces (rock) and valley-floor segments. On Haldon it carries a mélange of periglacially disturbed clay-with-flints and -chert and shingle. The well-known shingle, identical with that on Staple Hill (1,000 ft.) in Somerset, is of the same general age as the Bovey Beds : its association with unrolled lumps of flint and chert weathered from the subjacent Cretaceous rocks on a surface which clearly post-dates the mid-Tertiary earth movements responsible for the Bovey--Chagford tectonic depression is indicative of sub-aerial denudation. It represents early Tertiary material which has been retained during the sub-aerial lowering of a pre-existing gravel-covered, and very probably deformed, marine plain.

The third surface (690-550 ft. O.D.) is seen to perfection in south-west Devon, e.g., on Roborough and Plaster Downs where it is backed by steeper slopes between 700 and 750 ft. Although less extensive elsewhere, its former existence is attested by spur bevellings north of Dartmoor and, less reliably, by summit heights south of the Moor. Stream patterns and morphology alike suggest that of the three late-Tertiary surfaces this alone may, in part at least, be of marine origin.

20. The shingle complexes of Bridgwater Bay : by C. Kidson.

The cliffs between Lilstock and Hinkley Point yield a steady supply of limestone shingle which is the main constituent of the beach ridges and shingle complexes further east. The cutting back of these cliffs, though at a relatively slow rate, has left a wide marine abrasion platform fronting them. An eastern extension of this rock platform is seen off Stolford.

Beyond Hinkley the coast is cut in unresistant Quaternary deposits. The abrasion platform is here represented by a wide expanse of mud flats and coastal recession has been much faster than further west.

Throughout the six miles of coast under discussion the beach is backed by a simple storm beach of shingle. In the short section between Stolford and Wall Common, however, the shingle is piled into a train of six shingle "complexes" in which shingle ridge is piled on shingle ridge in seemingly endless succession. There is clear evidence in the existence of "fossilised " vegetated recurved laterals that this state of affairs is of long standing.

The beach to the east of Wall Common has for a long time been starved of shingle as a result of these accumulations. The planting of rice grass by the Somerset River Board has had the effect of raising the level of the foreshore and thus preventing erosion, except during very high spring tides and in exceptional storms, but the rice grass tends to inhibit the longshore movement of shingle.

This depositional and erosional pattern stems largely from the abrupt change in the rock character in the Hinkley Point area where the cliffs cease, and the consequent changes in hydraulic conditions. The drift of beach material along the coast is from west to east, except in rare storms from an easterly quarter. The dominant wave direction is somewhat north of west. Beyond Hinkley the wave energy is increasingly dissipated in crossing the ever widening mud flats, until in the Stolford, Wall Common area, a critical point is reached in the capacity of the wave to move shingle and the shingle complexes result.

While there is no grading of beach material in the Chesil Beach sense of the term, the size of the shingle decreases from west to east. At the same time the proportion of non-Liassic limestone pebbles to increases. At Steart Point the ratio of Liassic limestone pebbles to other material is of the order of 1: 3. This non-Liassic material is either Triassic sandstone from further west in the Minehead area, or more probably superficial deposits of Old Red Sandstone material moved under peri-glacial conditions. Such materials are present at Stolford and in the cliffs to the west. It is at present thought that the increased proportion eastwards of non-Liassic limestone shingle is due to the relative ease with which the Liassic material shatters with weathering. Shattering in this fashion hastens solution of calcium carbonate in sea water and thus speeds the eventual destruction of the Liassic limestone pebbles.

The increased proportion of non-Liassic limestone shingle eastwards is also an observed feature of the individual shingle complexes. It is apparent that periodically the material at the western end of any shingle complex is reworked by the waves and feeds the distal point of its most seaward ridge. In this manner the complexes appear to move bodily eastwards. The increased proportion of non-Liassic material is probably a measure of this re-sorting. Work continues on these problems.