PROCEEDINGS
OF THE
USSHER SOCIETY

VOLUME ONE

PART SIX AND INDEX

Edited by
M. R. HOUSE

REDRUTH, SEPTEMBER 1967
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CONFERENCE OF THE USSHER SOCIETY
HELD AT EXETER, 1967

The proceedings of the sixth Conference of the Society were greatly sobered by the sad death of the Secretary a week before the Conference. Accommodation had been arranged in the University of Exeter, and an indebtedness is due to Professor Scott Simpson for allowing the use of his department for meetings.

PROGRAMME

Contributions which are printed in the text are marked with an asterisk.

3rd January, 1967

128. INVITATION ADDRESS. Dr. K. F. G. Hosking: "The recent search for ore deposits in S.W. England."
129. *Dr. W. R. Dearman : "Tectonic fluting structure."
130. *Dr. W. R. Dearman : "On the significance of northward facing structures at Duckpool, near Bude in North Cornwall."
131. *Dr. J. R. Hawkes : "Rapakivi texture in the Dartmoor Granite."
132. Dr. M. Stone: "The origin of apliites and pegmatites."
133. Dr. B. Booth: "Some aspects of the geology of the Land's End Granite."
134. *Prof. S. Simpson : "Problems of the geology of the Geological Survey One-inch Sheet Teignmouth (339)."
135. *Dr. P. A. Floyd : "Frequency distribution of some elements in the granitic rocks of S.W. England."
136. *Dr. E. C. Freshney and Mr. P. J. Fleming : "The Petrockstow Basin, N. Devon."
137. Dr. C. Bristow : "The origin of kaolinite clays of the Bovey and Petrockstow Basins."
138. Dr. K. F. G. Hosking : "The nature and significance of the potassium feldspar bearing veins of western Cornwall."

4th January

139. *Dr. S. C. Matthews and Mr. L. J. Moore : "A conodont fauna from the Westphalian of North Devon."
140. *Dr. R. L. Austin: "New conodont horizons in S.W. England."
141. *Mr. J. C. Harvey : "Conodonts from Veryan Bay, Cornwall."
142. Mr. C. J. Adams : "Some age determinations from Brittany and the Channel Islands."
143. *Mr. G. A. Gauss : "Structural aspects of the Padstow area, North Cornwall."
144. *The Rev. B. B. Clarke : "The Sandrock and other features of the cliffs at Mother Ivey's Bay near Padstow."
145. *Mr. N. F. Kenyon : "Undescribed bodies of weak tidal current areas in the Celtic Sea."
146. Prof. D. T. Donovan and Mr. A. H. B. Stride: "Possible drowned cliffs around the Celtic Sea."
147. *Mr. R. P. Kirby : "The fabric of head deposits in South Devon."
148. *Mr. M. Williams : "The New Red Sandstone outlier of Hollacombe, W. Devon."
149. *Dr. C. J. R. Braithwaite : "Possible Permian sediments in South West Devon."

OBITUARY

Dr. Frederick James Winsor Holwill

The sudden death, as a result of a cerebral haemorrhage, at the end of December 1966 of Fred Holwill cast a shadow over the 1967 Conference of our Society. That the Conference business ran smoothly and successfully in spite of the loss of its Secretary only a few days before the meeting started is a testimony to his efficient organisation. Everything had been thought of and prepared. This efficiency was typical of a man who cared deeply about everything he did. His life was governed by a strong moral conviction and service and integrity flowed from it.

Born in London in 1925 and brought up there Fred Holwill left school to join the Royal Navy and served as a commissioned officer from 1943 to 1946. Returning to civilian life he obtained a teaching diploma and got his first job on the staff of Bristol Grammar School. He gave this up in 1953 to read for an Honours Degree in Geology at the University of Bristol, having obtained an External London B.Sc. by correspondence in the meantime. From Bristol he went direct to a teaching post in the Department of Geology at Imperial College. At Bristol he had acquired a particular interest in palaeontology and especially in the coral faunas of North Devon and West Somerset, and with great determination he set about research on them. This brought him to our Conferences and in 1961 he gave us his first paper. Thereafter he was a firm supporter of the Society and in 1963 he took over the office of Secretary. His qualities of efficiency and devoted service had by then also been recognised and called upon by the Geologists' Association (Council and Field Meetings Sub-committee) and the de la Beche Club (Treasurer).

Members of the Society will know of Fred Holwill's published work which will be fully dealt with in an obituary to be published by the Geological Society of London. Suffice it to say that a promising research career is tragically cut short. All who knew him commiserate with his widow and two young daughters on their most grievous loss.

129. Tectonic fluting structure : by W. R. Dearman.

Tectonic fluting structure may be regarded as the converse of boudinage. Both are stretching structures, but whereas in boudins quartz separates during deformation into the necked part of the structure the converse is true of flutes (Fig. 1 a and b). A prerequisite for the generation of flutes would appear to be a joint infilling partition to resist the later flattening and accompanying stretching. Flutes are usually confined to individual beds of sandstone or other rock types more competent than their neighbours ; partitions of quartz in the examples studied are set normal to the bedding and are spaced out between semi-cylindrical grooves or channels set back to back on both sides of the bed. **In** contrast both sides of the unit involved in boudinage structure are gadrooned : decorated with a series of convex ridges.

Typical flutes, illustrated in Fig. 1, come from a variety of tectonic environments in which boudins also occur. Fluting structure was first noticed in a quarry on Tregeare Down (Grid Ref. 20(SX)248866) four miles from the north-east margin of the Bodmin Moor granite. The flutes in Lower Culm Measures cherts are sketched in Fig. lc ; they are arranged with their length parallel to the hinges of rather tight overturned folds trending east. Discovery of a loose block containing the example in Fig. ld in the calc-ftintas from the Meldon aplite quarry (G.R. 20(SX)568921) on the north-west margin of the Dartmoor granite revealed that the fluting structure was formed before the contact metasomatic conversion of the original chert into calc-flinta. Intersection of cleavage with the lamination suggests that here the length of the flutes is again parallel to hinges of local overfolds trending north-east. It is considered likely by Wright (in Edmonds and others, in preparation; Freshney, 1965) that the folds in the Okehampton area were tightened by the emplacement of the granite. The sequence of structural events could have been folding with formation of cleavage, development of strike joints infilled mainly with quartz, subsequent tightening of the folds with continuation of elongation in the a-tectonic direction - the fluting episode - followed by contact metamorphism and metasomatism (compare with Dearman, 1959, fig. 19).

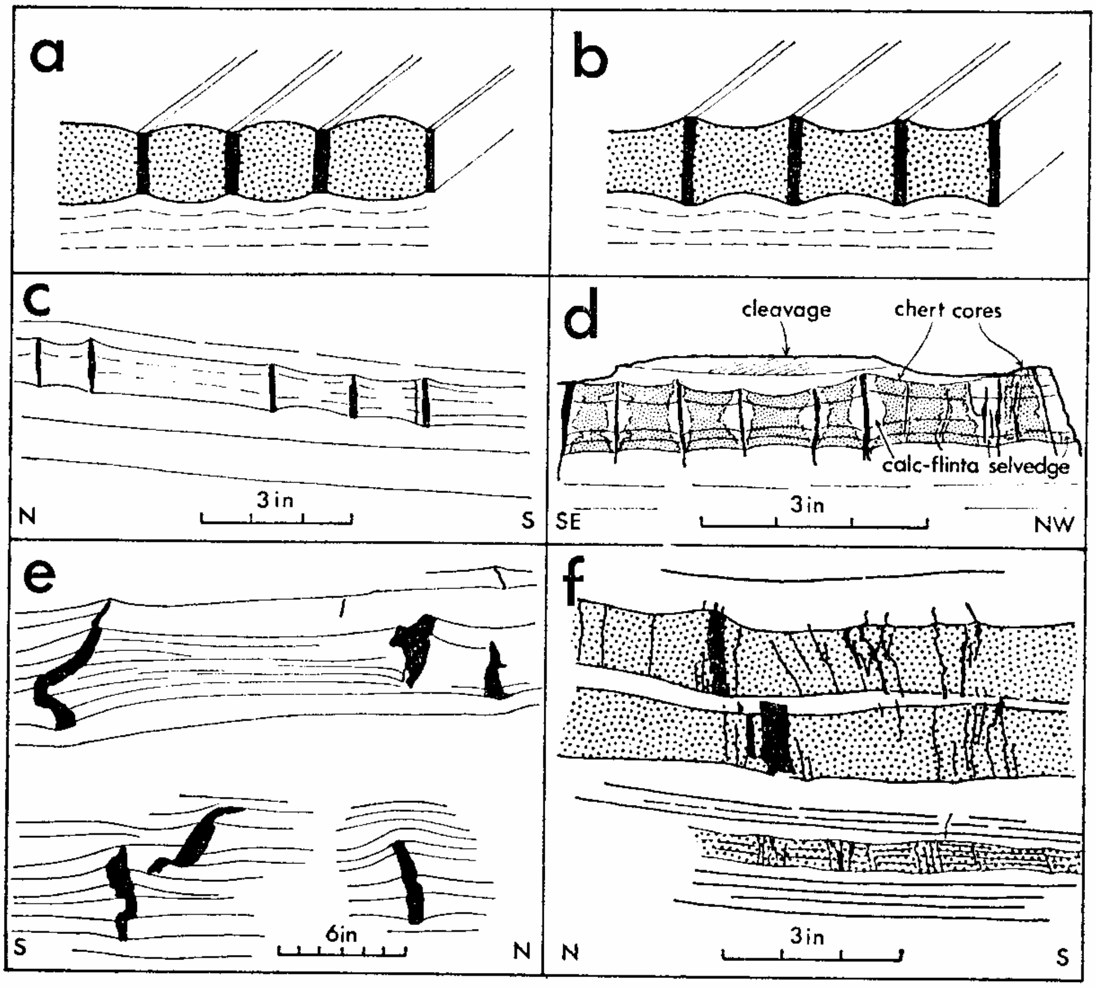

FIGURE 1. Fluting structures. (a) boudins ; (b) flutes ; (c) flutes in Lower Culm cherts on Tregeare Down ; (d) flutes in calc-flinta from the Meldon aplite quarry ; (e) flutes from Boscastle ; (f) flutes from Duckpool.

The two remaining examples are from coastal exposures in north Cornwall. At Boscastle (G.R. 20(SX)093917) the presumed Namurian black slates, grey siltstones and sandstones have been deformed twice (Dearman and Freshney, 1967). A consistent north-north-westerly strong mineral elongation is found in isoclinal folds with the same general, somewhat anomalous trend. Evidence of a similar elongation direction in slates to the south around Tintagel is provided by boudins with east-north-east long axes ; at Boscastle tectonic flutes in sandstones have the same trend (Fig. le). Quartz. partitions are bent, having yielded to flattening movements that induced irrotational strain by pure shear in the adjacent rocks.

In the Lower Westphalian Bude Sandstones just south of Duckpool (G.R. 21(SS)201116) flutes illustrated in Fig. If have been found in thin laminated sandstones and siltstones interbedded with shales. Upright horizontal folds, trending east, have been deformed again by smaller folds with similar trends. Boudins are present in massive sandstones and, like the flutes, are as expected parallel to fold hinges.

Fluting structures might provide a useful means of estimating quantitatively the strain that individual beds have undergone in the *ac* plane of deformation, as the initial thickness of the flattened bed is preserved at the partition. Even if the partition vein extends outwards into adjacent shales, as is not unusual, the junction between sandstone and shale is marked by a very rapid, often stepped, change in thickness of the vein.

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130. On the significance of northward facing structures at Duckpool, near Bude in North Cornwall :

by W. R. Dearman.

In a recent paper, Dr. H. J. Zwart (1964) has described the structures in the Devonian and Carboniferous rocks along the west coast of Devon and North Cornwall. He considered that vertical zigzag folds characteristic of the northern part of the Culm Measures outcrop around Hartland Quay had been deformed again in more southerly exposures by a consistently southward overthrusting movement. This second deformation has resulted in local associations of upright, inclined and recumbent folds. Recumbent folds have been formed preferentially on the southern limbs of anticlines while the northern limbs have only been flattened. Zwart, summarizing the structural history, concluded that "Due to the direction of movement few difficulties (of interpretation - W.R.D.) are encountered in the south limbs of the anticlines but their north limbs often show complications and faults". (ibid., p.521). Although interest in the structures has been stimulated, these and other new ideas have not gone unchallenged (Freshney, McKeown, Williams and Dearman, 1966 ; Mackintosh, 1966), and it is the purpose of this short note to demonstrate that minor structures on the northern limbs of anticlines indicate that there has been movement northwards on the north limbs of anticlines opposing the southward movements so common in the other limbs.

Structures south of Steeple Point, Duckpool, (Zwart, 1964, figs. 1 and 6) have been re-interpreted ; small folds at the base of the cliff are close to the axial region of a very large upright open angular fold that is defined by the distribution of thick black shales and massive sandstones in the cliff face (Fig. la). A distant view of the anticline shows that the beds in the northerly dipping limb have been thrown into a cascade of small angular zigzag folds that are overturned to the north. These minor folds thus face north and at the crest of the main fold a transition occurs to recumbent south-facing minor folds on the southern limb of the anticline. The latter minor folds are restricted to the crestal region, and the two sets of oppositely facing minor recumbent folds are separated by a curved fault (Fig, lb).

The next anticline to the south is a tighter fold, varying from a core with a symmetrical rounded profile at beach level, up through a complex box-fold into an enveloping angular fold rising to the full height of the cliff. With an angle of ninety degrees or slightly less, the fold as fully exposed in the full height of the cliff is inclined to the north. Angular zigzags inclined north are also exposed in the cliffs nearer to Sandy Mouth. In the example illustrated (Fig. Ic) the southern limb is plane, whereas the northern limb is kinked near the core, the dip decreasing downwards. This synclinal kink passes out from the region of the fold core into a single down dip drag-fold.

The movement pattern indicated by the minor folds in both examples is the reverse of that normally expected in an anticline formed by flexure. Instead of being directed up the bedding towards the axial region, the movements involve normal faulting displacements away from the hinge. The folds thus resemble the incongruous flowage fold of Bain (1931) illustrated by Fleuty (1964, fig. 8b). It is clear from this reversal of movement directions that the beds have been folded twice. Conclusive evidence of repeated deformation is provided in examples described by Zwart (1964, figs. 4 and 5) from Welcombe Mouth where a cleavage associated with the first, or upright, folds has been bent round the second folds. With both a southerly directed overriding movement as shown by many of Zwart's examples (Fig, Id) and northwards movements witnessed by the Duckpool structures (Fig, le), the movement pattern of the second deformation is localized within individual folds or limited groups of folds. If the main folds were upright before the second fold phase then the direction of overturning within groups of main folds, and the facing direction of the minor folds, would appear to be related to deformation on a larger scale. Late synclinorial and anticlinorial development, rather than just southward overthrusting movements towards the southern margin of the Culm Measures outcrop, might provide a more consistent explanation of the attitudes of major and minor fold structures. Continuity of bedding, maintained with minimal faulted displacement over the main fold hinges, would further imply a tectonic drive up the bedding on one limb, over the anticlinal crest, and a gliding down the other limb with crestal and flank crumpling producing the second phase of minor folding (Fig. 1f).

Generation of a cleavage during the first phase of folding, deformed during the second phase without imposition of a second cleavage, poses the problem of timing of the tectonic events. Both phases could have been immediately consecutive events; alternatively the second phase could have resulted from folding genetically related to Tertiary wrench-faulting, the other effects of which are already well known (Dearman, 1963).

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FIGURE 1. (opposite) Structures in the Bude Sandstones between Duckpool and Sandy Mouth north of Bude.

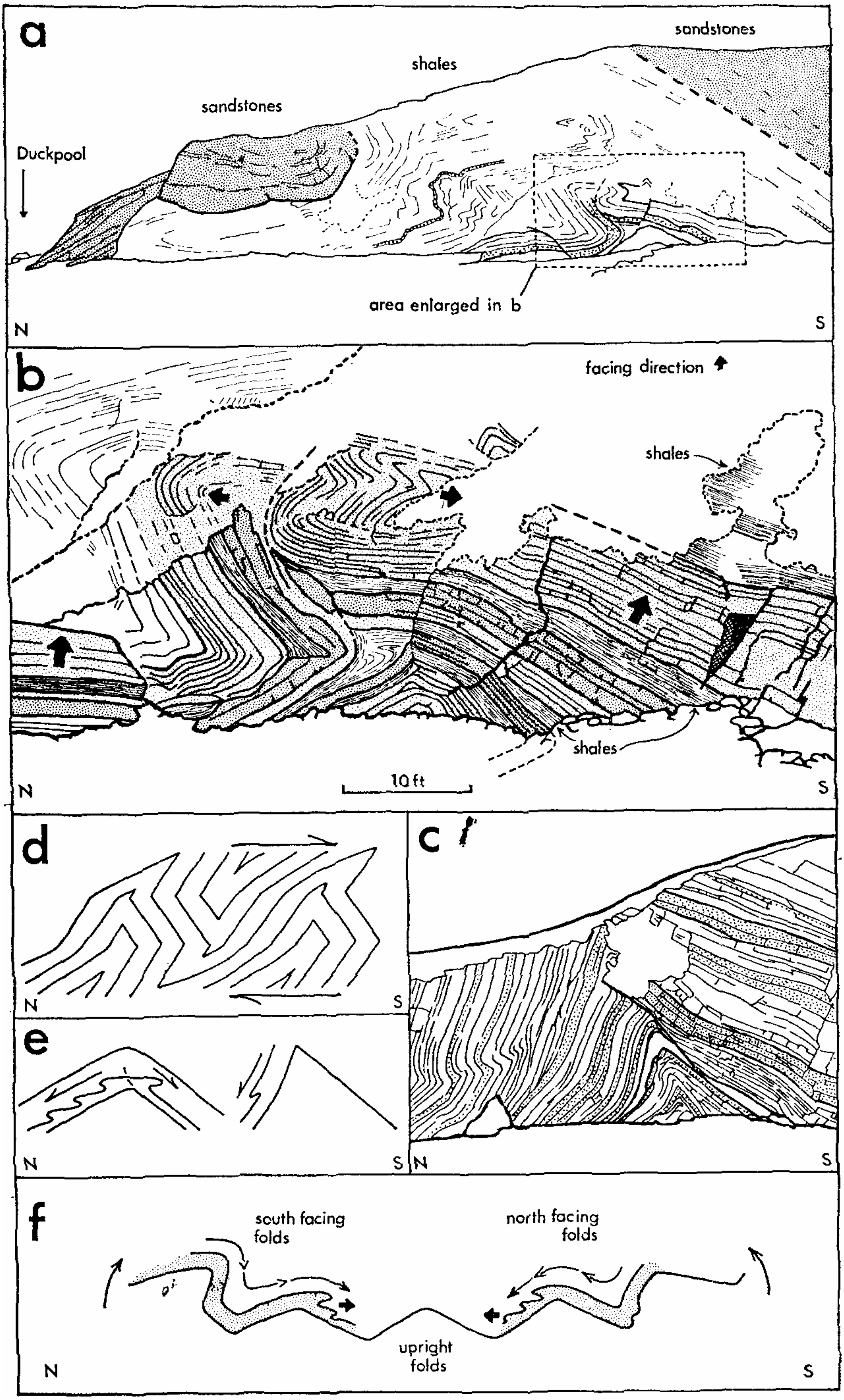
(a) The anticline just south of Duckpool with minor incongruous folds on the northern limb. The cliff is 200 ft. high. Inset marks structures illustrated in more detail in (b) below.

(c) Anticline north of Sandy Mouth, steeply inclined north with kinked north limb and incongruous minor folds. The cliffs are 200 ft. high.

(d) Relationship between first and second phase folds according to Zwart (1964, Fig. 11).

(e) Relationship between first and second phase folds at Duckpool.

(f) Generation of northward and southward facing structure by a second phase of deformation of upright folds.


a
sandstones
shales
sandstones
Duckpool
area enlarged in b
N
S
b
facing direction
shales
shales
10 ft
N
S
d
N
S
c
N
S
e
N
S
f
south facing
folds
north facing
folds
upright
folds
N
S

131. Rapakivi texture in the Dartmoor Granite : by J. Hawkes.

Rapakivi (from the Finnish, meaning rotten stone) has long been used in Finland to describe freely-weathering granites (see Zenzén, 1925). It was Sederholm (1891) who adopted the term specifically for the Pre-Cambrian, post-tectonic, magmatic granites in Southern Finland which are characterised by their susceptibility to weathering and which generally contain large, ovoidal, red-brown, potassium-feldspar crystals mantled by grey sodic plagioclase. Subsequent usage outside Scandinavia has been mainly in connection with the latter feature.

The mantling of potassium-feldspar by sodic plagioclase is relatively common in granitic rocks and has been ascribed, notably to Sederholm (1928), Tuttle and Bowen (1958), and Marmo (1962), to magmatic crystallization. In discussing rapakivi texture in the Tasiussak Granite, Southern Greenland, Dawes (1966) recently challenged the magmatic viewpoint. He emphasized that rapakivi perthites are not confined to the granite, but also occur in basic inclusions and in later basic dykes. In addition, the sodic-plagioclase of the mantles and concentric rings within the perthites is in optical continuity with the perthitic plagioclase lamellae. Accordingly, Dawes suggested that the texture might be due to exsolution of plagioclase from potassium-feldspars formed during a post-magmatic potash-metasomatism of the granite.

‘Rapakivi structures’ were recognised by Brammall and Harwood (1932) in hybrid rocks and basic xenoliths from the Dartmoor Granite. In fact they commonly occur in the main ‘big-feldspar’ and ‘blue’ granite facies as well. Crystals are euhedral or ovoidal and range up to 2.5 cm. in length (or as much as 4.0 cm. in granitized shale xenoliths), but because the potassic cores are pale-grey rather than red-brown, the rapakivi texture is not readily seen in hand specimen. A colour contrast between the mantle plagioclase and the central potassium-feldspar exists only where the plagioclase is partially koalinized.

In comparing stained ‘rapakivi’ specimens from Dartmoor with similar material from the Aland rapakivi Granite, Finland, the textural relationship of the core and mantle feldspars is seen to be identical. The interface between the two minerals is extremely irregular and the mantle plagioclase is in optical continuity with irregular patches and lamellae of plagioclase within the potassium-feldspar cores. Both feldspars contain scattered, almost graphic growths of quartz and numerous, small, randomly-oriented, zoned, sodic plagioclase crystals, some mantled by albite.

The common optical orientation of the mantle, patch and lamellae plagioclase accords with Dawes' observations on the ‘rapakivi’ perthites in the Tasiussak Granite, although it is not regarded as evidence for exsolution. For one reason, the irregular plagioclase lamellae in Dartmoor and Aland specimens differ from the regularly disposed, low-temperature-albite exsolution film structures typical of neighbouring, unmantled, potassium-feldspars. Also the common optical orientation of the mantle, patch and lamellae plagioclase is matched by a common twinning (lamellar, pericline or chess-board), while the size of the potassic cores relative to the thickness of the mantle plagioclase varies appreciably. These features are indicative of replacement rather than exsolution.

Many granitic masses contain evidence of widespread replacement of plagioclase by potassium-feldspar. In post-tectonic intrusions like Dartmoor and the Finnish rapakivis, the process was probably autometasomatic since the potassium-feldspar is orthoclase rather than microcline (Marmo 1962, Edmonds and others-in press). The smaller plagioclase crystals in these bodies appear to have been replaced haphazardly. With larger crystals, however, the central, more calcic areas, were commonly attacked first, which suggests that rapakivi texture simply represents an incomplete stage in the replacement process. It is perhaps significant that the maximum length of large plagioclase crystals in Dartmoor and Aland Granite specimens is approximately 2.5 cm. and that although many potassium-feldspar crystals are larger than this, none greater than 2.5 cm, across display rapakivi texture. (Granitized shale xenoliths in the Dartmoor Granite contain plagioclase crystals up to 4 cm, long. Some ` rapakivi ' crystals are of a comparable size.)

A critical factor in the replacement hypothesis is the apparent, relatively unstable behaviour of the anorthitic component of large plagioclase crystals under (auto)-metasomatic conditions. Further evidence of such behaviour is contained in Bailey and Grabham's (1909) account of the albitized dolerites of Central Scotland. They noted that porphyritic plagioclase crystals in the dolerites were always albitized in preference to the more sodic groundmass feldspar and that, within the larger crystals, the more calcic zones were picked out first. Hydrothermal sericite in granite plagioclases similarly conforms to this pattern. It is commonly developed in the central anorthite-rich portions of crystals in preference to the outer albite-rich zones.

If the replacement hypothesis is accepted, the numerous, small, randomly oriented, plagioclase crystals in the Dartmoor and Aland rapakivi feldspars can be regarded either as recrystallized relict patches of the original host, or as inclusions which received their albitic coatings during the potassiumfeldspathization process. Some of the quartz present may have been derived from the breakdown of anorthite molecules ; the rest possibly from the autometasomatizing fluid.

Summary. Rapakivi texture in the Dartmoor Granite (and by implication in the Aland rapakivi Granite) is thought to represent an incomplete stage in the autometasomatic, potassium-feldspathization of large plagioclase crystals.

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134. Problems of the geology of the Geological Survey One-inch Sheet Teignmouth (339) : by S. Simpson.

The resurvey of the area of the Teignmouth Sheet at present being carried out in the Department of Geology at Exeter University will involve the study of a number of problems of more than local interest. Some of the more important of these are outlined here.

(1) To what extent can the two distinct facies developments of the Upper Devonian-Lower Carboniferous successions recognised by Bristow (1963) be identified elsewhere within the area of Sheet 339 ?

(2) Can the Ugbrook Park facies of the Upper Carboniferous be considered as associated with one of the successions in the underlying strata ?

(3) Can autochthonous and allochthonous sheets characterised by two different Upper Devonian to Upper Carboniferous successions be distinguished and mapped across the Sheet ?

(4) To what extent can the Haldon Gravels be considered to be a pure residual deposit resulting from the solution of a thick layer of Chalk ? What were the conditions of accumulation of those parts of the Haldon Gravels which show evidence of rounding and sorting? What are the mutual relations of the two sorts of Haldon Gravels?

(5) To what extent can the gravel types of Haldon be recognised in the peripheral gravels, such as the Aller gravels, of the Bovey Tracey ball-clay basin? What is the relation of the peripheral gravels to the ball-clays?

(6) Is the surface defined by the heights to which the summits west and south of the Bovey Basin tend to rise the dissected exhumed sub-Cretaceous surface? If so could a part at least of the deposits of the Bovey Basin be derived from the Cretaceous deposits originally overlying the unconformity?

(7) To what extent is the form of the Bovey Basin purely determined by structure and to what extent has it been modified by erosion contemporaneous with or subsequent to the period of accumulation of the ball-clays?

(8) What is the tectonic style of the Carboniferous of the Middle Teign valley ? What is the direction of tectonic transport ? How does the overall movement picture tie in with that of the south-facing zone of the country immediately to the north ? Are there important normal faults trending east-west and throwing down to the north ? And if so are they of the type described by Dearman (1959) or Freshney (1965) or Mackintosh (1965)?

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135. Frequency distribution of some elements in the granitic rocks of S.W. England : by P. A. Floyd.

In view of the increasing numbers of analyses of granitic rocks from the S.W. plutons, an exercise was undertaken to see if an estimate of the source(s) of variation in any observed distribution could be found. That is, could any petrochemical significance be attached to the distribution of SiO_2, the alkalis, Fe and Mg in the S.W, granites.

Cumulative distributions were plotted on arithmetical probability paper with linear and logarithmic scales after the method of Tennant and White (1959).

Silica. Using all available SiO_2 analyses of the granitic rocks (including both early and late differentiates) a relatively symmetrical histogram (Fig, la) was obtained suggesting a normal distribution for silica. This was tested on linear probability paper and a single population emerged (Fig. lb) ; that is, all the points could be accommodated by a single straight line. This result differs from a similar construction for 440 Japanese “granites” (57-79% SiO_2) and 797 world “granites” (59-81 % $Si0_2$) by Ahrens (1963b, 1964) that in both cases showed the presence of two populations with a discontinuity at 72.8% SiO_2 (see Fig, lb), Ahrens (1963b) considers this SiO_2 value to possess some special “significance” as it corresponds very closely to the “granitic” high

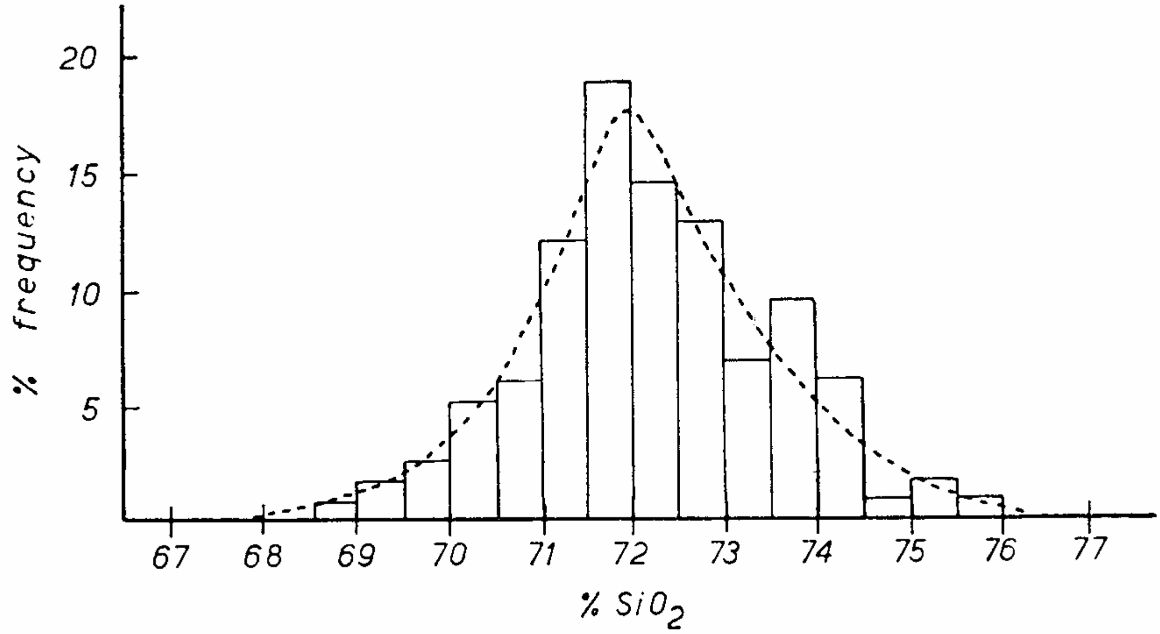

FIGURE 1a. Histogram showing the distribution of SiO_2 in all granitic rocks of the S.W. of England.

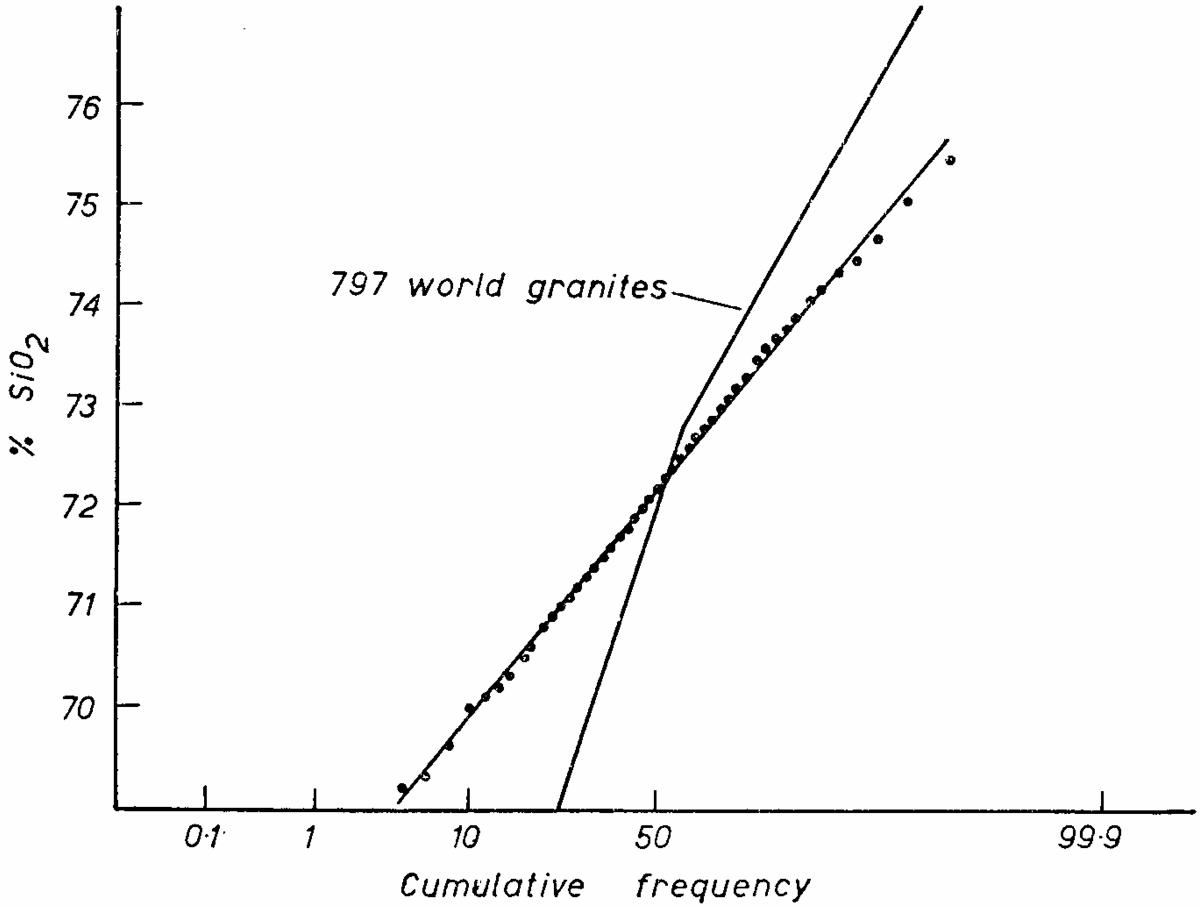

FIGURE 1b. Cumulative frequency distribution (linear scale) of SiO_2 in the granitic rocks of the S.W. of England compared with 797 world granites (Ahrens, 1964).

point of 73% SiO_2 in the distribution of SiO_2 in igneous rocks (Richardson and Sneesby, 1922). It must be borne in mind, however, that the term "granite" included many rocks of intermediate composition which may have affected the low-silica portion of the distribution (Ahrens population X).

Sodium. A cumulative frequency diagram (Fig. 2) for the individual granites with log concentration as variate, showed that (a) Na has a similar dispersion in each of the granite plutons and (b) two populations were present in the case of the St. Austell and Godolphin-Tregonning intrusions. By pooling all Na results (131 observations) it can be demonstrated that Na approaches two lognormal distributions with a discontinuity at 1.4% Na. It is considered that the two populations represent the difference in accommodating Na in plagioclase with a high-temperature structure (high-albite structure) and plagioclase with a low-temperature structure (low-albite or peristerite structure).

Potassium. K in all granitic rocks appears to approach a normal distribution, although a cumulative frequency diagram on probability paper shows that a straight line could fit all points above 2.5% K reasonably well, using

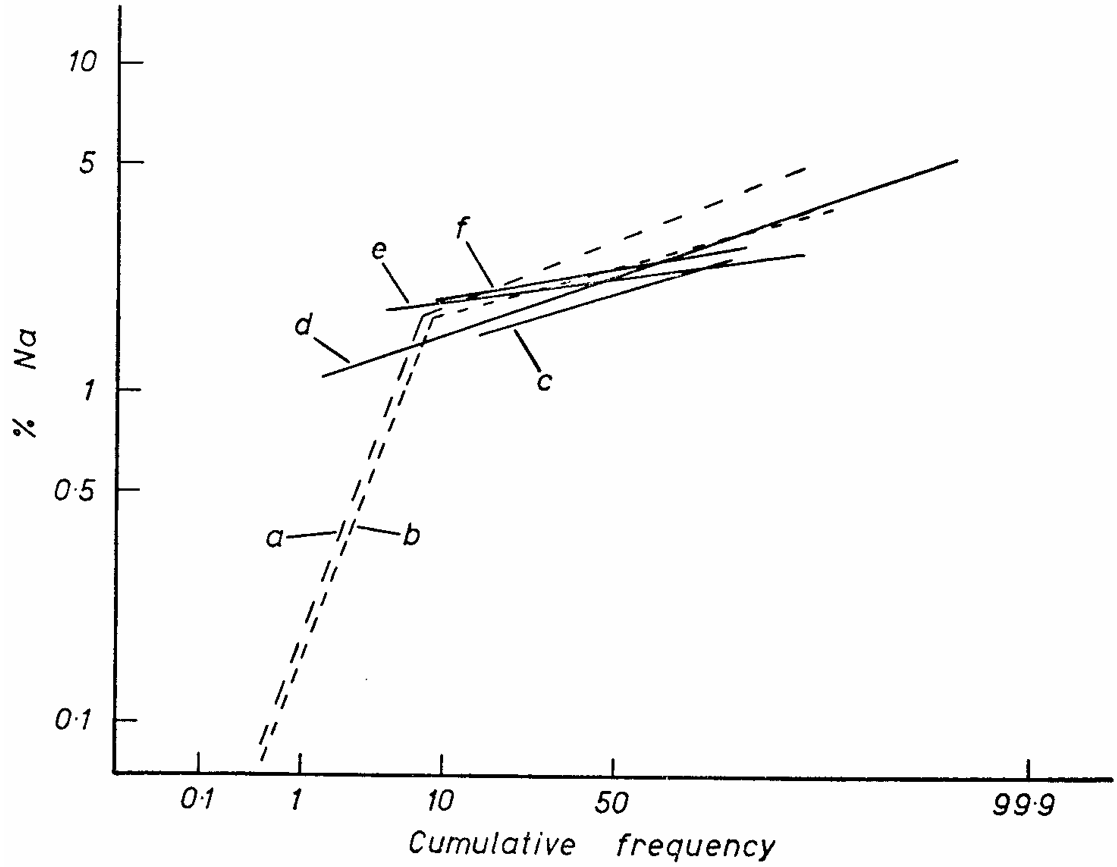

FIGURE 2. Cumulative frequency distribution (log scale) of Na in individual granitic plutons of the S.W. of England.
a = Godolphin-Tregonning, b = St. Austell, c = Carnmenellis, d = Land's End, e = Dartmoor, f = Bodmin Moor.

either a linear or logarithmic scale. As an F-test shows all observations (140) to belong to one population at all levels of significance tabled, a straight line "fits" all points marginally better using a linear scale. The suggestion of a single normal distribution for K is only tentative and may be considerably more complex in view of the metasomatic nature of this ion during late crystallization (Stone and Austin, 1961) and also the possibility of differential contamination by pelitic materials (Stone, 1966).

Trace alkalis (Li, Rb, Cs). Results for Li are confined to the St. Austell and Godolphin-Tregonning granites and in both cases appear to be log-normally distributed. Due to its particular chemical characteristics Li demonstrates coherence with Mg and Fe rather than with the other alkalis. This is clearly shown by the similarity of dispersion between Li, Mg and Fe in the St. Austell granites.

Rb and Cs on the other hand, probably follow K in being normally distributed and show a dispersion order of Cs > Rb > K. This is in reverse order to their respective abundances and has been commented on by Ahrens (1963a).

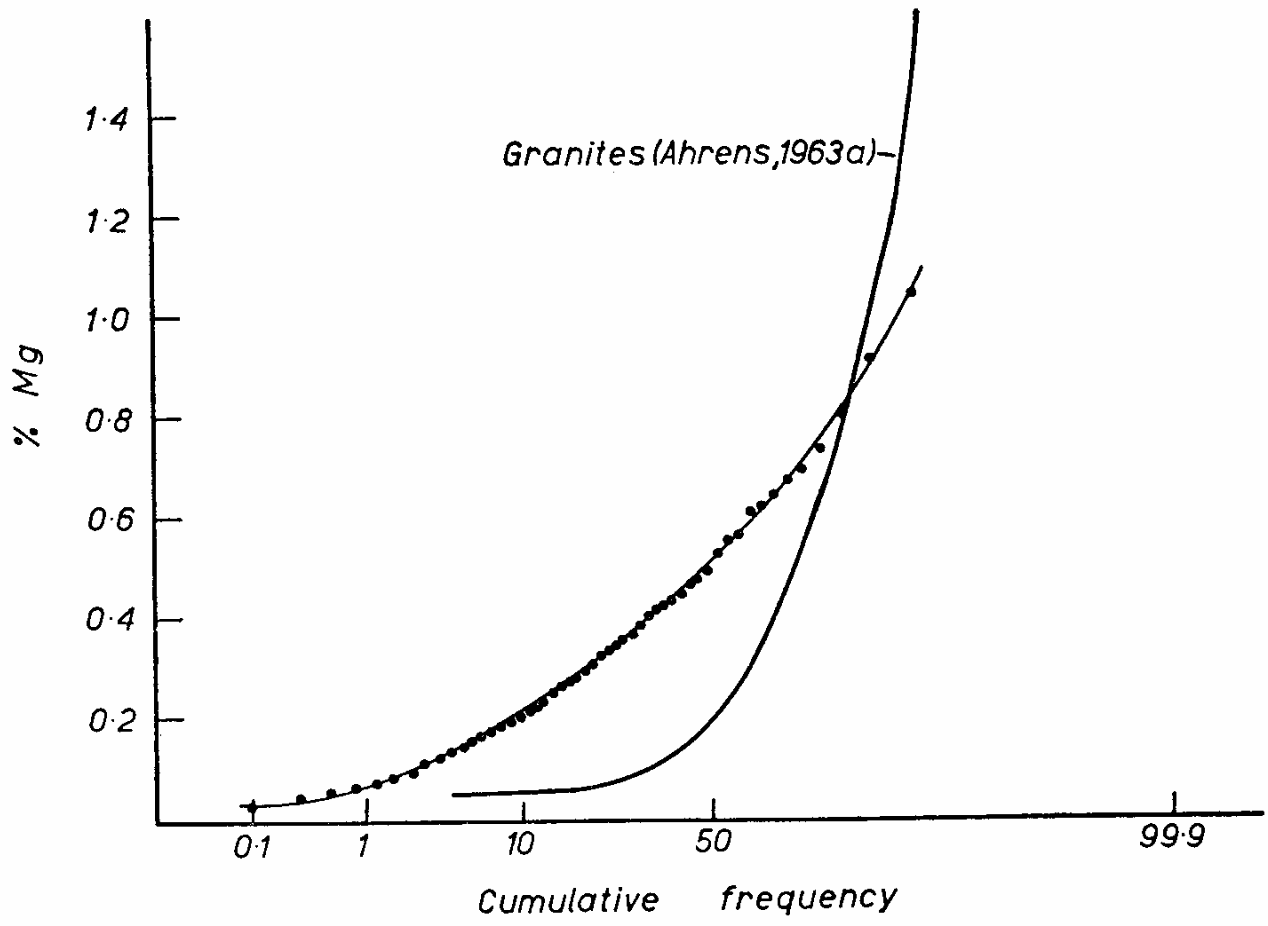

FIGURE 3. Cumulative frequency distribution (linear scale) of Mg in the granitic rocks of the S.W. of England compared with granites analysed by Carr and Turekian (1961) (Ahrens, 1963a).

Magnesium. Fig. 3 is a cumulative frequency diagram for Mg using linear scale probability paper. Deviation from linearity for Mg in both the S.W. granites and a series of granites used by Ahrens (1963a) is clearly indicated by the marked curvature of the plots. Testing on a logarithmic scale, however, reveals the existence of two lognormally distributed populations with a discontinuity at about 0.15% Mg. The major population includes all biotite-bearing granitic rocks and has a similar dispersion to Mg in Japanese granites (Ahrens, 1963a). The minor, lower concentration (0.02-0.15% Mg) population includes all lithionite- and muscovite-bearing fluorite and lithionite granites. The two populations could represent crystal-chemical differences in the accommodation of Mg in Mg-rich mica lattices (biotite) compared with Mg-poor mica lattices (lithionite and muscovite).

Iron. Total Fe could be represented by three lognormal distributions or a much more complex distribution of unknown character. If three distributions are present, the higher concentration populations (above 0.62% Fe) represent the early biotite-bearing differentiates and the lower concentration population, the late differentiates (fluorite and lithionite granites, micro-granites, aplites, etc.). The apparent complexity of the distribution may in part be due to the combing of Fe^{2+} and Fe^{3+} as total Fe, as well as possible mineralogical variation.

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136. The Petrockstow Basin : by E. C. Freshney and **P. J.** Fenning.

In an area between Yarde (SS 492 144) and Meeth (SS 548 083) a deposit comprising unconsolidated koalinitic clays of varying silt content, with subordinate sands, quartz gravels, lignitic clays and lignite, occurs between two north-westerly trending faults belonging to the Sticklepath fault zone. This deposit is thought to be of Oligocene age by analogy with the Bovey Beds of south Devon. To the north-west of Merton (SS 528 122) and to the west of Meeth parts of the margins of the deposit are probably unconformable stratigraphical contacts against the local Upper Carboniferous rocks.

Facies variations are discernible both axially and laterally in the basin. Axially, sand and silt are relatively more abundant towards the south-east, and conversely brown lignitic clays and lignites are less abundant south-eastwards. Laterally, in the northern and central parts of the basin, silts, sands and quartz gravels increase in proportion south-westwards, and seams of clay which are relatively free from silt in the area of the clay workings near Merton are unrecognizable amongst great thicknesses of silty to very silty clays found in the Institute of Geological Sciences (I.G.S.) Petrockstow Borehole (SS 5201 1041). The coarse gravels which occur at intervals near the south-west margin of the basin and in this borehole appear to be lensoid in cross-section, suggesting gravel-filled river channels. The silty clays found both in boreholes and in pit exposures commonly contain rootlet systems, and some lignites resting on seatearths were almost certainly formed in situ. Many of the clays exhibit sun-cracks, which are usually filled with sand, some being up to 4 ft. deep. Beds of red-brown laminated lignitic sand occur chiefly in the axial area of the basin, and many of them show small scour channels and are highly disturbed.

It is suggested that these beds represent part of the channel and flood-plain deposits of a large river flowing from the south-east along a valley controlled by the Sticklepath fault zone. The main river channel tended to be situated between the axis and the south-western side of the valley, but frequently spilled over to deposit silty muds on a flood-plain to the north-east, the finer silt-free muds being deposited farthest from the river. With the subsidence of flooding and the drying up of temporary lakes sun-cracking took place, and vegetation was established to produce rootlet beds and lignite seams. Contemporaneous movement on the bounding faults must have taken place to accommodate more than 1,973 ft. of sediments as proved by the Petrockstow Borehole. E.C.F.

During August, 1965, the Geophysics Department of I.G.S. observed 70 gravity stations covering 18 square miles on and around the Petrockstow basin. These measurements indicated a Bouguer gravity anomaly minimum of 7 milligals below the regional background centred one mile south-south-west of Merton. Accordingly, a further 44 gravity observations were made at 100 yd. intervals along the road between Heanton Lodge (SS 501 102) and Heanton Satchville (SS 535 114) to derive a more detailed gravity profile across the deposits.

To provide data necessary for an accurate interpretation of this profile the densities of 15 samples from various lithologies were measured and found to vary between 1.64 and 2.41 $g/cm.^3$ This wide density variation of 0.77 $g/cm.^3$ makes it difficult to assess a representative mean density for the deposits in the basin, especially since the density will increase with depth due to compaction. A density value of 2.10 $g/cm.^3$ was selected as a representative surface value for the deposits and density values ranging between 2.60 and 2.65 $g/cm.^3$ were determined for nearby Upper Carboniferous rocks, indicating a surface density contract of 0.50 $g/cm.^3$. Using this density contrast and ignoring compaction effects, then the gravity anomaly due to a prism, 1,400 ft. deep with a vertical western margin and an eastern margin dipping inwards at 40°, agrees well with the observed anomaly. However, the fact that increase of density with depth due to compaction would decrease the density contrast between the basin deposits and Upper Carboniferous rocks at lower levels, implies a basin deeper than 1,400 ft. by an amount related to the rate of density increase in the relatively unconsolidated basin deposits.

The Petrockstow Borehole was sited over the minimum gravity value and preliminary results of measurements made on the cores immediately after extraction show a density increase from 2.15 $g/cm.^3$ at surface, to 2.38 $g/cm.^3$ at a depth of 1,300 ft.

Recently more gravity profiles have been observed across the basin and a combination of these with a knowledge of the density variation with depth determined at the borehole should lead to an accurate assessment of the depth and possible nature of the boundaries of the deposits. With the latter problem in mind some resistivity and seismic refraction surveys have also been made, but initial results have proved inconclusive. P.J.F.

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139. A conodont fauna from the Westphalian of north Devon :
by S. C. Matthews and L. J. Moore.

The pattern of Upper Carboniferous stratigraphy in north Devon is known to be complex (Reading 1965 ; Prentice 1965) and the need for further palaeontological information is readily recognised. One of the better palaeontological opportunities in the district is offered in a Westphalian limestone which comes to outcrop west of Clovelly. The precise locality is 150 metres south of Blackchurch Rock (G.R. 21/300266) and about 5 metres north of the more southerly of two anticlines occupying the cliffs at this point. Rogers and Arber (1904) were first to report the existence of this rarity in the Upper Carboniferous rock succession, and they listed the cephalopods and lamellibranchs to be found there. The cephalopod fauna collected from bullions at the base of the main limestone band contains numerous *Gastrioceras circumnodosum,* both the cadicone and coronate forms being present. The horizon is that of the *Gastrioceras listeri* Marine Band in the paralic Westphalian.

The occurrence of an abundance of conodonts in the limestone, in association with the molluscan fauna, may be thought to deserve some attention. There is as yet no comprehensive statement on the sequence of Westphalian conodont faunas in Europe, and American work on the Pennsylvanian (on which our present knowledge of the variety of form developed in Upper Carboniferous conodonts chiefly depends) has only relatively infrequently referred to conodonts from the lower, Morrow-Lampasas range of the Pennsylvanian. Work currently in progress in Europe and the U.S.A. will do much to repair present deficiencies and will, it should be hoped, provide for precise use of conodonts as a means of dating Upper Carboniferous marine sequences. In the meantime, the characteristics of the conodont fauna encountered in the thin Westphalian limestone in north Devon may be remarked on thus :

1. The genus *Gnathodus* is represented by one form, *G. liratus,* only.

2. Idiognathodids are abundant, and varied in the detail of their ornamentation. They are almost exclusively slim, lanceolate in form, and have in all cases some remaining longitudinal ridges developed on the anterior part of the upper surface of the cup.
3. *Polygnathodella* is represented by the compact *P. attenuata* and by a more inflated form close to *P. convexa.*

The well-preserved bar-like forms need not receive specific mention here.

It is intended to pursue investigations of the conodonts in the Upper Carboniferous of north Devon whenever the occasional, and usually discontinuous, calcareous developments permit access to information on these faunas. The opportunity to deal with palae-ontology in a fully marine Upper Carboniferous succession is an unusual one in north-western Europe, and any profit that there may be in following out this opportunity is likely immediately to serve the task of unravelling the later history of the Upper Palaeozoic succession in Devon. Incidentally, given information on conodonts from paralic *Gastrioceras listeri* Marine Band sources, there might emerge the interesting possibility of comparing the vertical ranges of cephalopod species in marine and paralic facies.

The Central Research Fund of the University of London gave financial support to field studies by L. J. Moore (then a Tutorial Research Student at King's College, London) out of which this work arises. Mr. M. A. Calver's kindness in contributing identifications of the goniatites is likewise gratefully acknowledged.

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140. New conodont horizons in S.W. England : by Ronald L. Austin.

Correlation of the Avonian rocks of South West England with lower Carboniferous successions in other parts of the world is difficult, because of the absence from the Avonian strata of diagnostic macrofossils. Study of the Avonian conodont fauna has, however, provided a method whereby the type British Lower Carboniferous succession can be directly compared with that of other regions.

Conodont faunas from the standard cephalopod bearing lower Carboniferous rocks of Germany have been described by Bischoff (1957) and by Voges (1959). Collinson, Scott and Rexroad (1962) established a sequence of biostratigraphical conodont assemblage zones through the Carboniferous succession of North America. Recently the distribution of conodonts in the Dinantian of the Franco-Belgian Province (Conil, Lys and Mauvier, 1964) and in Australia (Jones and Druce 1966) has been published.

The conodont fauna of the Avonian at its type section in the Avon Gorge has been examined, as part of a comprehensive study of British Lower Carboniferous conodonts (Austin, Druce and Rhodes 1966, Rhodes, Austin and Druce 1967). Of the 242 samples collected at ten foot intervals through the section (K Zone-D2 Subzone), 108 yielded conodonts. There was great variation in the numerical abundance of conodonts. The K, Z and C_1 Zones had abundant faunas whereas the conodont fauna of the C_2, S and D Zones was sparse. Over 6,500 specimens were recovered and these were referable to 22 previously described genera, namely **Angulodus, Apatognathus, Cavusgnathus, Euprioniodina, Gnathodus, Hibbardella, Hindeodella, Ligonodina, Lonchodina, Magnilaterella, Mestognathus, Metalonchodina, Neoprioniodus, Ozarkodina, Plectospathodus, Prioniodina, Pseudopolygnathus, Polygnathus, Scaphignathus?, Siphonodella, Spathognatodus** and **Taphrognathus,** as well as to two new genera **Clydagnathus** and **Patrognathus.** Twelve biostratigraphical conodont assemblage zones have been established on the basis of the vertical distribution of distinctive conodont species and genera. This sequence of conodont faunas and zones offers an alternative method of correlation and age determination for rocks of Lower Carboniferous age. This sequence, together with those already known, will also aid the correlation of samples collected from isolated exposures in South West England, where macrofossils are either absent, or not diagnostic.

The relationship of the base of the Avonian at the Avon Gorge to the internationally accepted type section for the Devonian-Carboniferous boundary is dealt with in a forthcoming publication (Austin, Druce and Rhodes 1967). Williams (pers: comm:) who is currently studying conodont bearing limestones in North and South Devon has recovered an interesting fauna from the Lower Pilton Beds of North Devon. The fauna is older than the basal conodont fauna of the Avonian and adds support to the conclusion of Goldring (1958), that the basal Avonian strata are of Tournaisian age.

A conodont fauna, dominated by the genus **Icriodus** has been recovered from the Middle Devonian Hopes Nose Limestone of Hopes Nose. Study of this fauna is continuing.

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141. Conodonts from Veryan Bay, Cornwall : by J. C. Harvey.

Initial random sampling of the limestone outcrop in the centre of Kiberick Cove yielded a few conodonts in the microfossil residue. Further sampling over the whole outcrop was based on a string grid 15 x 5 ft. erected over the rock face, divided into 3 x 1 ft. sectors. The rock is a shaly limestone with lenticles of purer limestone. The outcrop has yielded about 100 conodonts including fragmentary specimens and the most common type so far recovered is a blade and platform icriodid type with opposed pairs of denticles ; a few simple conodonts similar to *Belodus* have been found, and one arched conodont. All are uniformly black in appearance and have been found spectrographically to contain iron. The material appears to be microcrystalline limonite. Three fragments of icriodids have been found in Catasuent Cove in a limestone lenticle.

The fauna so far recovered may tentatively be described as Lower Devonian, or earlier. No recognisable Middle Devonian icriodid species have been found.

143. Structural aspects of the Padstow area, North Cornwall : by G. A. Gauss.

Several fold events can be recognised and these are summarised below. Those subsequent to the first are usually of rather open style and local development and are, therefore, relatively subordinate.

1. The first folds of the area are those associated with the development of slaty cleavage which is parallel to their axial surfaces. They are everywhere recumbent and generally of near similar style, since the lithologies are mainly argillites, but are open rather than isoclinal in form. There appear to be two broad geographic areas present in which the pattern of these first folds is rather different.

West and south of Polzeath the folds all face north and plots of bedding/ cleavage lineations and fold axes give a distinct gently W.S.W. dipping point maximum. North and east of Polzeath, however, the folds generally appear to face south and there is a great variation in trend even over a short distance.

2. Later E.-W. trending folds can be widely recognised from their affect on slaty cleavage.

On the east side of Stepper Point mesoscopic folds of slaty cleavage are locally developed and have a gently N.W. dipping strain-slip cleavage parallel to their axial surfaces. There appears also to be a larger fold here belonging to this episode for slaty cleavage is rotated from a mean dip of 20° to the S.S.E. in the south to steeply dipping to the N.N.W. in the north. The change of attitude takes place over a N.-S, distance of a quarter of a mile.

In the north the slaty cleavage planes have small corrugations on them which are parallel to their intersection with the fracture cleavage and these trend W.S.W., approximately parallel to the first fold axes in this region.

East of the Camel Estuary mesoscopic E.-W. folds of slaty cleavage are fairly widespread as far north as Port Isaac. Here, however, the axially planar strain-slip cleavage, which is usually developed, dips at 40°-50° to the S.S.W. Folds of the Stepper Point type, with near flat axial surfaces, were not seen in association with these and hence it could not be determined whether they represent separate events.

The megascopic undulations of slaty cleavage which can be recognised both sides of the Estuary (Gauss 1966) and which also have W.S.W. trending axes may belong to this episode or may represent broad original variations in the cleavage configuration.

3. Described more fully elsewhere (Gauss op. cit.) are late N.W. trending folds of slaty cleavage which are generally only very locally developed, though the steep S.W. dipping strain-slip cleavage parallel to their axial planes can be more widely recognised. These can be seen on the mesoscopic scale as far north as Port Isaac and are often reflected in spreads of slaty cleavage π pole plots about a N.W. axis.

Regional Structure : It is considered that the two broad geographic areas mentioned above with different patterns of F1. folds represent two different tectonic regimes. That west and south of Polzeath belongs to a southern one in which tectonic transport, as evidenced by direction of fold facing, was from south to north. The broad structure in the Padstow area here is a recumbent syncline of which the Middle Devonian Grey slates largely occupy the inverted southerly dipping limb and the Upper Devonian Purple and Green slates occupy the normal northerly dipping limb. The mean fold axial surface dips fairly gently to the south and the general direction of younging is to the north.

North and east of Polzeath the rocks belong largely to a regime in which the tectonic transport was from north to south giving southerly facing folds.

The interpretation is supported by the evidence further to the north and south of the present area. To the south the general direction of facing of the first folds in the Devonian rocks is to the north, whereas north of Boscastle the general direction of facing is to the south.

In the Padstow area there is evidence that the two regimes have been brought into juxtaposition by northerly directed, near horizontal tectonic movements. These could account for the gently dipping strain-slip cleavage developed in the Stepper Point region and the fact that the same stratigraphic units occur in the two tectonic blocks. The fundamental problem of how seemingly contemporaneous regional northerly and southerly directed movements could take place during orogenesis, however, remains to be solved.

Reference :

GAUSS, G. A., 1966. Some aspects of the slaty cleavage in the Padstow area of North Cornwall. **Proc. Ussher Soc.,** Vol. 1, p,221-224.

144. The Sandrock and other features of the cliffs at Mother Ivey's Bay near Padstow : by B. B. Clarke.

The profile of the dolerite promontory ending in Merope rocks has erosion surfaces at 180', 120' and 100', almost the levels of the cliff notches at Pentire Head and possibly related to former sea levels, the steeper slopes being degraded cliffs.

The Devonian slates of the lunate bay make cliffs 50' high with smooth seaward sloping tops, possibly also fragments of a wave cut surface. This, frost shattered in places, is covered with thin superficial deposits - slatey head up to 6", worn smooth, followed unconformably by 12-18" of brown solifluxion clay with angular slate and quartz lumps, and finally, soft sand with comminuted sea shells and a dune sand fauna -*Cochlicella acuta, Helicella caparata* and *H. virgata.*

The cliffs are notched with a narrow platform about 40' O.D. The absence of the 25' surface is striking. On the 40' bench is a layer of coarse head followed by soft sand with lenses of harder clayey sand. Bedding is absent, but angular slate fragments occur in rough layers. The above dune shells occur with *Oxychilus aliarus* as well. A fragmentary second platform occurs about 5' above H.W.M. (15' O.D.).

At Little Cove, against the base of the cliff, and on the 15' platform, is a narrow bank of sandrock 15' thick, the top being 6' above H.W.M.S.T. ; and on the foreshore a large sandrock reef 120' long and at least 4' thick. This is almost covered by beach sand in summer, but exposed in winter when the level of the beach is lowered by 3'. The sandrock here has the following features - 1. It is largely comminuted shells. 2. It has clear stratification dipping 4-8° seaward (N.E.). 3. Some layers are cross bedded. 4. Bedding is not upswept at the cliff face as in dune sand. 5. Even bedding in the reef is extensive with flute marks but not ripple marks. 6. Slate fragments are water worn except near the cliff face, and coarse material has ovoid slate pellets. 7. Occasional large lumps of slate cross the bedding near the cliff face. 8. Dreikanter and polished grains are absent. 9. Pockets of coarse material have a bedding plane for one edge and the other a wavy line crossing the bedding, suggesting erosion by eddies flowing in mega-ripples. 10. Weathering reveals a vertical pillar structure reminiscent of stalactites.

11. Marine shells include *Chlarrtys varia, Notorus irus, Mytilus edulis, Gibbula umbilicus* and *Patella* sp. 12. The sandrock is faulted, one fault also affects the cliff face.

Marine shells, rolled slate pebbles, evenly laid extensive beds and erosion by eddies indicate marine deposition. This sandrock is different from the Trebetherick dune-sandrock, and appears to be a fragment of an old beach extending from 4' below the present strand to 10' above. The calcareous cement may derive from aragonite in the comminuted shells or thin limestones in the cliff. The material resembles beachrock and reef-sandstone forming at sea level in several parts of the world.

Removal of soft sand by winter tides exposed a nip in the cliff below the present strand with a roof carrying drips every few inches suggesting the origin of the pillar structure. Ovoid pebbles of sandrock on the seaward side of the reef demonstrate present-day erosion of the reef.

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KAYE, C. A., 1959. Shoreline features and Quaternary shoreline changes, Puerto Rico. **United States Geol. Surv. Prof. Paper 317 B,** p.49-140.

145. Undescribed sand bodies of weak tidal current areas in the Celtic Sea : by N. H. Kenyon.

The patchy sediments of Nymphe Bank, the westernmost zone of that part of the Celtic Sea described by Belderson and Stride (1966), have been re-examined by means of additional Asdic and echo-sounder traverses. The presumed sand bodies to be described occur at about 40 fathoms, in water subject to the weakest tidal currents of the Celtic Sea, with near surface maximum speeds of less than 0.75 knots.

The patches are often crescentic in plan view with a smooth convex border and a ragged concave border. Many of those examined are less than 1,000 metres long and are about 250 metres wide. Their long dimension is consistently almost north-south (i.e. approximately at right angles to the maximum tidal current direction) with the concave side mostly facing towards the east. All the bodies are flat topped in vertical profile and have a height above the surrounding floor of approximately four feet to six feet, their sloping borders appearing sharply defined on the Asdic records.

The origin of the new feature was discussed and it was suggested that they could be remanie features, possibly ancient beaches, formed at a time when sea level was lower. Or, because they do not have the known form of nearshore deposits, that they could be a new sediment transport feature characteristic of weak currents.

Reference :

BELDERSON, R. H, and STRIDE, A. H., 1966. Tidal current fashioning of a basal bed. **Marine Geol.,** Vol. 14, p.237-257.

147. The fabric of head deposits in South Devon: by R. P. Kirby.

Fabric analysis has been litle used to describe or identify head deposits. This paper examines the nature of head fabrics and the scope of fabric analysis in local Pleistocene stratigraphy.

Head has been examined in excellent cliff sections in Wembury Bay, S. Devon, about 1 km. east of Wembury Point. The formation of the features along this coast has been described by Orme (1960). There is a marine-cut bench at 10-15 ft. O.D. with occasional raised beach deposits. This is covered by up to 30 feet of head, the constituent material being predominantly the underlying Dartmouth Slates, but also including other local grits and limestones. As a deposit, the head is massive and remarkably uniform ; there are discontinuous sand horizons and local concentrations of large pieces of bedrock, but these differences in texture can be explained by minor variations of the periglacial processes during the formation of the head. Some cryoturbation occurs near the top of the head in one locality.

Fabrics were taken from the head at two sites, each from a zone about 4-5 feet above the base of the deposit. The method of working was similar to that commonly used for till. The large proportion of coarse material and paucity of matrix means that there is more mutual interference among the larger particles than is normally shown by tills. Dominant elongated particles were selected, and the orientation and dip of the a-axis of 100 particles were recorded at each site. The results (fig. 1) show that the preferred orientation is parallel to the bedrock and ground surface slopes ; also there are a few particles with a transverse attitude. In H1, the majority of particles dip upslope ; in H2, there is no preferred dip direction.

These orientation and dip characteristics of head fabrics are not different from those produced in till fabrics from unweathered ground moraine. However, using standardized methods of particle

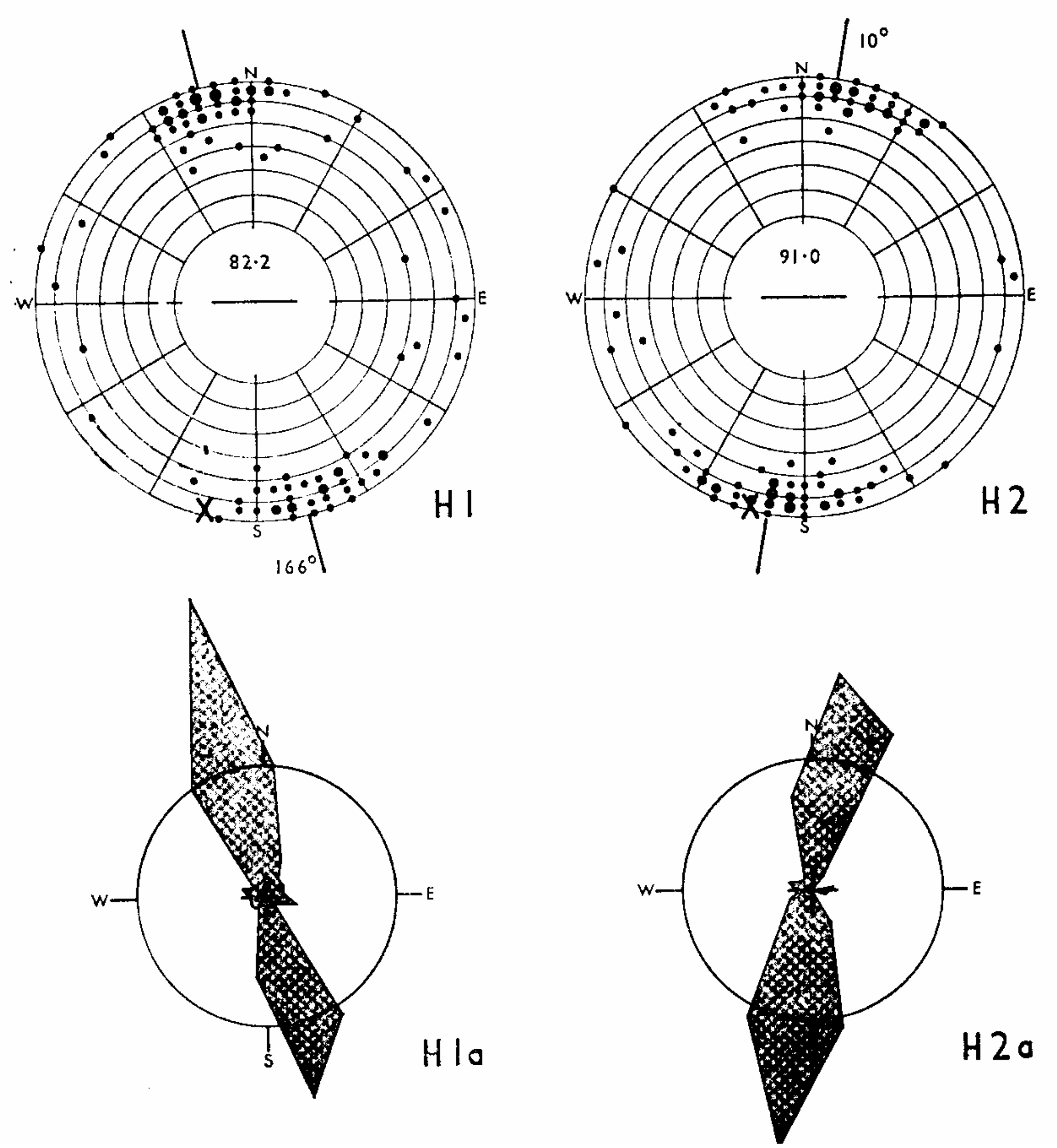

FIGURE 1. Fabric diagrams from head at Wembury. Point-diagram and rose compass versions are given. On the point-diagrams, the large cross indicates the amount and direction of surface slope at the site ; and the number at the centre represents the strength of orientation.

selection and measurement, it is thought that head may normally be distinguished from till on the basis of strength of orientation. A chi-square test has been carried out on all fabrics. This test indicates if there is a significant departure from a random azimuth distribution at a chosen level of significance. The numerical value of chi-square as derived is taken as representative of strength and orientation. Orientation strengths from the head deposits at Wembury and from other Scottish periglacial deposits is investi gated and are all found to be of the order of twice the strengths of typical till fabrics.

Apart from strength of fabric orientation, head and till may be distinguished on the basis of direction of orientation, except in the case where the direction of former ice-movement and the surface slope of the ground correspond. Site is the most important qualifying factor. Hill-top sites are unsuited to the development of a preferred orientation in head (Ragg and Bibby 1966) but should preserve original regional fabrics in till, whereas sloping sites are unsuited to the preservation of regional till fabrics. On low ground at the base of slopes, such as described from Fremington, N. Devon (Stephens 1966), genuine regional till and slope head orientations may be preserved together.

Although fabric analysis is helpful in distinguishing head from till, the technique is unlikely to be of value in separating two heads. The same orientation would be expected, as both are derived upslope of the point of rest. Also some variation in chi-square strength can be explained by slight variation in the depositional processes.

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148. The New Red Sandstone outlier of Hollacombe, West Devon (Abstract) : by M. Williams.

A much-faulted outlier of New Red Sandstone trends W.S.W.-E.N.E. between Headon Cross (SS 36660229), 14 miles E. 35° S. of Holsworthy church, and Dunsland Cross (SS 40520388), 34 miles east of that town (Williams 1966). It lies five miles west of the previously mapped outlier at Highampton (Ussher 1880 ; map 1906) and 13 miles south of that at Portledge Mouth (de la Beche 1839). Fig. 1 summarises the geology of the district.

The outcrop is structurally similar to the E.-W. Permian trough which lies east of Hatherleigh which will be described in the forth-coming Okehampton Memoir. Steeply dipping normal faults on both the north and south margins preserve the sediments in a trough-fault system. A major N.W.-trending dextral wrench-fault plexus which truncates the outcrop to the west also displaces the outcrop of the Bude Formation by 550 yards and a lamprophyre dyke at Langdon by up to one mile. To the east the outlier is terminated by a N.N.E.-trending fault which presumably downthrows west. (Information relating to the area east of National Grid line 40E was provided by Mr. E. A. Edmonds.) A succession of N.W. and N.N.W.-trending faults west of (SS 385030) upthrows the trough westwards and consequently narrows its crop.

The northern boundary fault is exposed at (SS 37250259) in a stream section where evenly-bedded inverted sandstones of the Crackington Formation, dipping steeply northwards, abut against fine gravelly conglomerates dipping S.S.E. ; a southern boundary fault is inferred from the structure and disposition of beds at (SS 37220238). Section A-B of Fig. 2 illustrates the stream profile and the general structure. Section C-D shows a more complete section through the sediments exposed in a deeply-cut stream 1.100 yards east of Hollacombe church. From 200 to 265 yards S.E. of the railway the New Red Sandstone-Crackington Formation unconformity is exposed.

The sediments are mainly wedge-bedded brownish red breccio-conglomerates. Intercalated red silty and pebbly sandstones, from six inches to six feet thick, show minor cross-bedding structures

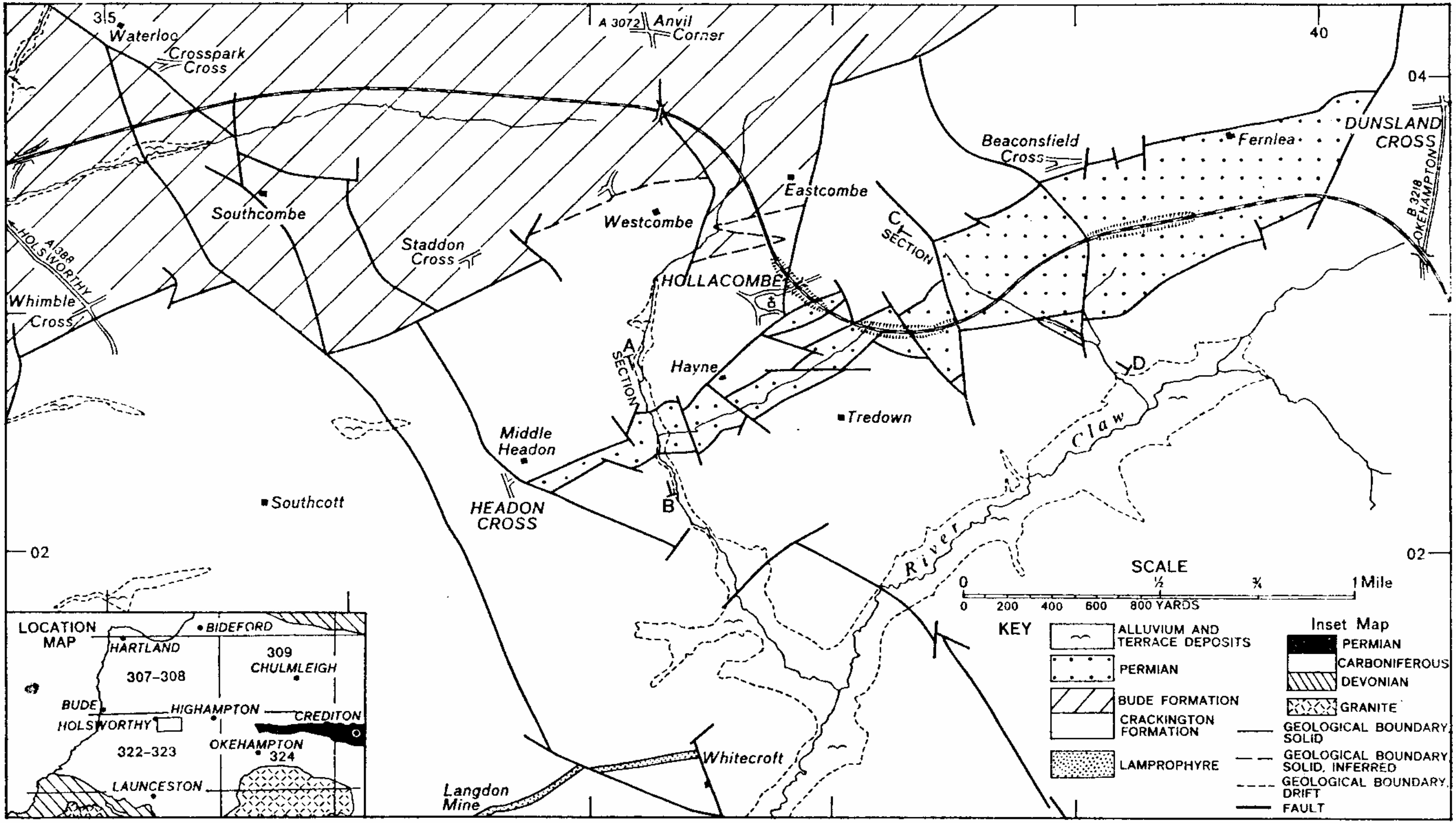

FIGURE 1. Geological sketch-map of the New Red Sandstone outlier of Hollacombe, West Devon.

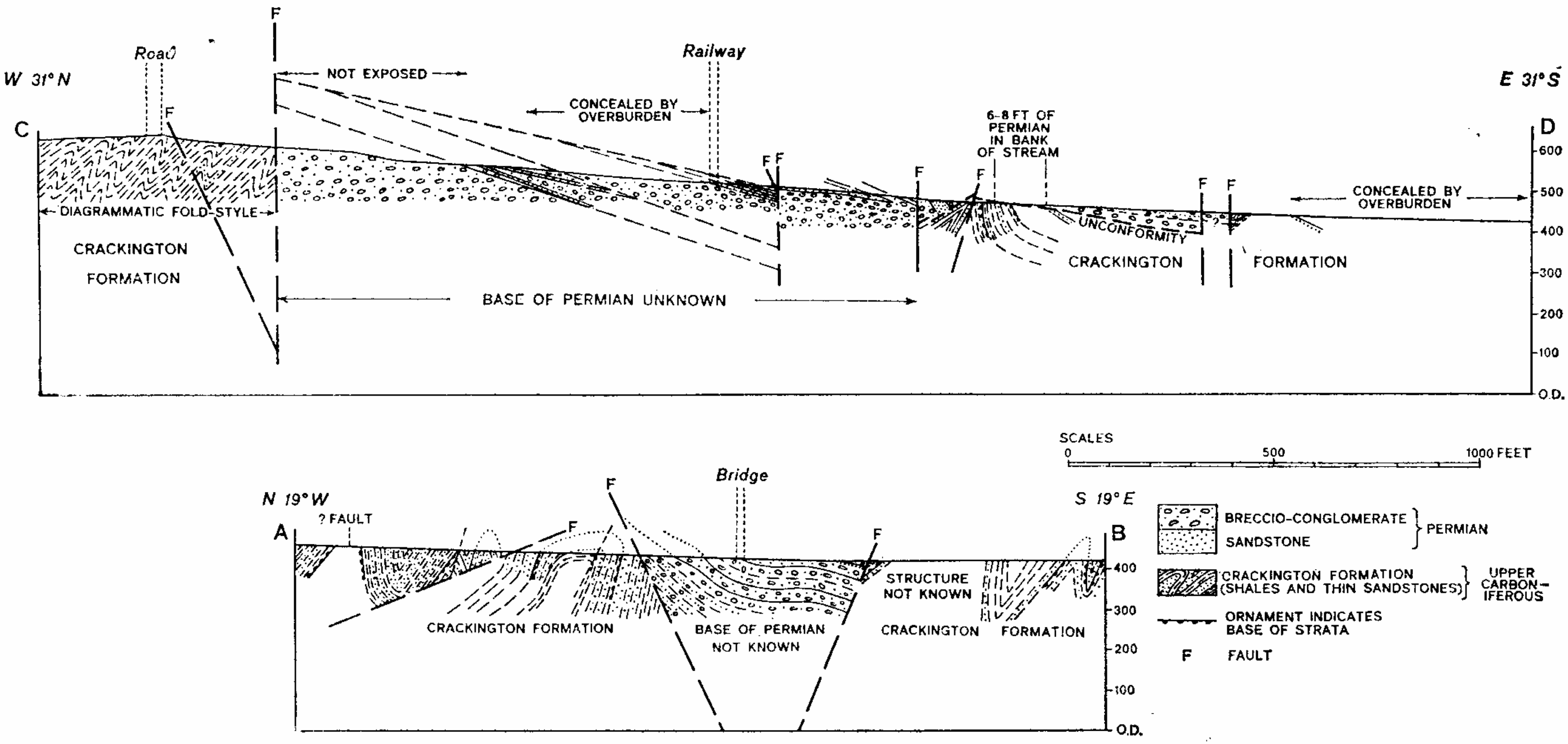

FIGURE 2. Sections across the Hollacombe outlier (lines A-B, C-D of Fig. 1).

and commonly carry clay pellets. In general the breccio-conglomerates consist of well-rounded pebbles and pockets of angular rubble set in matrices of sand and silt ; the fragments include locallyderived lilac to red-stained, olive-green and grey 'Culm' sandstones, dark siderite-cemented siltstones, and lamprophyre, together with well-rounded purple and grey pebbly quartzites and a few pieces of deeply-stained, weathered, porphyritic (?volcanic) rock. Apart from the sparsity of volcanic fragments, the breccio-conglomerates of this district strongly resemble the Bow Conglomerates farther east (Bow Beds of Hutchins 1958, 1963).

A brief examination of a few thin sections of the breccio-conglomerates and sandstones has revealed a well-developed carbonate cement, in some cases akin to sphaerosiderite. This also suggests a direct comparison with rocks near the northern margin of the Crediton trough ; Hutchins (1958) described calcareous sandstones and cements in specimens from the River Okement section and suggested that they formed a horizon low in his 'Bow Beds'.

Before further comparison can be made with Hutchins's results a detailed investigation of the 'pebble' and heavy mineral content from this new outcrop is necessary. As yet, additional information towards his interpretation of provenance is restricted to the probability that the lamprophyre fragments were derived from the south or south-east and that the possible volcanic pebbles came from well to the east.

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149. Possible Permian sediments in South West Devon : by C. J. R. Braithwaite.

The distribution of extensive Permian current-bedded sandstones and conglomerates, resting unconformably upon the Devonian and Carboniferous in East Devon, is well known (Lloyd 1933). Considerable areas of supposed Permian rocks are exposed on the sea floor south of Plymouth and Looe (Curry *et al.,* 1965), but recognizable Permian sediments are absent over the greater part of Dartmoor, the South Hams, and Cornwall, the exception being the small beach exposure at Cawsand Bay (Ussher 1907). The latter occurrence owes its preservation to faulting, and it is of some interest to know whether the Permian was formerly present over a wider area in South Devon.

The sediments examined are of importance both for the light they may shed upon this problem and for the interest which centres on their somewhat peculiar lithological characters. All localities examined lie within a few miles of Plymouth.

Known occurrences are 1. An area on the eastern face of the Breakwater Quarry (SX 50485365). 2. Approximately, 150 metres south-east of Devil's Point (SX 46075311). 3. Haye Quarry (SX 52904430 and SX 52665422) and Moorecroft Quarry, minor occurrences (approximating to SX 52465404).

In these localities a coarse conglomerate can be seen containing angular disoriented fragments of compact grey limestone, some of which reach 60 cms. maximum diameter, set in a red, somewhat shaly, matrix. The margins of these deposits, where visible, show discordant contact with adjacent Devonian limestones. Some blocks contain stromatoporoids, but in sections the limestones consist of a consertal crystalline mosaic and are clearly metamorphosed.

The red sediment is laminated, and laminae may be contorted or more or less planar : the Breakwater Quarry example contains well defined slumped beds. In sections this sediment can be seen to consist in most cases of a granular carbonate, together with granules of iron oxides. That in the Breakwater Quarry deposit comprises a dense hypidiomorphic mass of crystals which may be dolomite. In the Haye examples crystals are much more irregular and spongy in texture and a few authigenic quartzes can be recognised among them. There is little doubt that these deposits are considerably later than the containing Devonian limestones.

The presence of " veins of fine red sandstone " in the Plymouth area (Ussher 1907) and at Shoalstone Beach, Brixham (Lloyd 1933) is well known. Sections of these rocks from Plymouth show them to be composed chiefly of granular ?dolomite crystals in a ferruginous matrix, thus resembling some of the sediments here described. It has been suggested by a number of authors that these bodies are Permian in age.

It is concluded that the sediments described could have been deposited in more or less open solution cavities in the Devonian limestones, close to the sub-Permian land surface. The Breakwater Quarry and Devil's Point examples may have formed as a result of penecontemporaneous dolomitization of limeclast sediment. Some dolomite was deposited in spaces resulting from secondary solution, but an origin by direct precipitation of dolomite is thought unlikely.

Transport of the larger blocks with the normal laminated sediments is precluded on general hydrodynamic grounds. These are thought to have fallen into the cavities from walls or entrances, and convolute laminae to have resulted from disturbances within the normally placid environment brought about by impact.

Assuming these deposits to be Permian, the presence of essentially normal Permian material in Cawsand Bay would suggest that they are in fact remnants of a formerly more extensive Permian cover.

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1962 - 1967

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Part four, pp.131-202, November 1965.

Part five, pp.202-260, September 1966.

Part six and Index, pp.261-301, September 1967.

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To promote research into the geology and geomorphology of South West England and the surrounding marine areas ; to hold Annual Conferences at various places in South West England where those engaged in this research can meet both formally to hear original contributions and progress reports and informally to effect personal contacts ; to publish proceedings of such Conferences or any other work which the officers of the Society may deem suitable.

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