Royal Geological Society of Cornwall

ABSTRACTS
OF THE PROCEEDINGS
OF THE FOURTH CONFERENCE
OF
GEOLOGISTS AND GEOMORPHOLOGISTS
WORKING IN
THE SOUTH-WEST OF ENGLAND

CAMBORNE, 1961

Hon. Editor :

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assisted by
C. S. Exley and M. R. House

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ABSTRACTS OF THE PROCEEDINGS OF THE FOURTH CONFERENCE OF GEOLOGISTS WORKING IN THE SOUTH-WEST OF ENGLAND. CAMBORNE, 1961

The fourth Conference was held at the Camborne School of Mines in January, 1961, and was a combined meeting with the Royal Geological Society of Cornwall. The Conference is indebted to both for aid in organisation. The programme included two days of lectures and was followed by three excursions. Excursion A, to see the Gramscatho and Mylor Beds and structures at Polurrian Cove, Gunwalloe Church Cove and Towans, was led by Dr. E. M. Lind Hendriks and Mr. J. L. M. Lambert. Excursion B, to see the contact metamorphism and intrusions in the St. Michael's Mount to Tremearne region was led by Dr. K. F. G. Hosking and Mr. M. Stone. Excursion C, to study the geomorphology of the country between Hayle, St. Agnes and Helston, was led by Mr. C. E. Everard.

The Conference lectures which were given are listed below and numbered, and the abstracts which have been received have been printed in the same numerical order.

Once again the Conference is indebted to the Royal Geological Society of Cornwall for publishing these abstracts and the Conference is also appreciative of the help given by the Honorary Editor, Mr. J. Robson.

PROGRAMME OF FOURTH CONFERENCE

6th January

Morning session.

1. Professor L. U. de Sitter (University of Leiden). Guest speaker :"Structure, regional metamorphism and pluton intrusion in the Pyrenees."
2. Dr. C. S. Exley and Mr. M. Stone: "The origin and relations of the granites of South-Western England " (Discussion).
3. Dr. A. T. J. Dollar : "Some structures in the granites of Scilly"

Afternoon session.

4. Dr. F. C. Phillips :"Structural petrology of the schists of the Start Point area."
5. Dr. K. F. G. Hosking : "The significance of framboidal pyrite in Cornish and other deposits." 6. Mr. P. Floyd :"The geology of Land's End aureole of Tater-du."
7. Mr. J. C. Harvey :"Radioactivity measurements on the Dartmoor granite."
8. Mr. P. G. Wood: "A Radiation counter for geological survey work."
9. Mr. R. I. Howarth and Mr. P. M. Tunbridge : "Radiometric investigations in the St. Just area."

7th January

Morning session.

10. Mr. F. J. W. Holwill :"The Limestones of the Ilfracombe Beds."
11. Mr. S. C. Mathews :"A Carboniferous conodont fauna from Callington, East Cornwall."
12. Dr. M. R. House: " Goniatite zonation of the Frasnian."
13. Dr. M. N. Hill :"Structural trends of the Western approaches of the English Channel."
14. Mr. A. Stride : "Quarternary sedimentation around South-West England."
15. Dr. D. T. Donovan :" Sub-marine geology of the Bristol Channel."
16. Dr. W. Dearman : "Small scale tectonic structures"

Afternoon session.

17. Professor S. Simpson :" The structure of Devon and Cornwall."
18. Dr. A. T. J. Dollar: "Ancient erosion surfaces in Scilly."
19. Dr. N. Stephens : "Re-examination of some Pleistocene sections in Devon and Cornwall."
20. Mr. M. R. Weller :"The palaeography of the 430-foot shoreline stage in East Cornwall."
21. Mr. D. Shearman :"Cliff morphology of the Bristol Channel coast of North Devon."

2a. Relationships and Origins of the South-Western Granites: by C. S. Exley.

The porphyritic biotite-granites of Carnmenellis, St. Austell, Bodmin Moor and Dartmoor have certain shared features (e.g. included quartz, biotite and plagioclase in large perthite crystals : perthite crystals crossing aplite/granite junctions ; xenoliths in all stages of digestion ; andalusite- and biotite-rich clots) that suggest metasomatism and assimilation.

Additionally, the biotite-granites of St. Austell and Bodmin Moor have varying K-feldspar/plagioclase ratios. A preliminary statistical survey (based on Whitten, 1957) of the latter south of the A30 road suggests that low ground near the rivers Fowey and Warleggan correlates with both low K-feldspar/plagioclase ratios and kaolinization. Kaolinization affects plagioclase mainly (Exley 1959) and as the kaolinized districts of St. Austell and Dartmoor, as well as of Bodmin Moor, have relatively high plagioclase contents, the susceptibility of these granites to localized kaolinization appears to be a function of their original composition.

Joint patterns and mineralization in the St. Austell and Bodmin Moor granites correspond closely.

The three eastern intrusions form a sequence in which (E-W) mafic and accessory minerals (and Fe and Mg) diminish and perthite gives, way to sodic plagioclase (and K_2O/Na_2O decreases).

Each intrusion also has its own sequence. Dartmoor granites pass from original magma to "older" (K-rich) granite by assimilation and to "newer" (Na-rich) granites by differentiation (Brammall 1932). Bodmin Moor granites pass from Na-rich "normal "to K-rich "Godaver" and "fine" granites (Ghosh 1927). Here the later members seem (from the preliminary study mentioned above) to have become K-rich through contamination or metasomatism. St. Austell granites apparently follow a straightforward differentiation trend from K-rich contaminated "biotite" granite, through " lithionite " granites to Na-rich "fluorite." granites (Exley 1959). In each mass, the anorthite content of the plagioclase decreases with time.

These and geophysical data (Bott *et al.,* 1958, 1960) enable a model of the whole "batholith" to be devised. This has an inverted L-shaped' .cross-section with a vertical southern limb and an irregular upper

surface. Bott, Day and Masson-Smith agree with Brammall that the Dartmoor granites rose vertically in the south and flowed nearly horizontally north, stoping and assimilating their way forward; the compositions of certain St. Austell and Bodmin Moor granites also suggest this mechanism. Therefore the model has an envelope of cooler, contaminated magma (cf. Dartmoor "older" granite) and a core of hotter, more sodic and volatile-rich magma (due largely to differentiation) which may break out at the "hinge" of the "L", as at St. Austell.

Slight changes of temperature and concentration in the systems Or-Ab-An (Barth 1952) and $NaAlSi_3O_8$ (Bowen and Tuttle 1950) are important because they may produce a succession of K-rich or Na-rich solutions capable of metasomatizing earlier granite fractions.

References :

BARTH, T. F. W., 1952. Theoretical Petrology. Wiley, p.99-101.

BOTT, M. H. P., A. A. DAY and D. MASSON-SMITH, 1958. The geological interpretation of gravity and magnetic surveys in Devon and Cornwall. **Phil. Trans. Roy. Soc. London,** Ser. A, Vol. 251, p.161-191.

BOTT, M. H. P., 1960. Granites, crustal structure and isostacy. **Proc. Geol. Soc. London,** No. 1576, p.33.

BOWEN, N. L. and O. F. TUTTLE. 1950, The system $NaAlSi_3O_8$ - $KAlsi_{3O8}$. **Jour. Geology,** Vol. 58, p.489-511.

BRAMMALL, A., and H. F. HARWOOD, 1932. The Dartmoor granites ; their genetic relationships. **Quart. Jour. Geol. Soc. London,** Vol. 88, p.171-237.

EXLEY, C. S., 1959. Magmatic differentiation and alteration in the St. Austell granite. **Ibid.,** Vol. 114, p.197-230.

GHOSH, P. K., 1927. The petrology of the Bodmin Moor granite (eastern part), Cornwall. **Min. Mag.,** Vol. 21, p.285-309.

WHITTEN, E. H. T., 1957. The Gola granite (Co. Donegal) and its regional setting. **Proc. Roy. Irish** Acad., Vol. 58, Sect. B., No. 12, p.245-292.

2b. Genesis of the Granites of South-West England : by Maurice Stone.

Field evidence suggests (but does not prove) that the posttectonic granites of S.W. England were emplaced as magmatic rocks. A magmatic origin is indicated by (1) sharp contacts with country rocks ; (2) dilatational phenomena associated with some aplites (Tremearne) ; (3)

disorientated zenoliths ; (4) flowage folds outlined by biotites in some aplites (Carnmenellis) ; (5) deformation of marginal country rock.

However, evidence has been presented to show that many of these rocks have undergone potash metasomatism and recrystallisation subsequent to their crystallisation as aplitic or aplogranitic rocks. (Evidence to be published elsewhere indicates that metasomatism and recrystallisation followed closely upon magmatic crystallisation) (Stone, 1960 ; Stone and Austin, 1961). Plots of molecular quotients of K_2O against Na_2O for the TregonningGodolphin granite (Stone 1960) and for the Dartmoor and Carnmenellis granites show inverse relations between these components ; lines of best fit have good correlation coefficients, but slopes (K_2O/Na_2O) which are lower than that expected for the ideal replacement of albite by potash feldspar or for the slope calculated from Battey's data on potash metasomatism in keratophyres (Battey, 1956). It is suggested that the lowering of slope is due, in part, to the assimilation of pelitic material. This would produce an enrichment in K_2O relative to Na_2O, but a lowering of total alkalis compared with the uncontaminated rocks.

Brammall and Harwood (1932) have provided evidence which suggests that the early magma was rich in Na_2O. The late terms at St. Austell and Tremearne are soda-rich also. This indicates that with respect to the common alkalis, there may have been little change in the composition of the liquid magma with time. Rocks which are believed to represent most closely the composition of the initial magma (less volatiles), lie to the sodic (albitic) side of the 1000 bar PH_2O ternary minimum of the experimental granite system. (Tuttle and Bowen, 1958).

If it is assumed that all the granitic rocks are the products of a magma, which corresponds in composition with a ternary minimum in the field of felsites and aplogranites, it is possible to account for the observed trend of soda enrichment with time as a trend of decreasing contamination and potash metasomatism.

References :

BATTEY, M. H., 1955. Alkali metasomatism and the petrology of some keratophyres. **Geol. Mag.,** vol. 92, 104.

BRAMMALL, *A.*, and H. F. HARWOOD, 1932. The Dartmoor granites ; their genetic relationships **Quart. Jour. Geol. Soc. London,** vol. 88, p.171.

STONE, M., 1960. The Tregonning-Godolphin granite. **Abstr. Proc. 3rd Conf. Geol. Geomorph. S.W. England, Roy. Geol. Soc. Cornwall,** p.13.

STONE, M., and W. G. C. AUSTIN, 1961. The metasomatic origin of the potash feldspar magacrysts in the granites of South-West England. **Journ. Geology** (in press).

TUTTLE, O. F., and N. L. BOWEN, 1958. Origin of granite in the light of experimental studies. **Geol. Soc. Amer.,** Mem. 74.

4. Structural petrology of the schists of the Start Point area : by F. C. Phillips.

Lineation is prominent throughout the succession in the Start Point area, in the Start mica-schists of the core of the anticlinorium, in the Bolt mica-schists, and in the intervening horizon of green schists. On an outcrop and in hand-specimen it arises largely from puckering of the micaceous or chloritic layers together with rodding of quartzose bands ; the rather regular lineated appearance of many outcrops when viewed from the south is in remarkable contrast with the intense gnarling and contortion when a convenient joint face is viewed from east or west. The lineation is subhorizontal in many places or plunges westerly at low to moderate angles. Stereographic plotting of measured lineations on a π-diagram shows a concentration of poles of lineations coinciding with the axis of an anticlinal structure plunging slightly south of west.

The microscope reveals that the lineation is expressed also in the elongation of individual grains, particularly mica. Diagrams of preferred orientation of quartz and mica show that the lineation coincides precisely with the axis of well-marked girdles. Both in quartz and muscovite these girdles are often completely and sharply defined, with angular widths in mica of only 30°- 40°. It is not possible to measure individual flakes in the felted purely micaceous layers, but uniformity of interference colour reveals that there is a high degree of preferred orientation not only in respect of parallelism of basal pinacoids with lineation but also in respect of alignment of a particular direction within the plane of the girdle.

Two sets of joints are well developed. *ac*-joints, at right angles to the lineation statistically, may be seen at spacings from a few inches upwards, and they are often infilled with quartz or albite and quartz. As a major joint system they, together with the lineation, often have a pronounced effect on the topography. At Seacombe Sands cave formation is proceeding along these joints and their deviation from the vertical in conformity with the westerly plunge of the lineation is well seen. A second system of joints consists of conjugate

sets of sub-vertical joints striking on an average N. 50° E. and N. 50° W. ; they are apparently shear-joints and weather out readily on the shore platforms. They are a prominent feature of aerial photographs of the coast.

The 'Start' Boundary appears to be undoubtedly a vertical fault. For some distance south of its outcrop the schists have suffered extensive post-crystalline deformation and are reduced to glossy phyllonites. To the north many of the structural features of the schists appear to be developed on a less intense scale in the Devonian rocks, and it is suggested that the rocks south of the fault are more likely to be Palaeozoic than Pre-Cambrian.

6. Geology of the Land's End aureole at Tater-du : by P. Floyd.

Tater-due is an erosion relic of the Land's End aureole situated some five miles S.S.W. of Penzance.

1. **Granite contacts.** The eastern extremity of Tater-du is faulted, while at the western end the roof of the granite is exposed. At the contacts a number of different associated phases have developed as follows :-(a) main porphyritic biotite granite, (b) finer granite contact phase, with occasional pegmatitic developments of orthoclase, (c) granitic vein phase, (d) aplitic phase, (e) quartz vein phase. All these phases are tourmalinized.

2. **Aureole rocks.** These belong to the hornblende-hornfels facies of contact metamorphism and are dominantly composed of meta-igneous rocks, although two thin meta-sedimentary horizons also occur.

(a) **Meta-igneous rocks.** Two main groups are recognised :

(i) Amphibolites, composed largely of hornblende and derived from ophitic doleritic intrusives by contact metamorphism;
(ii) Modified amphibolites, derived from the true amphibolites by Ca or K metasomatism.

These two main groups fall into six categories, the mineral assemblages of which depend on the intensity of the metasomatic processes. These categories (the rocks in most of which may or may not contain plagioclase) include amphibolites (with either hornblende or cummingtonite), biotitites, banded biotite-amphibolites (with biotite and either hornblende or cummingtonite), banded biotite-amphibolites, with calciferous zones (the most common category), calciferous amphibolites, and rocks composed of calcsilicates alone.

The contact metamorphism and metasomatic processes are indicated by a number of reactions, viz. :-replacement of hornblende by cummingtonite (local expulsion of Ca) ; progressive replacement of hornblende by diopside and grossularite (internal Ca metasomatism) ; replacement of hornblende by biotite (allochemical K metasomatism) ; replacement of ilmenite by granular sphene ; recrystallization of oligoclase to granular andesine ; retrogressive development of chlorite.

(b) **Meta-sedimentary rocks.** Two new pelitic horizons have been found interbedded with the amphibolites. At the base of the amphibolite a fine-grained adinole is developed. The pelites, which are spotted and laminated, are dominantly quartz-chlorite-sericite hornfelses and biotite-cordierite hornfelses. Cordierite and biotite have been produced by reaction between chlorite and Fe ore during contact metamorphism.

3. **Texture.** All the aureole rocks exhibit a well sheared and foliated texture, as is illustrated by their distinctly bedded nature. In the amphibolites, extensive shearing has given rise to numerous shear planes which were used as penetrative channels by Ca- and K-bearing metasomatic solutions.

7. **Radioactivity measurements on the Dartmoor Granite :** by J. C. Harvey.

In order to determine whether there are any well defined trends in radioactivity peculiar to certain areas or types of granite, 300 samples of granite from the southern two-thirds part of the Dartmoor granite have been measured for gamma activity.

The gamma activity comes from the isotope ^{40}K and accessory minerals that contain uranium and thorium. The method is to crush small chips from about 25 pieces of granite from a particular station and retain 125 gms. as the representative sample. This is put in a scintillation counter and the activity is integrated for one hour, then averaged and recorded as counts per minute. Readings on samples are alternated with measurements on the empty container to provide a check on the background activity. An index of the activity is obtained by subtracting the background activity from that of the sample.

When the activities of the 300 samples of both coarse and fine granite types are plotted on a frequency basis the distribution is seen to

approximate to a normal error curve. The felsites as a group show an average activity about 25% less than that of the coarse granites. The reason for this is not yet clear > it may be due to a different potash content, either of primary origin, or due to kaolinization.

To investigate the effect of kaolinization on activity 75 samples of one type of granite were taken from a small quarry, in three distinct stages of kaolinization. Fresh granite showed a definite trend towards higher gamma activity than that of the most kaolinized group. This test gave a useful indication of the spread of activities over one granite type from one place, as a means of assessing significant variations of activity for samples from the different stations over the whole area.

The activity of an equal amount of potash alum (10% potash) was found to give a 50% increase over the background. This is about half of the increase due to a sample of granite and shows that the potash content of the samples must be considered when assessing gamma activities.

When the activities of all granite types are plotted on a map there is a definite area of low activity in the south-west, and another on the eastern margin.

The next phase of the work will be an assessment of alpha particle activity of the same samples, using scintillation techniques, followed by a correlation of the results with the gamma measurements.

8. A **Radiation Counter for geological survey work:** by**P. J.** Wood.

The principle of operation and the design details of a radiation counter intended for survey work for the Geology Department of the University of Bristol was described.

There are several specific requirements for a radiation counter for these duties. The counter should be small and of light weight, and should operate from batteries available in any part of the world and should not require servicing or adjustments over a long period. The radiation counter demonstrated used transistor circuits throughout. The unit is self-contained, and operates from four U2 cells. Allowance has been made for battery ageing, no compensating readjustments being necessary. A warning device shows when the battery needs replacing.

The heart of the counter is the Geiger-Muller (G.M.) tube. In response to a burst of radiation, an anode to cathode electrical dis-

charge produces an electrical pulse across the anode load, which operates a trigger circuit. The method of reducing the rate of the incoming pulses is by the use of a series of binary stages. Each binary stage gives one output pulse for every two pulses at its input. In this design the output is presented to the operator as an audible signal in a pair of headphones.

Electrically, the radiation counter consists of the G.M. tube itself, a stabilised D.C. converter, a trigger circuit, five binary stages, and an audio amplifier feeding headphones.

The D.C. converter supplies the high tension of about 400 volts required from the 6 volt battery source. It uses a blocking oscillator and a voltage quadrupler circuit, and the rectified output is stabilised by a control transistor used in conjunction with a corona stabiliser valve. The output voltage is adjustable by means of a potentiometer. A neon valve used in an RC oscillator circuit gives warning when the battery voltage falls below three volts by failing to flash.

The trigger circuit uses a single transistor and ferrite transformer as a monostable device.

Each of the five binary stages uses two resistance-coupled OC71 transistors. The operator can select the appropriate output by a switch, to reduce the count to a convenient rate.

The battery drain is 23mA at 6 volts. The high tension supply can produce any voltage between 350 and 490 volts for the G.M. tube, the voltage remaining constant within one percent throughout the working life of the batteries. The basic count can be reduced by any power of two up to thirty-two. The unit is at present awaiting field trials at the University of Bristol.

9. Radiometric investigations in the St. Just area : by R. J. Howarth and P. M. Tunbridge.

Since 1958, work has been carried out to locate uranium deposits and map radioactive anomalies in the St. Just area.

Initially, the work of localising veins was to be carried out by field analysis using chromatographic techniques. This proved useful as a method of rapid batch sample analysis, and led to the development of a simple field test for uranium (in the region of 50-1,000 p.p.m.), it did not, however, prove to be a practicable field survey method.

The radioactivity survey was carried out using a fully transistorised, portable counting rate meter using a halogen quenched Geiger-Muller tube. With this apparatus, a large-scale iso-rad map was prepared showing the surface radioactive anomalies in the Kenidjack Castle area.

The majority of the uranium mineralisation noted was of a secondary type. However, the dumps at Wheal Edward contained pyrite and arsenopyrite veinstones, with pitchblende as a late accessory. Secondary mineralisation was complex, the majority of the samples deriving from weathering of the dumped material *in situ.* Many samples defy positive identification even after extensive X-ray work. However, the secondary minerals, meta-torbernite, uranophone, phosphuranylite and uranopilite have been identified.

Further work on an anomalous uraninite occurrence in the area is being undertaken, together with an investigation of the radioactivity of the rock types encountered in the area, with a view to its application as a means of mapping their contacts by accurate radiometric methods.

10. The Limestones of the Ilfracombe Beds : by F. J. W. Holwill.

A re-examination of the Ilfracombe Beds which are exposed in the cliff sections between Combe Martin and Ilfracombe shows that they contain they contain only two bands of massive limestones ; these are constantly repeated both by folding and faulting. Between the two main limestones is a third limestone band, thinner, but with a very distinctive lithology. These three limestones are named as follows :

David's Stone Limestone.

Combe Martin Beach Limestone.

Jenny Start Limestone.

This table also shows their stratigraphical relationship. They are separated by a variable thickness of shale ("shillot") with some arenaceous bands and occasional very thin (up to two inches) detrital limestones.

Each of the main limestones contains a distinctive fauna ; that from the Jenny Start Limestone is considered to be of Givetian age, and that from the David's Stone Limestone is probably Lower Frasnian. The Combe Martin Beach Limestone contains a fauna unknown

elsewhere in England, but very similar to that found in the Givetian and Frasnian Limestones of Bohemia. The boundary between Middle and Upper Devonian is thought to lie between the Combe Martin Beach and Jenny Start Limestones. Correlation of the limestones has shown that the total thickness attributed to the limestone succession by J. W. Evans, should be reduced from 1,300 feet to about 320 feet.

11. A Carboniferous conodont fauna from Callington, East Cornwall : by S. C. Mathews.

A conodont fauna collected from Viverdon Down, one and a half miles south of Callington, shows that part of the chert succession in this area is to be referred to the Pericyclus Zone of the Lower Carboniferous. The conodonts occurs as moulds in a siliceous shale and latex casts have been used in the present study.

Forty-one " species ", belonging to eighteen " genera " have been identified. The forms with greatest time-significance are *Scaliognathus anchoralis, Hindeodella segaformis* and *Doliognathus lata,* the three indices proposed by Voges for the Anchoralis Zone (II*p*) in the Lower Carboniferous of the Sauerland. Gnathodids and pseudopolygnathodids are present in abundance and the whole fauna shows striking resemblance to those collected from the Erdbach horizon of Germany.

The Callington fauna includes, as a minor element, species of the genus *Palamatolepsis.* Although there is again close correspondence with Germany, there must be a difference in interpretation, for German workers hold that specimens found in the Carboniferous have been reworked. The Callington occurrence yields no other evidence to support such a suggestion, and the appearance of palamatolepids is not accepted as sufficient grounds for assuming derivation of Carboniferous sediments from rocks of Devonian age.

Agreement with American occurrences is less precise. A superficial difference between American and European faunas reflects two different attitudes to the definition of "species". Nevertheless, by comparison of associations of forms - in this case, comparison with the faunas from the Chappel Limestone of Texas and the Pierson Limestone of Missouri, each of which contains the distinctive *Scaliognathus anchoralis* - it seems that there may be a real difference between Lower Carboniferous and early Mississippian faunas.

12. Goniatite zonation of the Frasnian : by M. R. House.

Matern, in 1929, established the current usage of dividing the Frasnian (Upper Devonian) into three goniatite zones. The lowest zone, of *Pharciceras lunulicosta,* is characterised by the genera *Pharciceras, Synpharciceras, Koenenites, Timanites* and early *Ponticeras.* The middle zone of *Manticoceras cordatum,* a combination of two of Wedekind's Frasnian Zones of 1913, has *Manticoceras, Neomanticoceras, Beloceras, Mesobeloceras, Eobeloceras, Ponticeras* and early *Archoceras* and *Crickites.* The upper zone of *Crickites holzapfeli* contains most genera of the Cordatum Zone, but with distinctive species of *Manticoceras, Crickites, Archoceras,* and *Aulatornoceras.* The entry of *Cheiloceras* above marks the base of the Famennian.

All three of these zones can be recognised in England (House 1958) and in North Cornwall it will be possible to give considerable refinement to the detailed succession of the Cordatum Zone. Recently opportunity has allowed the author to study and collect from the Frasnian of New York State and from the type area around Frasnes in southern Belgium.

In New York State *Pharciceras* occurs in the Tully Limestone (for stratal terms see Cooper 1942 where the Tully is probably wrongly included in the Middle Devonian) and in the overlying Geneseo Shale and Sherburn Sandstone there are evolute *Ponticeras* similar to those of the Lunulicosta Zone of Germany. The Cordatum Zone succession begins with the Genundewa Limestone and continues up to the Angola Shale. Several successive faunas occur and of particular interest are the discoidal species of *Manticoceras* in the upper part. The Hanover Shale above has constricted species of *Manticoceras* and a similar fauna in Ohio has *Archoceras wabashense, a* species close to A. *angulatum* from the Holzapfeli Zone of Saltern Cove, Devon, where constricted *Manticoceras* is also common. During the work *Cheiloceras* was found in the Gowanda Shale, marking the basal Famennian. A comparison of the American and European ammonoid successions has been prepared (House 1961).

In Belgium no goniatites are known from the Assisse de Fromallennes which is taken as the basal Frasnian (for terms see Fourmarier 1954), nor are goniatites known from the type Givetian: there is thus uncertainty as to whether the Frasnian/Givetian stage boundary precisely corresponds to the Terebratum/Lunulicosta zonal boundary. The first goniatites, *Ponticeras* and *Tornoceras*

occur in F1b. The whole of the Assisse de Frasnes and the lower part of the Schists de Matagne belong to the Cordatum Zone, and discoidal *Manticoceras* are common at the base of the latter. Several distinct faunas occur within the Schists de Matagne which have still to be worked out.

Two main conclusions have emerged from the work. First, that the German zonal scheme holds in particular detail in Belgium, England and North America. Second, that Matern's lumping of Wedekind's middle Frasnian zones was premature, and, in fact, greater refinement is possible.

References :

COOPER, G. A., 1942. Correlation of the Devonian Sedimentary Formation of North America. **Bull. Geol. Soc. America,** vol. 53.

FOURMARIER, P., 1954. Prodrome d'une description geologique de la Belgique. **Brussels.**

HOUSE, M. R., 1958. Devonian ammonoid faunas in south-west England. **Bull. Geol. Soc. America,** vol. 69.

HOUSE, M. I2., 1961. Observations on the ammonoid succession of the North American Devonian. **Jour. Paleontology,** vol. 35. MATERN, H., 1929. Die Gliederung des Adorf Stufe. **Senckenbergiana,** vol. 11.

WEDEKIND, R., 1913. Die Goniatitenkalk des unteren Oberdevon des Martenberg bei Adorf. **S.B. Gesell. Naturf. Fr.,** (1913).

13. Structural trends of the Western approaches of the English Channel :

by Dr. Maurice Hill.

Extensive measurements with a towed nuclear precession magnetometer (Hill, 1959) have been made in the area of the English Channel westwards of the longitude of Plymouth to the continental shelf edge. These indicate broad ridges and troughs in the total magnetic field lying roughly parallel with the axis of the English Channel. The structures producing these features correspond closely in position with the boundary of the depression in the basement rocks of the English Channel investigated by Day *et al* (1956) using the seismic method of exploration. It appears possible, although it is not yet certain, that the magnetic features extend over the continental shelf edge into deep water. Further work in the area is planned.

On the continental shelf, to the north and south of this broad magnetic relief, small magnetic anomalies occur which are presumably associated with intrusions of igneous (probably basic) rocks reaching close to the surface of the sea floor. There are no topographic indications of their existence.

On the continental slope and shelf to the west of Brittany, there is complex magnetic relief, without the obvious alignments existing further to the north.

References :

DAY, A. A., HILL, M. N., LAUGHTON, A. S. and SWALLOW, J. C. (1956). Seismic prospecting in the Western Approaches of the English Channel. **Quart. Jour. Geol. Soc.,** vol. 112.

HILL, M. N. (1959). A ship-borne nuclear-spin magnetometer. **Deep-Sea Res.,** vol. 5.

14. Quarternary sedimentation around S.W. England : by A. H. Stride.

During the last five years R.R.S. "Discovery II" has obtained quite a lot of information about the surface of the continental shelf south and west of Britain by means of echo-sounding and echoranging equipment. The direction in which sand is being moved can be inferred from the profile of sand waves and the path it is following is shown by streamers of sand. Both features occur on large areas of the floor under examination. The direction of transport is the same as the direction of motion of the strongest tidal stream at almost any place.

The western half of the English Channel and as far west as the edge of the continental shelf appears to be largely a region of westerly bed transport. Between this and the south coast of Eire there is a region of muddy deposits, inferred to be a region of deposition. At the eastern end sand is being supplied from the Bristol and St. George's Channel. Sand gives way to fine sand, to muddy sand, and finally mud in the direction of transport, for both streams. The transition from fine mud to sand seems to be rather abrupt in places. The presence of sand waves suggests that the deposits of sand should be current bedded.

Available evidence shows that sediments of the inner part of the shelf are characterised by molluscan shells and shell debris and the outer part of abundant foraminifera. The outermost few miles of the shelf is locally characterised by large sand waves which appear to be an edge effect due to the tidal streams " feeling " the shelf.

15. Geology of the Bristol Channel Floor : by D. T. Donovan.

Preliminary results of a geological survey over Easter, 1960, show that the Bristol Channel is largely floored by Mesozoic rocks, thought to be

principally Lias. These rocks can be traced westward to about 4° 20' W., where they pass beneath superficial deposits. Superficial deposits also cover most of Swansea and Carmarthen Bays.

The granite of Lundy Island is approached closely on the north and south by Palaeozoic rocks, which crop out continuously from Lundy to Hartland Point. The extent of the granite is believed to correspond closely with the outline of the island. (Dr. A. T. J. Dollar expressed disagreement with this view later in the day's proceedings.) Green igneous rock, comparable to a metamorphosed spilite, has been dredged in some quantity from Horseshoe Rock,. A shoal about four miles north-west of Ilfracombe. The surrounding area is floored by Upper Palaeozoic rocks probably continuous with the Devonian outcrops on the coast.

The inner part of the Bristol Channel is a Mesozoic trough between the Palaeozoic areas of North Devon and South Wales, probably continuous eastward with the trough south of the Mendips. A possible westward continuation of the trough has been considered and geophysical methods will probably be needed to tackle this problem.

The change in coastal morphology at about the longitude of Combe Martin, from a steep coastline to the east, to a lower and more gentle one to the west, was very striking as observed from the ship. This change occurs where the Devonian/Mesozoic boundary, which is close to the coast from Minehead to Combe Martin, swings out to sea. The nature of this boundary has not yet been determined.

The map which illustrated this contribution has been published in *Nature,* (vol. 189, pp.51-52, Jan. 7th, 1961).

16. The development of minor structures associated with shear cleavage : by Dr. W. R. Dearman.

The geology of the north-west margin of the Dartmoor granite has been described recently by Dearman and Butcher (1959). In that account particular emphasis is laid on the shape of the folds, which are typical Vee-shaped flexures with sharply rounded hinges, and on the control exerted by bedding plane attitudes on later dip slip faulting in directions normal to the fold axes. Faulting even on the scale of shear cleavage was subject to this same control and in the paper a brief

account is given of the distortion produced by shear cleavage in folds within the Slate-with-Lenticles Group. Further work has led both to the recognition of the shear patterns required to produce certain clearly defined types of fold distortion, and to the amounts and types of slip involved in particular deformations.

The original shape of the folds developed in the Slate-with--Lenticles Group may be studied in the Railway Quarry at Meldon, in many exposures on the East Okement River, and on the River Lyd upstream from the A386 road. Folds in the slates are similar in form with straight limbs which are thinner than the rounded fold apices.

Shear cleavage is developed in well defined zones parallel to one or other of the bedding plane attitudes in the folds. As a result any particular zone of deformation will have affected laminations having all the attitudes possible within the fold form, thus giving a variable deformation pattern along the length of the shear zone in the movement direction (distinction from axial plane shear cleavage). Particularly susceptible to change are the rounded fold apices.

Homogeneous deformation by slip (Knopf and Ingerson, .1938, p.75 and Turner, 1948, p.164) has given rise to simple flexure zones. On the other hand, heterogeneous deformations lead to the local formation of isoclinal folds, folds with double apices, folds with pinched out apices, all with apparent axial plane cleavage. Fold limbs may be everted to produce monoclines and apparent drag folds.

In many examples the bedding, as indicated by lenticles in the slates, is rucked; each ruck, resembling a drag fold in shape, is bounded by shear zones. Attempts to reproduce this type of deformation pattern on the drawing board have suggested that in the moving mass there was a progressive change across the shear zone from narrow slip zones separating wider undeformed zones (Gleitbretter of Schmidt, 1932), through wide slip zones separating successively narrower undeformed zones, into slip zones bounded by actual fault planes. The overall effect is one of heterogeneous deformation, but within each individual slip zone deformation is homogeneous, leading to an interesting variant of Schmidt's Gleitbrett folds.

References :

DEARMAN, W. R., and N. E. BUTCHER, 1959. The Geology of the Devonian

and Carboniferous rocks of the North-West Border of the Dartmoor Granite. **Proc. Geol. Assoc.,** vol. 70, pp.51-92.
KNOPF, E. B., and E. INGERSON, 1938. Structural Geology. **Geol. Soc. Am., Mem.,** No. 6.
SCHMIDT, W., 1932. Tektonik und Verformungslehre. **Borntraeger, Berlin.**
TURNER, F. J., 1948. Mineralogical and Structural Evolution of the Metamorphic Rocks. **Geol. Soc. Am., Mem.,** No. 30.

17. The structure of Devon and North Cornwall : by Prof. S. Simpson.

North Devon. The Bristol Channel occupies the site of an Alpine tectonic trough (Jones 1930) which coincides with a Mesozoic depositional basin. (This is concluded from the fact that this part of the Bristol Channel is in line with the Bridgwater Flats which has these features.) The Trias which is particularly thick under the Bridgwater Flats probably rests on Coal Measures. (This follows from the way in which the Trias is banked against the anticlinal Triassic hills of the Mendips, Broadfield Down, etc.) Extrapolating westward it is probable that Coal Measures are present under the Bristol Channel north of Exmoor.

Thus a fault, which must have been present already in Triassic times, must separate the Coal Measures of the Bristol Channel from the Lower Devonian of the Exmoor coast. On gravimetric evidence Bott, Day and Masson-Smith (1958) have suggested that the Devonian of Exmoor may overlie Coal Measures, and that this has been brought about by the thrust which is supposed to carry Devonian over Carboniferous Limestone at Cannington Park. This thrust may be the fault postulated above. A fault along the line of the coast is implied by geomorphological evidence (Simpson 1953). The great fault along the East Lyn valley parallel to the coast is also suggestive. The low angle of cleavage dip near the coast at Lynton implies relief in a northerly direction and supports the idea of a thrust.

North Cornwall. Recumbent folds consisting mainly of Upper Devonian and Lower Carboniferous occur between Bodmin Moor and Dartmoor. This region is flanked on the north by Upper Carboniferous with a folding of a style which suggests a high tectonic level, and on the south by intensely deformed Lower Devonian and, at Start Point, by metamorphics.

If the recumbent folds have come into position by gravitational sliding it is possible to regard them as the original cover of

the older and more deformed rocks of the *south.* It is very difficult to understand how they could have been forced out from underneath the younger and less deformed rocks which occur to the north of them. It is suggested that there must be a fundamental structural line separating an exotic recumbent zone from autochtonous Upper Carboniferous to the north.

The southward facing structures of Meldon (Dearman 1959) would lie north of this line. South of the line any southward facing recumbent structures would only be local and exceptional.

References:

BOTT, M. H. P., A. A. DAY, and D. MASSON-SMITH, 1958. The Geological Interpretation of Gravity and Magnetic Surveys in Devon and Cornwall. **Phil. Trans. Roy. Soc. London,** Ser. A., vol. 251.

DEARMAN, W. R., and N. E. BUTCHER, 1959. On the Geology of the Devonian and Carboniferous Rocks of the North-West Border of the Dartmoor Granite, Devonshire. **Proc. Geol. Assoc.,** vol. 70.

JONES, O. T., 1930. Some episodes in the Geology of the Bristol Channel Region. **Advancement of Science, Bristol 1930.**

SIMPSON, S., 1953. On the development of the Lyn Drainage System and its relation to the Origin of the Coast between Combe Martin and Porlock. **Proc. Geol. Assoc.,** vol. 64.

19. Re-examination of some Pleistocene sections in Cornwall and Devon: by N. Stephens.

A critical examination was made of a series of wave-cut platforms of early Pleistocene age (extending from present H.W.M. to the 60-foot level), and overlain by a single raised beach (containing erratic material and with associated sand dunes) and multiple head deposits (frost rubble) which can be observed at many points on the coast of Devon and Cornwall. At the Fremington clay pits near Barnstaple a calcareous boulder clay (containing erratics and shell fragments and very similar to the Eastern General Till of SouthEast Ireland) was described to overlie a well-rounded gravel deposit, which was considered to be part of the raised beach of the outer coast.

Large erratic boulders were described from Croyde Bay, Saunton, Trebetherick, Pendower and Porthleven, resting on the wave-cut rock platforms. Some of these erratics were contained in or sealed below the raised beach, or were sealed below the Main or Lower Head where the raised beach was absent. These large erratics were probably floated into position, on to already existing platforms, by pack ice or icebergs

in the early Pleistocene : no boulder clay has been associated with them in the coastal sections. As the Fremington boulder clay overlies the equivalent of the raised beach it cannot have been responsible for the emplacement of the large coastal erratics at Croyde and Saunton.

The overlying head deposits consist of material which has moved down the coastal slope as a kind of sludge, and spread out as a great ` apron ' or solifluxion terrace, often of wide extent. No marine deposits transgress the surface of the heads, and thus the low angle terraces owe their form to solifluxion and not to marine abrasion. It was shown that two head deposits were sometimes present, separated by sand layers, or differing from one another in the degree of weathering which each has suffered. The term Main or Lower Head was used for the usually more massive, thicker, and often highly weathered deposit in contact with the rock platforms, the raised beach and the large coastal erratics : this head showed evidence of having been disturbed by frost action at a stage later than its movement seawards as sludge (e.g. at Godrevy). The term Upper or Younger Head was used to indicate the generally thinner layers of fresh head (lacking deep weathering), but which were also seen to be disturbed by frost convolutions and wedges. Capping the heads, and forming the present surface of the solifluxion terraces were variable depths of hillwash, and soil, sometimes containing Mesolithic artifacts.

The sequence of events as revealed by the investigation may be stated as follows :

Period	Godrevy	Barnstaple Bay
Post-Glacial	Soils, hillwash, alluvium, submerged peats, sand dunes : limited marine submergence of the coast; strong coast erosion of Pleistocene deposits	

Period	Godrevy	Barnstaple Bay
Würm/Weichsel Glaciation	Frost disturbance Upper fresh head. Some buried channels cut in rock ?	Frost disturbance Upper fresh head.
Interglacial	No trace of marine deposits.	
Riss/Saale	Frost disturbance. Main or Lower Head	Solifluxion ‘earth’. Fremington (= Irish Sea Ice Boulder clay reach-

Glaciation		ing N. Devon : = Eastern General Till of S.E. Ireland).
	Some buried channels cut in rock	
Interglacial	Cemented sands or Sandrock. Raised beach.	Sand dunes. Cemented sands or Sandrock Raised breach
	(both contain erratic material)	
Mindel/Elster Glaciation	Large erratics reach the coasts of Devon and Cornwall (e.g. Croyde granulite gneiss, Saunton red granite, Porthleven gneiss).	
Early Pleistocene	Cutting of a series of rock platforms by wave Action.	
	St. Erth deposits	Hele-Ellerslie sands and gravel

Reference :

MITCHELL, G. F., 1960. The Pleistocene History of the Irish Sea. **Advancement of Science, 1960.**

20. The Palaeogeography of the 430-foot shoreline stage in East Cornwall : by M. R. Weller.

The Pleistocene period in E. Cornwall began with a marine transgression to 600-700 feet and the landforms bear witness to succeeding sea levels at 400 and 200 feet above present sea level.

The Geological Surveyors described a wave-cut platform, sloping 430-250 feet, with a beach deposit, between Boscastle and Tregardock in N. Cornwall. Professor Balchin attempted a reconstruction of this shoreline in the Camel basin in 1937, but field work does not support all of his findings. There is no evidence that the Allen-Camel watershed was breached by the sea north of Bodmin ; the present cols are due to subaerial dissection and the terrace at the Camel-De Lank confluence is river cut. There is no evidence that the platform is terminated downslope by a 240-285-foot platform. The slope of 26 feet per mile from the 430 foot shoreline near St. Endellion to the 270 foot summit at Stepper Point, is not unreasonable for a wave-cut platform. Study of the surveyed profile, and the river terraces of the Camel suggests that the river segment above 600 feet was graded to the 430-foot shoreline near Bodmin. A succeeding stage of erosion is marked by valley benches at 150-180 feet above the present Camel estuary and considerable dissection of the 430-foot platform occurred at

that time.

The 430-foot shoreline and platform remnants can be traced as large embayments within the present lower Fowey and Tamar basins. Milner suggested in 1922, that a narrow gulf of this sea extended along the Tamar valley to connect with an enlarged Bude Haven bay in the north, but the nature of the valley cross-section, where the Tamar is incised in the granite of Hingston Downs, precludes this possibility.

The Fowey river above Golytha Falls may have been graded to the 430-foot shoreline near Lostwithiel. At the 600-700 foot shoreline stage the upper Fowey flowed south into the sea through the gap at Redgate, to which terraces are related. The river was diverted to the present westerly course with the subsequent regression. The west-east section of the Fowey may have been a subsequent tributary of a former Camel which extended south through the present Bodmin-Lostwithiel saddle. The upper Camel may then have been diverted by marine encroachment at the close of the 430-foot stage.

The indented nature of the 430-foot shoreline suggests a transgression, but this appears inconsistent with the theory of a Pleistocene regression. However, the regression may have been oscillatory in nature.

References:

BALCHIN, W. G. V., 1937. The Erosion Surfaces of N. Cornwall. **Geo-graphical Journal,** vol. 118.

MILNER, H. B., 1922. The Pliocene Deposits of Cornwall. **Quart. Jour, Geol. Soc. London,** vol. 78.