21. *The* GEOLOGICAL STRUCTURE *of the* ST. DAVID'S AREA (PEMBROKESHIRE).

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[PLATE XLIV—MAP.]

CONTENTS.

I. INTRODUCTION.

THERE is probably no district in Wales with regard to the geology of which such serious divergencies of opinion exist as the neighbourhood of St. David's. The only rocks upon which authorities are in any way agreed are the sedimentary Lower Cambrian deposits, which form the geological datum-line for the area; and differences exist even here, as to whether they include contemporaneous tuffs, and as to the composition of the basal conglomerate and sandstone. With regard to the age of the various acid and basic tuffs, the basic igneous rocks, the quartz-porphyries, and the granitoid rock of St. David's, relatively to the Cambrian and *inter se*, entire disagreement exists throughout.

The interpretations of the sequence fall, however, into two main groups, associated respectively with the names of Dr. Hicks and Sir Archibald Geikie. The former is, on the whole, supported by Prof. Bonney, Prof. McKenny Hughes, and the late J. F. Blake, who were all well acquainted with the district; and the conclusions arrived at by Sir Archibald Geikie and Dr. B. N. Peach have been confirmed after careful examination by Prof. C. Lloyd Morgan.

The problem may be simplified by eliminating one point of disagreement. The late Dr. Hicks considered that the tuffs, sheets, and dykes could be divided into two unconformable series, termed by him Arvonian (earlier) and Pebidian. No other observer has confirmed this hypothesis, and, in order to avoid prolixity, it is proposed not to make any special reference to it. Eliminating, then, this point, the two conflicting views may be summarized as follows:—

(1) GEIKIE and LLOYD MORGAN. The tuffs form the base of, are conformably overlain by, and pass up into the Cambrian rocks. The St. David's granite, with associated quartz-porphyries, is intrusive in and later than both tuffs and Cambrian; the junctions exposed between them are intrusive, at least in most cases.

(2) Hicks. The tuffs (Pebidian) are unconformably overlain by Cambrian deposits, which are largely composed of their detritus. The St. David's granitoid rock is both pre-Cambrian and pre-Pebidian, the exposed junctions with the tuffs and Cambrian being all faulted. The quartz-porphyries are not connected with the granitoid rock.

The literature of the subject, up to 1883, has been fully summarized by Sir Archibald Geikie in his paper in vol. xxxix of this Journal (pp. 262-66). Of those which have appeared since, the most important are Dr. Hicks's defence in vol. xl (1884) p. 507, and the paper with a map of rock-exposures by Prof. Lloyd Morgan in vol. xlvi (1890) p. 241.

A study of these papers led to the conclusion that the only hope of definitely settling the problem lay in the preparation of a detailed map of the district; and the work was begun by laying down the outcrops of the Cambrian rocks, as accurately as possible, on the 6-inch maps. These outcrops were found to be much faulted, and the faults thus indicated could be followed into the adjacent tuffs, which latter, after allowing for the discontinuity caused by these faults, were successfully resolved into a series of marked constancy when traced from one part of the district to the other.

The faults are so numerous in and near the cliffs that the coast-section fails to afford complete guidance to the complex structure of the area, which could not have been unravelled if the inland exposures were not very numerous. Some difficulties in mapping are caused by the local presence of Boulder-Clay, but the only large continuous mass of it occurs in a band, running east and west, to the north of the city, and thus lies outside the critical area.

Thanks to Dr. Hicks the Cambrian succession is well known, and the following short account may be given, as providing the most trustworthy basis and the datum-line for other rocks.

II. The Cambrian.

The Cambrian in the St. David's area is represented by (*a*) the Caerfai or *Olenellus*-Beds; (*b*) The Solva or Lower Paradoxidian; (*c*) The Menevian, or Upper Paradoxidian; and (*d*) The *Lingula*- or *Olenus*-Beds.

(*a*) The Caerfai Beds.

(1) Basal Conglomerate.—This has been described in detail by several observers, particularly by Sir Archibald Geikie & Dr. Peach [1] and by Dr. Hicks.[2] It is variable in texture, but always very coarse at or near the base, where, in addition to rolled quartz and quartzite-pebbles, there are usually boulders of the neighbouring Pebidian. The pebbles and grit are set in a sparse matrix, which is highly micaceous. The conglomerate causes a marked feature

[1] Quart. Journ. Geol. Soc. vol. xxxix (1883) p. 288.
[2] Rep. Brit. Assoc. 1890 (Leeds) pp. 803-804.

when underlying pasturage or paths, and is consequently easy to trace and to map with exactness, where not obscured by drift.

The finest exposure is that in the Caerbwdy Valley, where it attains a thickness of 70 feet: usually it is about 40 feet thick. Normal junctions with the Pebidian are shown east and west of St. Non's Bay, at Maen Bachau, and at Whitesand Bay. The conglomerate has been most assiduously searched by investigators for fragments of the Pebidian and Dimetian. Subangular pebbles comparable with the former are common, but no undoubted coherent fragment of the latter has been found.

(2) Green Sandstone.—A fine-grained, well-bedded rock, weathering ochreous where moist. In the specimens that I have examined, the grains are of uniform size, measuring about ·1 to ·2 millimetre in diameter, and principally quartz. Felspar is fairly plentiful, and there are also grains of felsite, palagonite, clastic biotite, ilmenite, and ferruginous spherulites.

The matrix is plentiful, mainly of chlorite associated with minute particles of various minerals, such as epidote, and, where crushed, sericite. With such a composition the rock might be expected to be sensitive to thermal metamorphism.

The usual thickness of the Green Sandstone is from 400 to 500 feet, but near Porth-Clais it thins considerably, down to between 150 and 200 feet. Some of the diminution may be owing to compression, as it is more squeezed in this district than elsewhere.

(3) Red fossiliferous Shales, with *Lingulella primæva*, etc.—These beds are usually not more than 50 feet thick, and have been put with the next group in the maps.

(4) Purple Sandstone.—This is usually about 900 feet thick, and near the top becomes a coarse grit, with small granitoid pebbles that have been compared to the Dimetian.[1]

(*b*) The Solva Beds.

The Lower Solva Beds consist of 150 feet of yellow grits and flags; the Middle and Upper Solva of 1500 feet of grey or greenish flags and sandstones, with a purple band about one-third way up the series.

(*c*) The Menevian.

This division consists of about 600 feet of black shale.

The foregoing succession is substantially that recorded by the late Dr. Hicks.

The detailed mapping of these Cambrian rocks reveals a system of faults, most of which have their general direction either from north-north-east to south-south-west or from east to west. These

[1] T. G. Bonney, Quart. Journ. Geol. Soc. vol. xlii (1886) p. 358.

faults, the position of which can be determined with great accuracy owing to the marked lithological differences among the Cambrian rocks, cut up the volcanic group into a series of blocks, or areas within which faulting does not occur, unless the possibility of pre-Cambrian faulting be taken into consideration. No evidence has, however, been found that any fault exists which does not cut the Cambrian rocks when traced up to their boundary.

The order of sequence of the beds in each block has been noted, and the portions of the succession thus obtained have been pieced together into a series that has yielded consistent results over the whole district.

The entire succession, so far as known, has a visible thickness of over 3000 feet on the west side of the St. David's granite, where the whole of the sequence is seen. On the east the upper half only occurs, but seems thicker than the corresponding portion on the west. The real base is nowhere seen.

III. The Pebidian.

From the highest to the lowest known beds, the Pebidian series consists essentially of submarine rhyolitic and trachytic tuffs. A certain amount of intermediate material (augite-andesite) occurs in the lower half, which is distinctly more basic, and, speaking broadly, coarser than the upper half. In the eastern area, the later rhyolitic phase is ushered in by a great acid conglomerate. The fragments in this conglomerate and elsewhere are, except when very small, well rolled, and are associated (except in the bands of finest grain) with a variable amount of quartz-grains which seem in all cases to have been derived from igneous rocks, and occasionally, though rarely, show unabraded crystal-forms. Broken felspars, both orthoclase and acid plagioclases, are found plentifully throughout the series. Lenticles of pink or green shale occur at several horizons. Contemporaneous lavas appear to be totally absent. The rocks that have been described as lavas are, as will be shown later, all post-Cambrian intrusions.

The Pebidian rocks fall readily into fourteen or fifteen constant subdivisions, which group themselves naturally into four series (A, B, C, D), to which it seems convenient to give local names from the locality where each is typically developed and can be best studied. Their sequence is tabulated in the index accompanying the map (Pl. XLIV), with the letters which I have attached to the various bands. Assistance in mapping is also afforded by a quartz-felspar-porphyry sill which maintains a constant horizon.

(A) The Penrhiw Series.

The lowest or Penrhiw Series is named from the fine exposures in the neighbourhood of Penrhiw Vicarage, north of St. David's. It consists of alternations of red and green tuffs, becoming progressively more felspathic and gritty towards the top.

The lowest bed shown in the district (A 1) is composed of purple-red and grass-green hälleflintas,[1] occasionally with coarser bands. It is well developed at both ends of the bridge north of the cathedral, and at the point west of Porthlisky. It undoubtedly exists, as shown by the numerous blocks in the soil, east of Carn Poeth, but it is not there seen *in situ*.

In microscopic section the absence of felspars such as are found in the later silicified rocks of D 4 and F 2 is noticeable. The rock consists of sericite and quartz, with grains of chlorite and opaque matter and occasional epidote. Quartz largely predominates, forming a fine-textured aggregate.

The next subdivision (A 2) is best exposed at the fine sections in the western cliff of Porthlisky; and again in the quarries of Penrhiw, north of the cathedral. The identity of the beds at these two localities, fully 2 miles apart, is singularly striking. The subdivision consists throughout of alternations of red and green gritty tuffs. The lower bands are fine-grained and sheared, the upper part is coarser. The red tuffs are often somewhat basic, and weather in a rusty manner. A distinctive characteristic is the presence of bluish fragments which weather white. In microscopic section, these fragments are seen to be bits of devitrified glass crowded with globulites (?). The outline of the fragments is a succession of little concavities, but it is not clear whether these are due to original gas-bubbles or to the weathering-out of a perlitic structure. A certain number of true vesicles filled with siliceous matter undoubtedly occur, but they do not seem sufficiently numerous to account for the peculiar outline of the fragments. The matrix of the red tuff is ferruginous, and includes felspars and decomposition-products.

In the green tuffs felspars are more plentiful, and the matrix is nearly isotropic, apparently consisting chiefly of scales of a pale chlorite. The included fragments are mostly olive-green flakes of a felsite much like that of the red tuffs, but containing a considerable amount of chlorite. Fragments of vesicular trachyte resembling that presently to be described in connexion with B 2 (p. 369) occasionally occur.

A noticeable point in the felsite-fragments of both red and green tuffs, is the occurrence in the devitrified ground-mass of elongated areas with ragged margins, which extinguish straight. This peculiarity in structure may be due to an original trachytic composition. The green tuffs are progressively more felspathic and gritty towards the top, passing gradually into the next subdivision.

(A 3)—Wherever the bed just described is seen, it is overlain by a felspathic grit (A 3), which is one of the most useful horizons in the Pebidian. In the extreme south-west of the district, near

[1] I use the term hälleflinta as indicating a homogeneous silicified rock with conchoidal fracture, and porcellanite as indicating a similar rock but with splintery fracture.

Ramsey Sound, it covers a wide area and is coarser than elsewhere. In hand-specimens, the rock is white or pale green, and contains scattered, subangular, pink or purple fragments; these sometimes weather out, leaving ferruginous hollows. Under the microscope, the rock is seen to consist essentially of grains of quartz and decayed felspar, set in a dusty epidotic matrix, with strings of chlorite and occasional fragments of felsite. The characteristic purple fragments are apparently hornblende-trachyte containing numerous vesicles. The ground-mass consists of small felspar-laths, extinguishing straight, showing marked fluidal arrangement, mingled with a great number of minute ferruginous grains to which the colour of these fragments is due. The vesicles are filled with some mineral, tending to form radial aggregates, which may be a zeolite. A few of the phenocrysts are orthoclase, but the majority are ferruginous pseudomorphs after hornblende, which in some cases contain corrosion-channels. The nature of the ground-mass of the tuff, in which these purple fragments are embedded, shows clearly that the ferruginous infiltration or replacement occurred before deposition in the tuff.

Not more than 150 feet of A 1 appears to be shown, and the remainder of the Penrhiw Series is about 800 feet thick, most of which is formed of A 2.

Schistose sill.—Above A 3 there occurs almost invariably a foliated quartz-felspar-porphyry sill, to be described later.

(B) The Treginnis Series.

The tuffs of the second or B series cover a large area to the west of St. David's, and are specially well shown on the farm of Treginnis-uchaf. The series is distinguished from all others by its basic character and by the occurrence of scattered fragments, fairly well rolled, varying from 2 to 20 centimetres in diameter, of red rock, described as a quartz-andesite,[1] which seems, however, to be a rhyolite.

The lowest bed of the series (B 1) is a gritty tuff composed of dull-red fragments in a green base. There is considerable variation in the nature of these fragments, the most abundant being a red, vesicular, glassy trachyte, very similar to that which will be presently described, but with much ferruginous matter. Less abundant are fragments of red glass with augite- and plagioclase-phenocrysts, a red rhyolite, and a rock apparently identical with the hornblende-trachyte of A 3. The thickness of B 1 is very variable, from a mere passage-bed a few yards thick at Penyfoel to at least 150 feet near Rhoson. It passes gradually into B 2, and has not always been separated from it on the map (Pl. XLIV).

[1] C. Lloyd Morgan, 'The Pebidian Volcanic Series of St. David's' Quart. Journ. Geol. Soc. vol. xlvi (1890) p. 258. The exposures marked on his map as diabase-tuff with quartz-andesite belong to this series.

(B 2)—The dominant component of the Treginnis Series (B 2) is a slightly gritty rock, of more basic composition than any other member of the Pebidian. It is at least 500 feet thick, and possibly much thicker in some places; but this horizon is usually so folded, and also distorted by basic intrusions, that an exact estimate is difficult.

The commonest phase of this subdivision has a characteristic mottled appearance, consisting of dark-green pebbles in a scanty red matrix, thus giving the effect of a red network on a green ground. This red matrix is highly ferruginous, and mostly opaque under the microscope; but it contains quartz-grains, small chips of lava, and patches of chlorite. The green pebbles consist of highly-vesicular glassy trachyte, the cells of which are filled with epidote and chlorite, a common arrangement being a lining of epidote surrounding chlorite. Numerous orthoclase-laths occur, commonly measuring from ·02 to ·03 millimetre in diameter. They are more or less epidotized, and show marked fluidal arrangement. The vesicles may be so numerous that the rock is almost pumiceous. This mottled type, which weathers in a rusty ferruginous way, covers fully five-sixths of the area occupied by B 2. The matrix, however, may increase in quantity and vary considerably in colour. The most important variation is that which occurs plentifully in the extreme south-west of the district, near Penmaenmelyn and Porth Henllys, in which the matrix makes up at least half of the rock and is dark green in colour. It can be seen in several places, notably on the promontory east of Pen-dal-aderyn, to pass into the common type. This green matrix is a little paler than the red in thin section, otherwise showing no difference by transmitted light; but the trachyte-fragments in the only specimen examined are full of orthoclase-phenocrysts, which I have not found numerous elsewhere. Another variety, with a copious pale-green or pinkish-green matrix, may be seen near Trefeithan.

Most of the specimens of B 2 contain fragments of a rock composed of abundant augite-phenocrysts set in a hyalopilitic groundmass of decayed felspars (andesine), augite, iron-ore, and various products of alteration; and also fragments of a rhyolite with perfect quartz-bipyramids. Both of these lava-fragments contain veins and occasional vesicles filled (before denudation) with—in the augite-andesite, chlorite—and in the rhyolite, calcite.

The filling of these veins before deposition in B 2 shows that the andesite and rhyolite were already somewhat altered; but the trachyte-fragments, on the other hand, were still comparatively fresh: for their marginal vesicles have been filled with the ferruginous matrix of the enclosing tuff, showing that they were still empty at the time of deposition. Some vesicles have been partly filled by ferruginous matter, and subsequently lined with epidote.

The big scattered pebbles of red rock which characterize the Treginnis Series show under the microscope a dusty devitrified glass with strong flow, numerous phenocrysts of orthoclase and plagioclase, and small quartz-bipyramids—apparently a rhyolitic structure. The lava has picked up little bits of a trachyte.

In the Pebidian rocks so far described the ground-mass is largely chloritic even when iron (red)-stained. The higher beds now to be described have a different type of ground-mass, but the change is not abrupt, being rather of the nature of a passage.

(C) The Caerbwdy Series.

These higher beds cover nearly all the volcanic area east of St. David's. Their junction with the underlying Treginnis Series is clear only in a strip of country, barely 600 yards wide, running east and west through Treginnis-isaf, south-west of St. David's, in which a nearly complete Pebidian succession has been preserved.

The Caerbwdy Series is always felspathic, and has a characteristic bluish-green coloration, often mixed with white. The texture in hand-specimens changes greatly from one horizon to another, varying from a coarse conglomerate to a hälleflinta; under the microscope the matrix presents a characteristic appearance throughout the series. It consists of a clear mosaic of quartz, the minute components of which range commonly from ·01 to ·10 millimetre in diameter; but it varies in texture from point to point, coarser and finer patches and ramifications being irregularly intermingled. Chlorite is always intimately intermixed with this ground-mass, and when plentiful aggregates into irregular patches. The mineral is pale in thin sections, fibrous, and of low birefringence. Granular epidote occurs in nests and strings. Embedded in this matrix, throughout the series, are scattered broken crystals of orthoclase and oligoclase, measuring from ·2 to ·8 millimetre in length.

This matrix is clearly the result of the alteration of a fine-grained acid ash, and in a few cases small concave fragments may be recognized in ordinary light; but they are indistinguishable between crossed nicols, owing to the silicification which the rock has undergone. This series attains a thickness of at least 1500 feet, and can be studied most easily in the magnificent section along the Caerbwdy Valley, about a mile east of the city. The lowest portion of the series (C 1) forms a passage from the basic Treginnis to the acid Caerbwdy rocks. It is only exposed east of Treginnis-isaf, the lower part having a greenish matrix, with red and green enclosures, the upper part being felspathic, green and white. It has not been separated from C 2 on the map (Pl. XLIV).

The next division (C 2) has been termed by previous observers the Clegyr Agglomerate, but should rather be classed as a conglomerate. It is highly felspathic and variable in texture, with bands of porcellanite. The normal white and bluish-green matrix contains patches (often an inch in diameter) of the black or greenish-black chlorite, previously referred to. In this are embedded rolled pebbles of hälleflinta and quartz-porphyry of all sizes, sometimes exceeding 30 centimetres in diameter.

Above the Clegyr Conglomerate comes a finer-grained rock (C 3) composed of the same materials. No definite line can be

drawn between the two, but the change is sufficiently rapid for field-mapping. The included bits of hälleflinta and patches of chlorite do not as a rule measure more than 4 or 5 millimetres in diameter. It is well exposed in the Caerbwdy Valley and on Carn Gwil Geli, north of Treginnis-isaf. The rock becomes finer at the top, where it passes into bedded blue hälleflinta (C 4).

The finest section of C 4 is again in the Caerbwdy Valley, where it has been quarried and is at least 90 feet thick. It is here an evenly-stratified, blue, bluish-green, or green rock with bands of yellow, minutely-porous stone, all breaking with a conchoidal fracture. The blue and green stone is translucent in thin splinters, and often looks like bottle-glass. Thin bands occur of coarser felspathic rock. Microscopically the rock is of the usual Caerbwdy type, but with little chlorite and only rare felspar-crystals. This bed can be easily traced, on account both of its lithological characters and of the clearness of the exposures, and consequently is an important clue in working out the details of the structure. From the Caerbwdy Valley it can be followed north-eastwards up to the main road, and south-westwards to the cliffs of St. Non's Bay, of which it forms a considerable part. West of St. David's it is again exposed 150 yards west of Treginnis-isaf and on Carn Fach, both localities being within 200 yards of the cliffs of Ramsey Sound.

Above the hälleflinta just described comes a thick group of felspathic and porcellanitic rocks (C 5), much like C 3 in general appearance, but often distinguishable by the absence of the fragments of green hälleflinta usually seen in the lower division. The most typical rock has a peculiar 'pepper-and-salt' appearance, due to the presence of multitudes of greenish-black specks set in a pale felspathic ground. The specks are shown by the microscope to be patches of chlorite or epidote, in a ground-mass of normal Caerbwdy type. Here and there a few bands occur in which quartz-grains (of igneous origin) are sufficiently numerous to give a gritty aspect to the rock.

(D) The Ramsey-Sound Series.

This series is characterized by the presence of a considerable amount of sericite due to shearing, and by the comparative rarity of fragments of lava or older tuffs. The rocks are usually rather soft and thoroughly schistose.

The lowest division (D 1) is a sheared blue (occasionally yellowish-white) rock, sometimes exhibiting grains of quartz and felspar, but otherwise without recognizable fragments. Often the shearing has taken place along irregular surfaces, breaking the rock up into rugose lenticles; but more frequently, especially in the northern part of the area, it is finely fissile, indeed almost papery. Thin sections show that it is closely allied to the Caerbwdy Series, and is indeed but a slight modification of the same material, the only important difference being the presence in some specimens of pyrites.

Owing to the readiness with which it decomposes, good natural exposures are not common, but an excellent section may be seen in the banks of the Alan River, three-quarters of a mile north of St. David's. The total thickness, where measurable, is about 200 feet.

The next division (D 2) consists mainly of schistose rocks, built up of red and green lenticles containing small 'eyes' of variable composition. These eyes are commonly composed of felspar or quartz, but occasionally of felsite, altered trachyte, or magnetite. The lenticles in which they are set consist essentially of chlorite and sericite in minute scales. Interbanded with the above is always a fissile pale-green or yellow rock, flecked with olive-green. A good exposure occurs near Carn-arwig, in the cliffs of Ramsey Sound, where the thickness is about 300 feet; a little farther north the gradual passage to the underlying beds is clearly exposed. The section of these beds at Porthlisky has been described and referred to by various authors, notably Sir Archibald Geikie, who recognized their identity with the rocks of Ramsey Sound; but the amount of shearing here is quite exceptional, and consequently they do not afford good material for the study of the original characters of the rock.

This division is overlain by purple or yellow porcellanites (D 3), sometimes containing quartz-grains. They seem to be about 120 feet thick at Porthlisky, but are so torn out by shearing that no trustworthy measurement can be made. Slides of these rocks from Carn-arwig and the city of St. David's resemble those of the Caerbwdy Series; the broken felspars, however, undoubtedly include andesine, not recognized in the latter.

The highest tuffs shown in the district (D 4) form the north-eastern cliffs of Porthlisky. They consist of soft, pulverulent, schistose rocks of various pale colours, with a tendency to silicification in strings and patches. They differ markedly from any other part of the Pebidian, and are seen only at this locality.

In view of the great age of the Pebidian, the preservation of the original characters of many of the fragments in the tuffs is remarkable; thus the orthoclase-trachyte fragments in the Treginnis Series are almost as fresh as some of the Tertiary trachytes in Skye, described by Mr. Harker. The red rhyolite from the same series shows good flow-structures and unaltered felspar-phenocrysts; while occasional fragments of augite-andesite are less altered than the post-Cambrian intrusions described later, the felspar-laths being easily determinable. The chief alteration of the tuffs consists in the silicification of the matrix of the acid members, which is so marked that it seems to have been taken as evidence of thermometamorphism due to quartz-porphyries.

IV. The St. David's Granophyre.

Immediately south of St. David's occurs the disputed granitoid rock, termed by Dr. Hicks 'Dimetian.' Its true nature as an igneous rock was demonstrated by Sir Archibald Geikie in 1883; and, as it has been frequently described, no more need be said with regard to its petrographical characters than that it is of variable texture, highly siliceous and coarsely granophyric, consisting of quartz, orthoclase, oligoclase, a little microcline, chlorite (probably after biotite), and ferruginous matter, with nests of epidote. It weathers in a fissile manner, and decays, where there is moisture, to a characteristic yellow colour. The quartz has a dirty appearance, owing to numerous inclusions, often specially developed along planes of cleavage.

The granophyre frequently shows signs of crushing, and is traversed by bands in which the rock is greatly shattered.

V. Extent and Boundaries of the Dimetian.

According to Dr. Hicks, the Dimetian was of pre-Pebidian age and all its boundaries lines of faulting; the view taken by Sir Archibald Geikie was that the rock was a granite of post-Cambrian age and its boundaries, in the main, intrusive junctions.

Although many geologists have visited and written about the district, there is no really accurate map of the area covered by this rock; and the next step found necessary in this investigation was to lay down, as well as the ground would admit, its exact boundaries. At the extreme north-east of the mass a rock was found having a general resemblance to the ordinary Dimetian, but of a more porphyritic nature, the quartzes in particular being bi-pyramidal. A section shows its ground-mass to be granophyric, with a markedly finer structure than anything seen in the normal Dimetian, the other constituents being however identical. It seemed probable that this was only a marginal modification, and this view is supported by the fact that the same rock has been met with again in clear ground at the edge of the mass in several places, especially near Rock House on the north side and near Castell on the north-west side.

But it is on the west side that the most important evidence has been obtained, where a hitherto unobserved extension of the Dimetian of some size has been met with. Commencing about Rhoscribed Farm, a mile south-west of St. David's, this extension can be fairly well traced for a distance of 1100 yards westwards from the main outcrop as hitherto known. It forms a somewhat narrow belt about 300 yards wide, bounded on the north and south by faults, both of which can be seen cutting the Cambrian rocks in the cliff-face of Ramsey Sound. When traced towards the cliffs it was seen to undergo a change in character, and at the western part of the outcrop, about Treginnis-uchaf, is obviously identical with the foliated porphyritic sill already mentioned as occurring at a

constant horizon in the Pebidian (p. 368). It is most important to note that the actual western edge of this prolongation is in contact with, and presumably passes under (for there is no sign of a fault), the member (B 1) of the Pebidian which forms the roof of this sill. As the exact position of the remaining boundaries of the Dimetian is not a matter of serious dispute, and the discussion of their nature and meaning with reference to the Cambrian is dealt with later (p. 377), it will be convenient now to give some further details of the sill, in view of its importance as bearing on the relation of the Dimetian to the Pebidian.

The sill has been traced for a considerable distance, and its outcrop is shown on the map (Pl. XLIV); clear evidence of its intrusive character is seen near Porth Henllys, where it breaks up and interdigitates with the beds of its roof (B 1). In thin section the intrusion always shows a parallel structure, and at times a banded structure, the matrix of the strips varying in texture from cryptocrystalline to a fairly coarse mosaic. In this are set porphyritic crystals of quartz, orthoclase, and oligoclase; the quartz, which is abundant, occasionally shows corrosion-channels, but is never rounded like the crystals seen in the quartz-porphyry dykes described below. The orthoclase at times shows graphic intergrowth. The quartz-crystals are often broken, the larger being cracked and the different portions sometimes actually separated, but never dragged out. Numerous small jaggedly-triangular pieces of quartz also occur, especially when the rock is finer-grained; these appear to be the débris of larger crystals. A variable amount of sericitic mica is present in the ground-mass, suggesting a slight amount of cataclastic structure; but in some specimens the amount is so small, that the foliation of the rock is probably in the main protoclastic and to some extent connected with its viscous nature before consolidation.

The general petrological resemblance to the marginal modification of the granophyre, and the fact that this modification appears to pass into a rock identical with the sill and at the same horizon, suggest that the latter is simply the tapering edge of a laccolitic intrusion of which the St. David's rock (Dimetian) is the core. If the views here put forward are justified, the granophyre must be intrusive in the Pebidian.[1]

VI. Quartz-Porphyry Dykes.

In the St. David's area, in addition to the granophyre, there are a number of acid dykes (quartz-porphyries), described by Dr. Hicks as in the main of Arvonian age and therefore entirely unconnected with the Dimetian: the view taken by Sir Archibald Geikie was that they are not only connected with, but in some cases apophyses, or outward prolongations of the margins, of the granophyre. The term Arvonian has been dropped by general consent; but, although these dykes are probably a later phase of the granophyric

[1] The rock here described as a sill was included by Dr. Hicks in his Pebidian; a description of it was given by Thomas Davies, Quart. Journ. Geol. Soc. vol. xl (1884) p. 552, nos. 32 & 33.

magma, and thus of the same general age, no evidence has been found to suggest that any are apophyses of the latter.

It is not disputed that some of them cut the granophyre, but it has been contended that near Rock House, south of the city, the granophyre passes gradually into a material identical with that of the dykes. In the field close to (north of) Rock House there are two rocks present: one the marginal modification of the granophyre, the other a typical quartz-porphyry. The exposures are not clear enough to justify the positive statement that the porphyry cuts the marginal modification; but the former can be followed well within the main granophyre without in any way losing its identity. Outside the granophyre, near St. David's Cathedral, the quartz-porphyries are more abundant, but never lose their distinctive character; if they were the prolongation of the margins of the granophyre, they should have an unbroken course towards its edge. This, however, is not the case, for any connexion is severed at the surface by an outcrop of the Pebidian, exposed specially well at and about the Deanery. The view that these quartz-porphyries are separate from the granophyre seems to be confirmed by an examination of the ground-mass, which is microgranitic; while the finer phases sometimes approach the micropœcilitic structure, and this structure is maintained even when they occur well within the granophyre, as at Rock House. Spherulitic modifications have been described by various authors, but they do not afford any additional evidence against the view that the granophyre and the dykes are approximately contemporaneous.

So far, then, it has been shown that the granophyre is almost certainly intrusive in the Pebidian; and that the dykes are so is obvious, on the north side of St. David's Cathedral as well as in other localities. The relation of all these rocks to the Cambrian now remains to be considered.

VII. Relation of the Cambrian to the Granophyre and the Volcanic Series.

There are two diametrically opposite views as to the relation of the Cambrian to Dr. Hicks's Pebidian and Dimetian: his view was that there was a great break in time marked by a violent unconformity; whereas Sir Archibald Geikie's view is (1) that there is no break of structural importance between the Cambrian and the Pebidian; and (2) that the Dimetian is an intrusion in the Cambrian. As two types of relationship are involved in the latter interpretation, it will be convenient to discuss each separately, beginning with the first.

Nature of the Junction between the Cambrian and the Pebidian.

In mapping the ground, it has been found that the base of the Cambrian, in this particular area, cannot be proved to rest upon any

member of the two lower series of the Pebidian. At the easternmost point of the district which has been mapped in detail, near Vachelich and Llandruidion, it is in contact with the lowest division (D1) of the Ramsey-Sound Series; and, from the breadth of outcrop of the latter, it must be near the top. Tracing the conglomerate westwards to the Caerbwdy Valley, it is seen resting upon the basal bands of the Ramsey-Sound Series, and so small is the thickness of these beds here that the staining described on p. 377 has extended through them to the underlying Caerbwdy Series (C 5). At the arch in St. Non's Bay, which has been repeatedly described,[1] the conglomerate lies at some depth below the top of the Caerbwdy Series, as, allowing for a neighbouring dyke of quartz-porphyry, not more than 140 feet of its uppermost division (C 5) appears to be present. Passing to the west of the Bay, the base of the Cambrian is clearly transgressive, as at the Stacks of the bathing-place, although it still reposes on C 5, there is now only 40 feet of this division present. In the little Bay, south-south-west of St. Non's Chapel, only 15 feet of the division intervenes between the easily recognized hälleflinta (C 4) and the base of the Cambrian. After passing this point, the junction is a faulted one and continues so for some distance.

It is thus seen that, between the Caerbwdy Valley and the western part of St. Non's Bay, the Cambrian has transgressed over fully 400 feet of the Pebidian.

On crossing the granophyre to the Porthlisky area, a patch of Cambrian hitherto unrecorded is seen to occur a little inland from the cliff; but, as its exact relations to the tuffs are not known, and the Pebidian rocks are greatly deformed, it does not afford trustworthy evidence of transgression. Nevertheless, if the view (also Sir Archibald Geikie's) that these schistose rocks are identical with those of Ramsey Sound be correct, the base of the Cambrian must be at least 1000 feet higher in the Pebidian than at St. Non's Bay.

The Cambrian conglomerate is not seen again, until the cliffs of Ramsey Sound are reached; but in the southern outcrops no normal junction occurs. As, however, it is now clear that the highest series is undoubtedly represented here, the argument just put forward holds good in this case, for we have at least 900 feet more Pebidian present below the Cambrian than at the western end of St. Non's Bay without reaching the base of the Cambrian. A normal junction does actually occur at the arch in Maen Bachau, the horizon in the Pebidian being probably the upper part (D 3) of the Ramsey-Sound Series; but the outcrop is so narrow, and the rock so deeply stained, that its identification is difficult. The only other normal junction exposed is a mile and a half farther north, at Whitesand Bay, where the conglomerate rests upon D 2, about the middle of the Ramsey-Sound Series, an horizon that is certainly at least 600 feet above that of St. Non's Bay.

From the evidence just given it may be fairly claimed that an unconformity between the Cambrian and the Pebidian has been established.

[1] See Quart. Journ. Geol. Soc. vol. xlvi (1890) pp. 244 *et seqq.*

Staining by the Conglomerate.

Where the junction with the Pebidian is exposed, the rock immediately underlying the conglomerate, to a depth of from 10 to 20 feet, has always a peculiar red coloration, not observed in the Pebidian at any other point of the district. As this colour always decreases in intensity, in rocks of similar composition, farther from the base of the conglomerate, it is clearly due to staining. Whether this is produced by water percolating through the Cambrian, or by exposure during erosion, seems an open question; but, beyond any doubt, it has no connexion with a stratigraphical horizon. This staining is of considerable antiquity, for it is certainly older than the oldest faulting.

Relation of the Cambrian to the Granophyre.

The detailed examination of the boundaries of the granophyre shows that most of the margins that can be traced with reasonable certainty are faults, which are shown in the accompanying map (Pl. XLIV). It is a point of the highest importance that these faults are in most cases the prolongation of faults clearly proved in the adjacent Cambrian. The facts regarding the faults themselves may be summarized as follows:—

(1) Along the southern margin of the main mass, the boundary is a reversed fault that crosses St. Non's Bay and dies out eastwards in a minor overfold. This is clearly one of the oldest faults in the district, for it is shifted 120 yards northwards by a later fault.

(2) For a considerable part of its outcrop the granophyre is bounded by faults that belong to a series, trending north-north-east and south-south-west, forming a feature and an integral part of the present structure of the district.

One of these faults bounds the eastern side of the southerly prolongation of the granophyre, and is seen in the cliff-face at Ogof Llesugn, where it brings the Middle Solva Beds against the basal conglomerate. A branch-fault comes off here, and this fact has been noted by the late J. F. Blake, who accurately described and mapped this critical section. He showed that the outcrop of conglomerate seen here is at no point in contact with the granophyre, but is involved in a series of interlacing injections of basic igneous rock.[1] Basic intrusions of this type along lines of fault are a feature of the entire district.

(3) The western portion of the northern end of the granophyre is bounded by a great fault with a general west-north-west and east-south-east direction, the outcrop of which is again shown on the map (Pl. XLIV) cutting the Cambrian, both east and west of the city. The existence of this fault near the city was clearly grasped by Dr. Hicks, who failed, however, to trace its further course.

Owing to the exceptionally clear nature of the exposures in the Porth-clais area, all previous writers have focussed attention on the evidence seen there. One side claims all the junctions as essentially faults, the other as essentially intrusive. The maps given here show that these junctions are for the most part prolongations of faults proved by detailed mapping to cut the Cambrian; and thus Hicks's contention is, in this area, substantially correct. In order to make

[1] Quart. Journ. Geol. Soc. vol. xl (1884) pp. 299 *et seqq.*

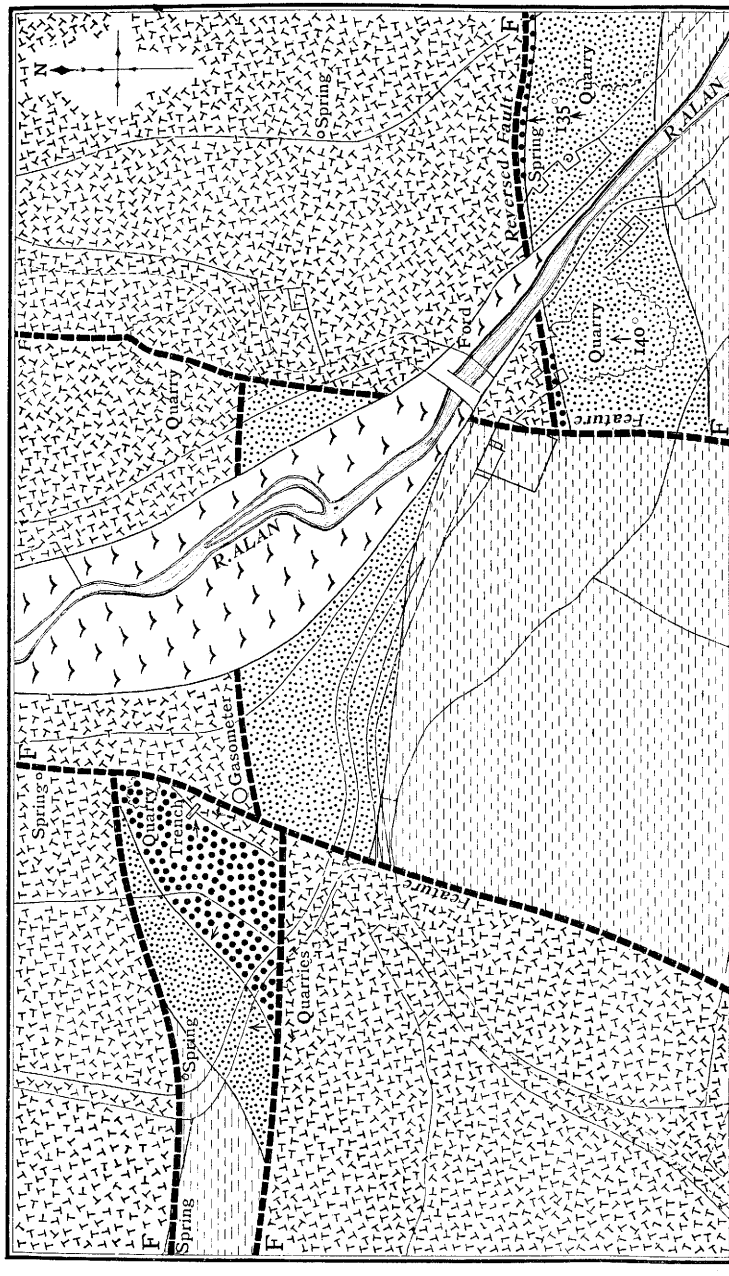


Fig. 1.—*Map of the Porth-clais area (basic dykes not shown), on the scale of 25 inches to the mile.*

sure of this point, this special area has been mapped out on the scale of 25 inches to a mile (fig. 1, p. 378). It was this detailed mapping that led to the discovery of the only known normal junction of the Cambrian and the granophyre, and the fact that this existed would probably have never been known but for the recent establishment of the Gas-works. Before these were erected, there was a farm-service road leading from the high road to a quarry in the conglomerate. This road formerly kept clear of the bank flanking the Alan in which the quarry occurs. In this bank-face, quite at the foot of the hill, fragments of the conglomerate only occurred, and it was a natural inference that this rock continued to the foot of the bank. When the Gas-works were built, the road had to be shifted closer to the bank, and, in so doing, the fault already mentioned as shifting the Cambrian at Ogof Llesugn was cut open, showing that the granophyre occurred on both sides of it.

It was thus obvious that there must be in the bank-face, on the west side of this fault, the original junction of the granophyre and the Cambrian conglomerate. Mr. G. Barrow, when on a visit to me, drew my attention to the supreme importance of this fact, and suggested a further visit with the object of cutting this junction open. This has since been done, and the section laid open exposes the Cambrian conglomerate resting upon the eroded surface of the granophyre. The position of the small opening made is shown on the 25-inch map, and has also been photographed; it has been left open for verification by subsequent observers.

The basal band of the Cambrian here is so like the decomposing Dimetian, that in a first opening made it was actually taken for it, and it was only distinguished by some very small pebbles of the characteristic pink quartzite which occurs in much larger pebbles higher up in the conglomerate. The actual junction is found in a second opening: the only means of distinguishing the two rocks at first was the presence of these minute pink pebbles, and it was not until the opening was enlarged that the junctions were defined.

It is clear that the basal band of the conglomerate is the finest débris of the granophyre, and however we may account for the fineness of this base of the conglomerate, it is accompanied by an equivalent diminution in size of the scattered pink quartzite-pebbles. There is no trace of faulting, or of any marginal modification of the granophyre, and no sign of thermal action is seen in the Cambrian when actually touching the igneous rock. The latter, on the contrary, shows clear signs of decay previous to the deposition of the Cambrian Conglomerate.

Basic Intrusions.

The basic igneous rocks of the district have been classified by previous observers into two distinct series—(*a*) intrusive dykes, and (*b*) contemporaneous sheets or lavas. It is universally agreed that the former are post-Cambrian; but the latter have been held to be

substantially contemporaneous with the Pebidian, and in view of what has gone before would therefore be pre-Cambrian. Evidence, however, has been obtained tending to prove that the latter are also post-Cambrian, and further, that they simply represent different modes of occurrence of the same material.

The rocks here described are striking features of the scenery west of St. David's, where they project like sea-stacks above the general rough platform-level of this part of the district. The material composing the stacks is of much finer texture than that of the more conspicuous masses near the north coast recently described by Mr. J. V. Elsden; in addition, they are locally vesicular, and these features have presumably led to their being described as lavas.

The small patch forming the stack nearest St. David's (Clegyr-foia) seems to be intrusive, but its age must clearly go with that of the more important mass on the west. The extent and mode of occurrence of the latter are shown on the map (Pl. XLIV); it is nearly 2 miles long, and, as its trend is roughly parallel to the strike of the Pebidian, it gives at first sight the impression of a sill or lava. Its true nature can be determined by examining its margins. Its junction with the Pebidian is very irregular, and is best exposed on and about Rhoson Crags. Here the continuity of the mass is broken by a long narrow strip, partly enveloped, of Pebidian, seen on the northern and eastern flanks of the crag, the junction being approximately parallel to the stratification of the tuffs; but on the south the margin makes a right-angled bend, and is seen on the bare rock-face to cut across the bedding for a distance of some 15 yards. It is thus clearly intrusive in the Pebidian.

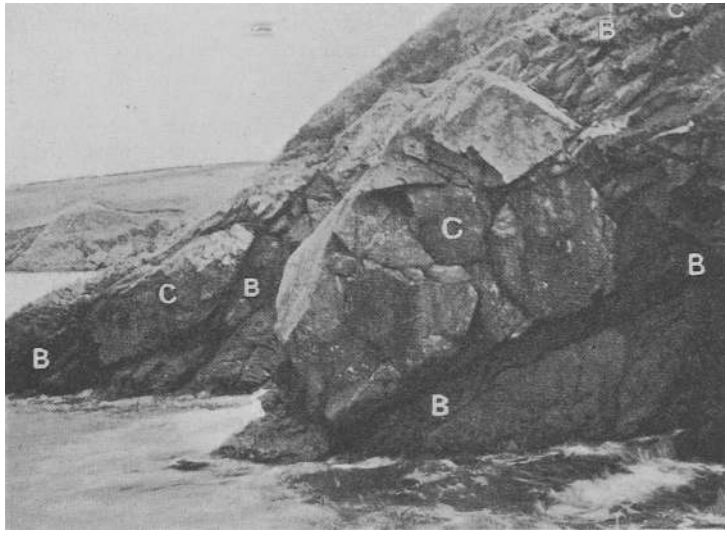
As the mass is traced from north to south it is soon seen that, where the path of a fault known to cut the bedded rocks is crossed, no trace of the fault occurs in the basic igneous rock, raising at once a suspicion that it is even later than the post-Cambrian faulting. All doubt of the post-Cambrian age is dispelled by an examination of the coast-section at Carn-arwig. The cliffs here, for about a quarter of a mile, are exclusively composed of the same basic material, except at one locality; here the basal Cambrian conglomerate also occurs, as several (at least six) more or less lenticular masses completely enveloped in the igneous rock, which must thus be post-Cambrian. Three of these masses are shown in the accompanying photograph (fig. 2, p. 381), kindly taken, after considerable trouble, by Mr. John Barrow.

If the coast-section near the main mass of basic rock is examined, the fault-planes and ramifying cracks are often seen to be filled with basic material substantially identical in structure and composition with portions at least of the mass inland. These would seem to be films given off from the margin of the mass, and this view is strengthened by the fact that, although these small intrusions are very numerous in the district, they have not been met with piercing the larger masses.

Thus the field-relations do not support the view that these basic rocks are lavas, as has formerly been supposed; neither does the

mode of occurrence of the vesicles, when they are carefully examined. They are not characteristic of the edges of the basic masses; indeed, they rarely, if ever, occur near the margins, but rather

Fig. 2.—*Cambrian conglomerate involved in a basic intrusion; west of Carn-arrig, Ramsey Sound.*



J. Barrow photogr.

[B=Basic intrusion; C=Conglomerate.]

some way within the intrusion. The best illustration of the latter point occurs at Carn Howell, where small vesicles, usually about 3 millimetres in diameter, are very abundant, but at a distance of at least 100 yards from the margin.

VIII. Summary.

The conclusions arrived at may be briefly summarized as follows:—

(1) The Pebidian consists of a bedded series of tuffs, composed of detrital volcanic matter deposited under water. Although some of the material may have been blown directly into its present position, the bulk has been washed down from a land-surface.

(2) This has resulted in the formation of singularly persistent bands of deposition, capable of being traced for considerable distances and mapped out on the ground, the structure of which has thus been determined.

(3) The process of mapping has shown clearly that there is a strongly marked unconformity between the Pebidian and the overlying Cambrian.

(4) The St. David's granophyre (Dimetian) is probably a laccolite, terminating along one edge at least in a sill-like prolongation clearly intrusive in the Pebidian. The post-Pebidian age of the whole is thus established.

(5) The actually observed junctions of the granophyre and the Cambrian are all faults—except in one case, where, on being cut open, the conglomerate is seen resting upon the eroded surface of the Dimetian. No trace of contact-action has been seen anywhere at the junction of these two rocks. The pre-Cambrian age of the granophyre is thus clear.

(6) No basic lavas have been met with in this area, those forming the 'stacks' being clearly of an intrusive nature and of post-Cambrian, if not of post-faulting, age.

The pre-Cambrian age of Dr. Hicks's Pebidian being so clearly proved, it seems only just that the name should be revived, if not indeed extended to other areas, as he suggested. The contemporaneity of the series with similar rocks of pre-Cambrian age in other areas cannot be claimed as definitely established; but, if any general name is applied to these rocks, such as those of Charnwood and the Uriconian, Dr. Hicks's term should have priority.

The friends at St. David's who have shown me kindness are too numerous to mention; but I must name Mr. H. P. Jackson, Master of the Secondary School, and Mr. William Davies, of Rhoscribed Farm, who kindly granted permission to dig a trench on his land and afforded us much useful information. Above all, I owe to Mr. George Barrow, not only the original suggestion that I should attack this complex area, but constant assistance and advice which alone made the production of this paper possible.

EXPLANATION OF PLATE XLIV.

Geological map of the St. David's area, on the scale of 3 inches to the mile.

Discussion.

The Chairman (Dr. Teall) referred to the keen controversy that had taken place in that room about a quarter of a century ago on the subject of the St. David's rocks, and remarked that the Author's very careful work tended to show that both the combatants were right and both were wrong.

Mr. Barrow drew attention to the gradual advances in our knowledge marked by the present paper. When Hicks began work at St. David's, the geologists of his day often took the faint foliation of such rocks as the Dimetian for the last trace of bedding in an intensely-altered sediment; and, holding this view, they

GEOLOGICAL MAP
OF THE
ST. DAVID'S AREA,
PEMBROKESHIRE.

Scale:—
3 Inches = 1 Mile.

N

ST DAVID'S HEAD
Treleddyd-fawr Rocks
Undifferentiated Upper Cambrian
iron-pan
Lleithr
Rhodiad
Dowrog Pool
WHITESAND BAY
Blown Sand on Boulder-Clay
THE BURROWS
Blown Sand
Cambrian bogs
Probable position
Approximate line of Fault
Menevian
Ogof Golchfa
Conglomerate on Sheared Tuff
Carn Howell
pan
Emlych
R. Alan
Porth Selau
Carn Sulin
Carn-Poeth
Undifferentiated Upper Pebidian
Penrhiw
ST DAVID'S
Vachelich
Windmill
Rock House
Brynygarn
Rhoson
Porth Stinian
Trefeithan
Clegyr-Foia
R. ALAN
Numerous Basic Dykes
Maen Bachau
Treginnis-uchaf
Rhoscribed
Treginnis-isaf
Trelerwr
Ogof-y-ffos
Minor Overfold shown in Cliff.
CAERBWDY BAY
ST NON'S BAY
CAERFAI BAY
Porth-clais
Caran-wig
(Photograph)
Conglomerate involved in Andesite
Porth Henllys
Porthlisky
Ogof Llesugn
Basic Sill in Vertical Solva Beds
Pen-dal-aderyn
Penyfoel
Pen Pedol
Quartz-Porphyry in Trachytic Tuff
Careg-yr-Esgob
Careg Fran
Chandruddan
ST BRIDE'S BAY
RAMSEY SOUND

INDEX OF COLOURS

CAERFAI BEDS
- Middle and Upper Cambrian
- Purple Sandstone
- Red Shale
- Green Sandstone
- Conglomerate

- BLOWN SAND
- ALLUVIUM
- GRANOPHYRE (g)
- QUARTZ-PORPHYRY (p)
- BASIC IGNEOUS

UPPER PEBIDIAN (Rhyolitic Group)
- Ramsey Sound: D4 D3 — D3 D4; D2 — D2; D1 — D1
- Caerbwdy: C5 C4 — C5; C3 — C3; C2 C1 — C1 C2

LOWER PEBIDIAN (Trachytic Group)
- Treginnis: B2 B1 — B1 B2; Sill — S
- Penrhiw: A3 — A3; A2 — A2; A1 — A1

Undifferentiated Pebidian — U

J. F. N. Green del.
Bemrose & Sons, Ltd. Derby & London.

naturally took the Dimetian for the oldest rock in the district. The view was strengthened by the fact, that until within the last two years every known junction with the Dimetian was a fault. Taking the view that it was a post-Cambrian intrusion, Sir Archibald Geikie looked for 'contact-action,' and thought that he had found it in the intensely-hardened aspect of some of the rocks. This hardening, however, was now known to be due to silicification, and was often best seen far away from the margin of the Dimetian. A wholly new interpretation had been given by the Author to the mode of occurrence of the fine-grained, more or less basic rocks that rose like stacks out of the platform south-west of St. David's. They contrasted so strongly in texture with the intrusions of St. David's Head that they were first naturally considered as approximately-contemporaneous sills in the Pebidian; the Author, however, had now conclusively shown that they were not only post-Cambrian, but later than the faulting.

Mr. J. V. Elsden said that, although he had seen many of the sections described by the Author, he was not in a position to discuss the main questions involved, as his own work had lain farther north. With regard to the basic intrusions, however, he had expected to find rocks of the St. David's-Head type in the St. David's complex, and had searched for them somewhat perfunctorily and without success. It was, therefore, with considerable interest that he recognized this type among the Author's specimens. The Author's observation that these basic intrusions were not affected by the post-Cambrian faulting was interesting, as tending to support the view at which the speaker had arrived with regard to the age of the St. David's Head intrusions, which might prove to represent a comparatively-late episode in the history of that area. He congratulated the Author upon the results of his careful and detailed investigations, which seemed so equally to divide the honours between previous workers.

Prof. W. W. Watts referred to the importance, as illustrated by this paper, of detailed mapping of difficult areas. All the junctions of the 'Dimetian' with the surrounding rocks in this area were faults, except the one referred to by the Author, in which, as in other known cases, by the departure of the fault from the older rocks, a mere trace of newer rocks had been found in unconformable contact with the granophyre.

The Author desired to say that he was most grateful for the kind compliments paid to his work by the Chairman and others who had taken part in the discussion. Boulders of the rocks described by Mr. Elsden, which differed greatly from the characteristic basic intrusives of the district, were very common, but they undoubtedly also occurred *in situ*, the specimens shown being from a deep well.