

29. *On some of the MELAPHYRES of CARADOC, with NOTES on the ASSOCIATED FELSITES.* By FRANK RUTLEY, Esq., F.G.S., Lecturer on Mineralogy in the Royal College of Science, London. (Read June 24, 1891.)

[PLATE XIX.]

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I. INTRODUCTION.

WHILE staying at Church Stretton during the autumn of last year I paid several visits to Caradoc Hill for the purpose of acquiring some information concerning the nature of the felsites which occur there. Many chips were collected, not only of felsites but also of basic eruptive rocks, and sections were subsequently cut from those specimens which seemed likely to show points of interest.

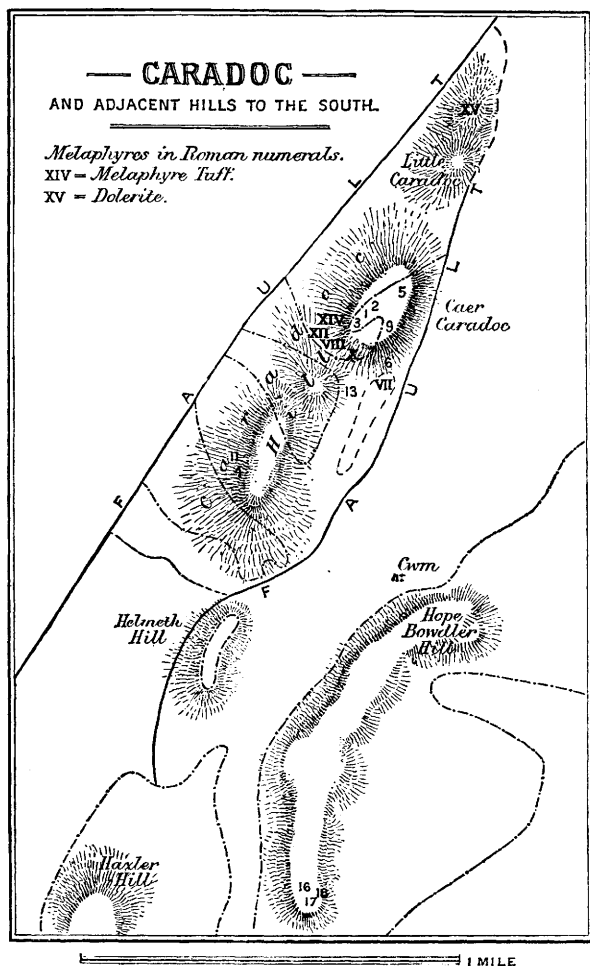
Although the structural geology of this area has been investigated by several observers since the publication of the Geological-Survey map, no account of the microscopic characters of these rocks appears, hitherto, to have been published. In the following paper an attempt is made to supply this deficiency to a certain extent, but, since the time at my disposal permitted the collection of specimens from only a limited portion of Caradoc Hill, chiefly from different spots situated to the south and south-west of the Camp, there remains much ground which the present paper leaves untouched.

The points from which the different specimens were derived are marked with some approximation to truth on the accompanying outline map, on which the geological boundaries laid down on the published Survey map are indicated. The Arabic numerals refer to the numbers with which the specimens of felsite, derived from those spots, were ticketed, while the Roman numerals denote basic eruptive rocks. The numbering of the specimens and sections bears no relation to any sequence in the field or relation of the rocks to one another, and has merely been retained to avoid any possible source of error from re-labelling.

II. THE MELAPHYRE SERIES.

The following are descriptions of certain selected types of the Melaphyre Series.

No. XII. S.W. side of Caer Caradoc, near the top of the hill. Altered vesicular basalt-glass. (Melaphyre.)



- Felsites (Rhyolites) 1, 5, 6, and 9:—more or less spherulitic and vesicular.
 „ „ 2, 3:—vesicular, with elongation of vesicles.
 „ „ 4, 11, 13, 16, 17:—perlitic.
 „ „ 18:—Rhyolite tuff.

A dark bluish-grey, vesicular rock, the vesicles being mostly filled with pale greyish-white or dark green substances. The weathered surfaces are rusty-brown and the amygdulæ at the surface have usually decomposed, leaving empty pores which impart a somewhat scoriaceous aspect to the rock. Under the microscope, in thin section, it is seen to consist of once glassy matter, now more or less devitrified by the development of microliths and globulites, and crowded with small granules and crystals of magnetite, together with little needles and skeleton crystals, often twinned, and these from their extinction-angles appear in many instances to be labradorite. There are also many small lath-shaped crystals of triclinic feldspar often considerably corroded (Pl. XIX. fig. 2). One or two of the skeleton crystals are shown in fig. 7, magnified 75 diameters. Fig. 6 in Pl. XIX. represents what appears to be a diminutive pseudomorph of magnetite after olivine, magnified 140 diameters. Taking the boundaries of the crystal-section as the brachydome (021) and the brachypinacoid (010), the angle for the faces $021:0\bar{2}1$ approximates to 80° . Minute pale greenish grains are also present which may consist of a dusty admixture of chlorite with some other mineral.

The devitrified glass in the thinnest parts of the section appears nearly colourless; where thicker it is of a pale brown tint.

The vesicles in this rock are exceedingly numerous and very irregular in form (Pl. XIX. fig. 1). They are filled with quartz, a chlorite-like mineral (apparently delessite in part), calcite, and sometimes chalcedony and a substance resembling felsitic matter. The larger grains in these microcrystalline aggregates usually show a positive uniaxial interference-figure, but occasionally the emergence of a negative bisectrix may be noted in convergent light, indicating that a biaxial mineral (probably feldspar) is also present.

Quartz, chalcedony, or felsitic matter frequently borders the vesicles, the interior being filled with calcite only, with quartz only or with chlorite (delessite?) only, but often with an admixture of chlorite or delessite and quartz. The skeleton crystals are mostly of the H-shaped or swallow-tailed types. They very commonly show straight extinction, but in many cases the direction of maximum extinction makes angles with the axis of elongation varying from 12° to over 15° .

The rock appears to be closely allied to certain Bohemian melaphyres described by Bořický*. It doubtless represents the once vitreous, superficial portion of an old lava-flow of basalt or andesite, and is probably one of the most ancient examples of such a rock with which we are yet acquainted.

No. XIV. S.W. side of Caer Caradoc, at the top of the hill. (Melaphyre Tuff).—The fragments composing this tuff consist of a rock similar to that just described. They are mostly small, ranging from three or four millimetres in diameter to very minute dimensions. The sections of the fragments frequently show concavities on

* 'Petrographische Studien an den Melaphyrgesteinen Böhmens,' Archiv für Naturw. Landesdurchforsch. v. Böhmen, Bd. iii. Geol. Abth., Prag (1876).

their boundaries, such as are invariably seen on the surfaces of the fragments of tuffs formed from vesicular or scoriaceous lavas. (Pl. XIX. fig. 4.)

The general aspect of the hand-specimen is that of a dark iron-grey or bluish-grey rock, compact in texture, but appearing slightly vesicular when examined under a pocket-lens. It also shows some irregular spots of yellowish-white to pinkish-white crystalline matter, which effervesces briskly when touched with a drop of acid.

In thin section, under the microscope, the fragments composing the rock are seen to vary considerably in translucency, the groundmass in some being a more or less completely devitrified pale-brown glass, containing opaque matter which appears merely as fine dust under a magnifying power of 250 linear. In other fragments the opaque particles in the groundmass are larger, and the rock of which these fragments consist seems to differ in no appreciable respect from the melaphyre previously described which occurs in the immediate vicinity of this tuff.

In many of these fragments the magnetite grains are seen to be more closely massed along the margins of the fragments, giving rise to a narrow and perfectly-opaque black border, while in some instances the entire groundmass of the fragment has been rendered absolutely opaque through development of magnetite.

It has already been shown that a basic, vitreous lava, such as the basalt-glass of Kilauea, when heated for 260 hours at a temperature ranging from 700° to 1200° C., becomes strongly magnetic and absolutely opaque through separation of magnetite*. Bearing this fact in mind it may, I think, be inferred that the fragments constituting the melaphyre tuff of Caer Caradoc have not resulted from the mere crushing of a lava, but that they were ejected from a crater as lapilli and volcanic sand; that their surfaces, in many instances, were sufficiently heated to give rise to the formation of an opaque superficial crust of magnetite, while, in other cases, a more protracted roasting carried this process to its extreme limit, so that all the iron present in the lava in the protoxide state became converted into the magnetic oxide.

The action exerted upon a magnetic needle, when a specimen of the melaphyre lava (No. XII.) is brought near it, is exceedingly slight compared with that produced by a considerably smaller specimen of the melaphyre tuff (No. XIV.). Fig. 4 in Pl. XIX. represents part of a section of this tuff, magnified 18 diameters. The fragments and portions of fragments here shown exhibit a perfectly opaque groundmass, while the small felspar-crystals and skeletons lying in this groundmass appear unaltered and remain perfectly translucent. The broad light band passing diagonally across fig. 4 represents cementing material which, in this rock, consists of chalcedony. Irregularly shaped cavities occur in this cement, and these have been filled partly with pale green serpen-

* 'Notes on Alteration induced by Heat in certain Vitreous Rocks,' Proc. Royal Soc. vol. xl. (1886) p. 437.

tinous matter, probably derived from the decomposition of the pyroxenic constituents of the melaphyre fragments, and partly with calcite. Judging from the texture of this tuff, it is probable that the vent from which the lapilli were ejected was not very far distant.

No. VIII. S.W. side of Caradoc, about 80 feet below the Camp. (Amygdaloidal Melaphyre.)—A dark grey rock with small vesicles, some of which are filled with white and others with dark-green matter.

Under the microscope it is seen to consist of small lath-shaped crystals of triclinic feldspar, usually corroded and occasionally bent, together with magnetite (sometimes in octahedra, but mostly in irregular grains), and a considerable amount of green matter, which appears in some cases to be chlorite, but is not improbably a palagonitic substance resulting from the alteration of interstitial glass. The feldspar-crystals lie irregularly in all directions.

The vesicles are very irregular in form and some are filled with chlorite or delessite (the optical sign in the direction of the fibres is positive). Others are filled with calcite or quartz, while, at times, a little chalcidony is present. The section is stained in places by ferric oxide.

No. X. S.W. side of Caradoc, about 100 feet below the Camp. (Amygdaloidal Melaphyre.)—A compact dark brownish-grey rock with very small vesicles, some containing quartz, others a dark green substance. Under the microscope it appears, when examined with a low power, to consist of a felted mass of very minute feldspar crystals with opaque interstitial matter. The rock, in fact, shows the "pilotaxitic" structure of Rosenbusch, unless, indeed, the black interstitial matter represents a once glassy groundmass now rendered opaque by separation of magnetite, in which case the structure would once have been "hyalopilitic." The vesicles contain chlorite and quartz, and are very irregular in form. The section is traversed by some delicate fissures now filled with quartz.

Fig. 3 in Pl. XIX. represents portion of a section of this rock.

No. VII. S.E. side of Caradoc, low down, perhaps 150 or 200 feet below the Camp. (Melaphyre.)—A rather pale greenish-grey to brownish-grey, finely-crystalline rock, presenting no striking peculiarities to the unassisted eye. Under the microscope it is seen to be more coarsely crystalline than any of the preceding.

The feldspars, which constitute a large proportion of the rock, lie in all directions and, from their extinction-angles, appear to be labradorite, but in many cases they are partly converted into kaolin. Much brownish or greenish matter is present, often filling vesicles, in which case it usually forms divergent fibrous growths and minute spherulitic aggregates which have a positive optical sign. The section also shows rusty-brown patches of limonite, minute specks of pyrites and apparently a little unaltered magnetite. The feldspars are often corroded and sometimes bent.

No. XV. Little Caradoc, N.W. side, about 100 feet above the

road to Comley. (Dolerite.)—A greenish-grey holocrystalline rock of rather coarse texture, mainly consisting of dark-green augite and greyish felspar.

Under the microscope the rock is seen to consist of crystals of perfectly unaltered augite, labradorite often partly converted into kaolin, magnetite, and interstitial patches of chlorite. The augite crystals, as a rule, appear to range from more than three millimetres to about one millimetre in length. The crystals of labradorite are frequently of somewhat larger dimensions.

III. CONCLUSIONS WITH REGARD TO THE MELAPHYRES.

The foregoing descriptions show that, within a very limited area, the melaphyres of Caradoc differ considerably in texture and in structure. Some have once been basalt-glass or andesite-glass, such being the superficial portions of a lava-stream; others have possessed a certain amount of interstitial glass which has subsequently been rendered more or less opaque by the development of magnetite, while, at times, it appears to have been converted into a substance possibly allied to palagonite.

In some of these rocks the crystalline texture is very fine (pilotaxitic), while in the case of the dolerite from Little Caradoc it is comparatively coarse. Furthermore, near the summit of Caradoc we have a basalt-tuff or andesite-tuff.

These rocks are spoken of as altered basalt or andesite, since any pyroxene or olivine which they may once have contained is in most cases so completely replaced by alteration-products that it is impossible to define their original mineral constitution with precision. This is also partly due to the allotriomorphous character of those minerals which have undergone decomposition. The felspars and magnetite are, as a rule, the only original constituents which remain unaltered, and these at times have suffered very considerable change.

The term melaphyre, as indicating an altered basalt or andesite, seems perfectly applicable to these old lavas.

The dolerite of Little Caradoc differs from these rocks, in that the augite remains perfectly fresh, or is only altered along minute fissures, and the felspars are more or less turbid and altered, while in the lavas of Caradoc proper it is the pyroxenic constituent which has undergone decomposition, but the felspars remain fresh and, as a rule, unchanged.

Whether the dolerite of Little Caradoc may be regarded as a volcanic neck or plug, from which the basic lavas lying to the south-west of it emanated, is a point which field-work can alone demonstrate or disprove, but, taking into consideration the gradations of texture which these rocks present at different levels, such a supposition comes within the range of possibility.

IV. THE FELSITIC SERIES.

The Felsitic Series in the Caradoc area is a very important one, but extremely difficult to work out under the microscope, since the structures characteristic of rhyolites are, in most cases, obscure, so obscure, in fact, that, unless exceptionally thin sections are examined, they may often completely baffle detection. After careful examination, however, it has been possible to recognize not only spherulitic structure and occasionally bands of spherulites, but also perlitic structure. The latter is very obscure in the best examples, but is sufficiently marked to prove that the structure is present.

It may be fairly well seen in a section made from a specimen collected a little above Caradoc Coppice, near the southern end of the hill and on its north-western flank. Very faint indications of the structure were first seen in this and in one or two sections from other spots in the neighbourhood. The sections were then reduced in thickness, and, in the thinnest portions of them, perlitic structure was found to be unquestionably present although still obscure. In ordinary transmitted light it is less easy to detect than between crossed nicols, and in the latter case it is rendered more apparent by a rapid rotation either of the section or, if a Dick microscope be used, of the nicols. The reason of this appears to be that the crystalline grains which lie in or along the perlitic fissures are, as a rule, slightly larger than those which constitute the main mass of the rock and that, although the optical orientation of the different grains along any one perlitic fissure is very diverse, yet on rapid rotation either of the section or of the crossed nicols the maximum illumination of one grain in the series is so quickly followed by the maximum illumination of each succeeding grain that the retina retains these impressions sufficiently long to receive the general impression of a narrow ring or of a number of narrow rings more brilliantly illuminated than the remainder of the section. Without having recourse to rotation these rings can, however, still be seen (Pl. XIX. fig. 5).

Spherulites are somewhat plentiful in these rhyolitic rocks. They are usually small, but not difficult to detect even under low powers. For the most part they are irregularly distributed, but in some of the sections examined they are more closely massed and occasionally coalesce in irregular bands.

Setting aside the devitrification which these rocks have experienced, we have their exact counterparts in many spherulitic obsidians of comparatively recent date, notably in those of the Yellowstone District, especially in some which occur near the Madison River.

Ordinary fluxion-banding appears to be very poorly represented in the Caradoc rhyolites. Evidence of such structure has been better seen on the ground than under the microscope. On the S.E. flank of Caradoc, a little to the south of the Camp and about half way up the hill, there is, for instance, an outcrop of felsite, on the weathered surface of which there is a well-marked banding visible. At this

point the strike is S. 80° W. and the dip about 55° towards the north. A microscopic section of this rock, however, shows scarcely any traces of fluxion-banding.

Irregularly-shaped vesicles, filled with quartz &c., are often present in these rhyolites, and they occasionally show a tendency towards elongation in a definite direction. This is well seen in some of the exposures of rhyolite occurring at the top of Caradoc close to and within the Camp; but the forms of these vesicles, when viewed under the microscope, are often remarkably irregular, throwing out processes in all directions, the latter frequently constricted to mere threads near their points of origin from the main vesicle, then expanding and finally tapering to sharp points. In spite of this irregularity, however, they may be seen to have a rudely linear arrangement in the rock. Fluxion structure, as evidenced by streams of microliths, is not to be detected in rocks which have undergone such complete devitrification, save perhaps in hazy banding, produced by slight differences in crystalline texture.

For the purpose of ascertaining how far certain structures in vitreous rocks may be destroyed or rendered invisible through subsequent alteration, I have examined a number of sections of unaltered obsidians and pitchstones in search of perlitic and fluxion structures, so delicate that devitrification would almost infallibly obliterate them or render them so indistinct that they could no longer be recognized with any certainty. The following are a few notes on the subject, which may possibly be of some interest:—

1. In a perlitic obsidian (from Schemnitz, Hungary) the breadth of the perlitic fissures ranges from about $\frac{1}{3600}$ to $\frac{1}{3400}$ of an inch. Such a continuous perlitic fissure, when seen in section, may often be observed to thin away from the larger dimension to nothing. One can easily imagine that the devitrification of such a rock would result in the total obliteration of the more delicate fissures.

The fluxion-banding in this section consists of streams of microliths. A portion of one of the broadest lines in one of these streams measures $\frac{1}{1200}$ of an inch. Devitrification might not obliterate such a band, but it might easily render the recognition of its component microliths impossible.

2. In a section of a Mexican obsidian no fluxion-banding whatever is visible under the microscope, the only indication of flow consisting in the uniform direction of elongation of included gas-pores. The numerous microliths present in the section lie with their longest axes in all directions.

There are, therefore, in such a rock no structures which would bear testimony to its origin after devitrification. The result of such change would be simply a felsite without fluxion-banding and without perlitic structure.

In cases such as these, mode of occurrence and associations in the field could alone give a clue to the original nature of the rock.

The best example of fluxion structure which I have yet met with in the Caradoc district is in a rhyolite-tuff occurring at Bowdler's Chair at the southern extremity of the Gaerstones ridge. The

specimen collected, which is merely a small surface-chip, is a brown to dark purplish-grey rock, showing a brecciated appearance when examined with a pocket-lens.

The section has been taken at a depth of about an inch from the weathered surface and shows, under the microscope, that the rock is in great part composed of fragments of rhyolite (devitrified obsidian) which exhibit a delicate, well-defined fluxion-banding. This banding is frequently sinuous, but some of the fragments show markings which approximate to damascene structure.

The fragments are completely devitrified, displaying a micro- to crypto-crystalline structure when viewed between crossed nicols. There can, I think, be no doubt that they are fragments of devitrified obsidian.

With regard to the material in which they are embedded a more guarded opinion should be given. It is somewhat darker in colour than the rhyolite fragments and contains numerous little crystals and fragments of crystals of felspar, some of which show the repeated twin-lamination of plagioclase and, in one good example, the extinction-angle clearly indicates labradorite. Occasionally small grains of quartz may also be detected on employing convergent light. A little magnetite is likewise present.

This matrix, in which the larger rhyolite-fragments lie, also contains much smaller rhyolitic fragments, practically mere dust. The section is traversed by a network of very delicate fissures, which are filled with quartz and which cut through the rhyolitic fragments and the substance in which they are embedded.

V. CONCLUSIONS WITH REGARD TO THE FELSITES.

Looking at all the evidence afforded by the felsites described in this paper and by others collected at the same time but showing less marked characters, it seems that we have, in the Caradoc area, a great thickness of rhyolites, probably associated with tuffs, which, if of fine texture, might easily escape recognition in the field or afford no clear proof of their origin even under the microscope. The rock of Bowdler's Chair appears, in part at least, to be an unquestionable rhyolite-tuff, and as the adjacent felsites seem closely to resemble those of Caradoc, it may, I think, be assumed that the Caradoc and Hope Bowdler masses form part and parcel of one great series of lavas and tuffs, which, judging from their thickness, must once have been continuous over a wide area.

Before attempting to examine these rocks, I was aware that Prof. Blake* and Dr. Callaway† had alluded to the presence of rhyolites among them, but since their writings contained no detailed description which afforded evidence that these rocks were true rhyolites, further investigation seemed desirable. In the

* 'On the Monian and Basal Cambrian Rocks of Shropshire,' *Quart. Journ. Geol. Soc.* vol. xlv. (1890) p. 386.

† 'On the Unconformities between the Rock Systems underlying the Cambrian Quartzite in Shropshire,' p. 120 of this volume.

foregoing paper I have, therefore, endeavoured to supply some of the proof which seemed, hitherto, to be wanting.

VI. SUPPLEMENTARY NOTE.

When this paper was read I was not aware that Prof. Lapworth had been devoting his attention to the eruptive rocks of Caradoc and its neighbourhood. In the discussion which followed, Sir Archibald Geikie alluded to the detailed map which Prof. Lapworth had constructed and of the existence of which I was unfortunately ignorant.

On writing to Prof. Lapworth he most generously gave me a large amount of valuable information relating to his work and forwarded his unpublished map to me for inspection. The latter is, unquestionably, a very careful and detailed piece of surveying: a map which, when published, will be the most important exponent of the geology of this district which has ever appeared. On it the basic rocks and rhyolites are duly recognized, while the boundaries of many intrusive sheets which, in my brief examination of the ground, passed unnoticed by me, are laid down.

It is only just that I should take this opportunity of bearing testimony to the splendid work which Prof. Lapworth has done, and is doing, in this district, and I would also gratefully acknowledge his courtesy in so readily communicating the result of his labours.

EXPLANATION OF PLATE XIX.

- Fig. 1. Vesicular melaphyre (altered vesicular basalt-glass). S.W. side of Caer Caradoc, near the top of the hill. $\times 30$ linear.
2. Ditto, $\times 140$, showing corroded feldspars.
3. Melaphyre (amygdaloidal), showing pilotaxitic structure. S.W. side of Caradoc, about 100 feet below the Camp. $\times 45$.
4. Melaphyre tuff (altered vesicular basalt-glass tuff). S.W. side of Caer Caradoc, at the top of the hill. The broad, pale, diagonal band represents cementing material. $\times 18$.
5. Perlitic felsite (devitrified obsidian). Above Caradoc Coppice, S. end of Caradoc Hill, N.W. flank. $\times 45$. Crossed nicols.
6. Portion of the section represented in figs. 1 and 2, showing a pseudomorph of magnetite after olivine. $\times 140$.
7. Portion of the section represented in figs. 1, 2, and 6, showing skeleton crystals. $\times 75$.

Figs. 1, 2, 6, and 7 are from specimen No. XII.

Fig. 3 is from specimen No. X.

Fig. 4 „ „ „ No. XIV.

Fig. 5 „ „ „ No. II.

DISCUSSION.

The PRESIDENT alluded to the detailed mapping of the Caradoc region by Prof. Lapworth, which, though not yet published, was known to many Fellows of the Society, and included the recognition of rhyolites, rhyolitic tuffs, and basic sheets. He believed that the views of Prof. Lapworth and Mr. Rutley would be found to be in the main accordant.

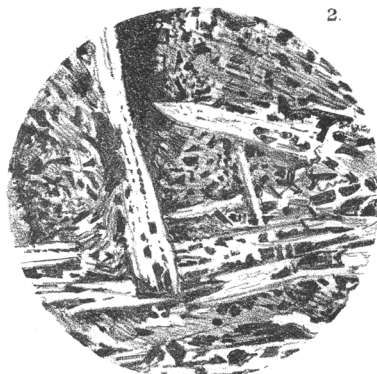
Prof. BONNEY also spoke.

THE AUTHOR, in reply, stated that he had not seen the large-scale map of Caradoc, mentioned by the President, nor was he aware that Prof. Lapworth had mapped these volcanic rocks. He trusted, however, that, in both instances, the results would be found to correspond.

He fully endorsed Prof. Bonney's remarks with reference to the difficulties met with in attempting to work out the original structures in the felsites.



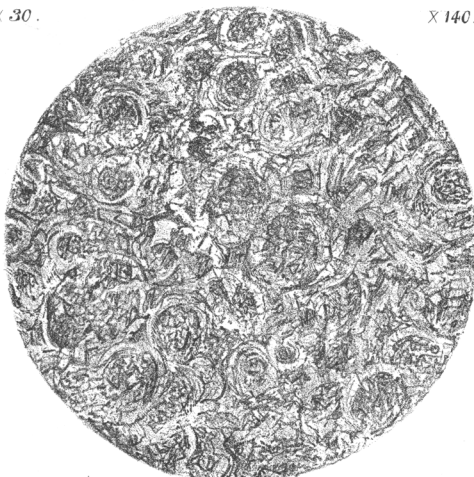
$\times 30$.



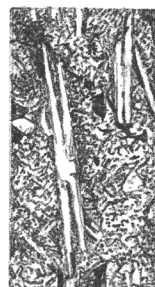
$\times 140$.



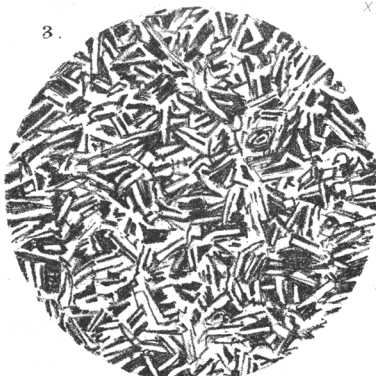
$\times 140$.



$\times 45$.



$\times 75$.



$\times 45$.



$\times 18$.

Frank Rutley del. F.H. Michael lith

Mintern Bros. imp

1, 2, 3, 4, 6, 7. MELAPHYRES OF CARADOC HILL.

5. PERLITIC FELSITE ABOVE CARADOC COPPICE.