AUSTRALASIAN ANTARCTIC EXPEDITION
1911-14
UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, D.Sc., F.R.S.

SCIENTIFIC REPORTS.
SERIES A.
VOL. IV.

GEOLOGY.

PART 6.

CERTAIN EPIDOTIC ROCKS FROM THE MORAINES, COMMONWEALTH BAY.

BY
J. O. G. GLASTONBURY, B.A., M.Sc.

WITH ONE PLATE.

PRICE: ONE SHILLING AND SIXPENCE.

Wholly set up and printed in Australia by
THOMAS HENRY TENNANT, GOVERNMENT PRINTER, SYDNEY, NEW SOUTH WALES, AUSTRALIA.
1940.

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PART 6.

CERTAIN EPIDOTIC ROCKS

FROM

THE MORAINES, COMMONWEALTH BAY.

BY

J. O. G. GLASTONBURY, B.A. M.Sc.

[A.A.E. Reports, Series A, Vol. IV, Part 6, Pages 183-196.
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Issued, May, 1940.

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CERTAIN EPIDOTIC ROCKS

FROM THE

MORAINES, COMMONWEALTH BAY.

BY

J. O. G. GLASTONBURY, B.A., M.Sc.

1.—INTRODUCTION.

Rocks of this kind from the Expedition collections have been discussed by Dr. Stillwell (this series, Vol. III, Pts. 1 & 3), but several distinct types remain to be described. These will be dealt with here.

All the rocks here described were collected as erratics from the Moraines at Cape Denison. It has been found possible to divide them into five main groups.

As is to be expected, there is not a sharp division between some of these groups. Sub-group (2) of group (A) is clearly a modification of sub-group 1, to which it has very close affinities. The extent to which saussuritization must develop before a rock is placed in sub-group 2 is decided almost solely from the subjective point of view. Even so, there is no doubt that the members of one extreme have important differences from those of the other extreme. A difficulty, ultimately of the same nature, is encountered in the separation of members of group (D) from those of groups (A), (B), and (C). Again, the classification is subjective for the reason that so few rocks are here dealt with that one could not draw up a classification table from Rosiwal analyses which would be comprehensive enough to be of value. Much the same is true of the classificatory position of group (E). Some of its members could quite well form a sub-division of group (A), while others have affinities with the porphyritic rocks.

The nomeclature employed calls for little discussion. The names which have been adopted are those in general use. The detailed descriptions of the individual rocks will show the more specific characters such as schistosity, etc. In group (D) the rocks are tentatively classed as epidosites. This, however, is not in accordance with the strictest use of the term. Epidosites are ordinarily taken as those rocks in which epidote comprises at least eighty per cent of the rock and which have quartz as practically the only accessory mineral. In the present group, however, while the epidote content certainly exceeds the minimum requirement, the accessory minerals are not ordinarily quartz. Indeed, quartz is sometimes entirely absent. In view of this, and that felspar or actinolite figures prominently among the accessories the extended significance of the term and some justification for this extension are apparent. No particular group name is given to group (E). The members are quite different from one another except for the common property of having suffered some cataclasis.

The genesis of rocks such as these has been discussed by Stillwell (op. cit., above). There is little need to add to what he has remarked except to emphasize that much of the calcic material required for the formation of the epidote has come from exterior sources. In other words these rocks have, with few exceptions, suffered a kind of alteration which is not metamorphism " in sensu stricto." There are, however, one or two rocks which have been affected in the latter manner ; these will be indicated more particularly in the sequel.

II.—PETROGRAPHY.

GROUP (A).

Sub-group (1).

The Felspar-Epidote Rocks.

The members of this group are Nos. 883, 615, 715, 589, 815. No. 589 has peculiarities which prevent its being included satisfactorily in any of the above groups. It fits most closely in group (A) and consequently is described here. No. 815 is allied to the hornblende, biotite, chlorite rocks of group (D). Its more general properties associate it with the members of group (A). It, too, is treated here. No. 883. Massive pink felspar comprises the main portion of this rock. A subordinate amount of olive-green epidote occurs extensively on one face of the specimen.

Microcline constitutes about 80% of the rock. It occurs in granular patches where the grains are, for the most part, of simple outline. The mineral is patchily turbid, portions of the one grain being quite clear and others highly kaolinized. The cleavage is prominently developed. The refractive index is low. Cross hatching twin effects are characteristic. Some sections show only one set of twin lamellae which are invariably spindle-shaped and unevenly distributed through the grain. Rarely a crystal without twins is seen.

The only other mineral present is yellow-green epidote. It is prominent because of its high relief and relative colour-strength. Its distribution is most sporadic. Its origin is obscure. Certainly its calcic content was not in the original microcline rock. Its occurrence in the hand specimen points to solution effects being important in its development.

No. 615. Large pink felspar crystals are separated from one another in this rock by streaks and veins of yellow-green epidote. A dark green ferro-magnesian also is present. A dull greyish vein of quartz crosses one part of the rock.

The mineral composition of this rock is a little more complicated than that of No. 883. Microcline, quartz and epidote are essential, while chlorite, sphene, apatite, magnetite and tremolite are important accessories.

The microcline is not nearly so common as in the previous rock. Its general characteristics are, however, much the same.

Quartz which was absent from the preceding rock is quite important here. It occurs as clear masses whose refractive index is higher than that of the microcline. It seems related to the crystals of epidote as a base in which the latter formed. This is shown by the idioblastic nature of the epidote prisms which quite commonly lie in the quartzose masses. Allied to these two minerals and in close association with them are needles of actinolite. These needles are found in tufts which apparently emanate from the vicinity of the epidote prisms and proceed into the quartz areas proper. They are definitely confined to the quartz regions, and do not occur in the felspathic portions of the rock.

In addition to the properties described above, the epidote is seen in pleochroic crystals of yellow-green colour. They are not only associated with quartz, but lie between adjacent microcline crystals. An unusual feature is the intimate juxtaposition of large sphene crystals with epidote in one or two places. Superficially the sphene resembles the epidote ; high relief, strong borders and colour-likeness in some positions. The explanation must be that local concentrations of titanium have resulted in the formation of the sphene, while round these nuclei the excess calcic and aluminous material have produced the more usual epidote.

The chlorite present is interesting. It is strongly pleochroic in pale blue-green and straw colour. It is scaly or flaky. It is almost isotropic or else shows anomalous birefringence colours. In places it is associated with epidote to which material it is giving place. The other minerals present call for no further comment.

No. 715. This is a gneissic rock consisting of poorly defined bands of pink felspar and greenish epidote. Two of the larger faces of the specimen represent an earlier vein along which the specimen was broken from a larger slab. The vein consists of a peculiarly yellow-green mass of epidote ; one face of the vein is pronouncedly corrugated.

The gneissic character of the rock is seen under the microscope to be the result of intrusion of solution matter along lines of weakness. These contain practically all of the quartz in the rock and certainly all of the coloured constituents. These last are like those of No. 615, except that epidotization has not proceeded quite so far, and that less sphene and more magnetite and apatite are present.

The veins, as in the case of No. 615, are thrust between microcline grains.

No. 589. Fine bands consisting of white felspar and light bottle-green epidote make up this rock. Stains of hydrated iron ore minerals are present.

The gneissic banding is by no means so prominent under the microscope, but rather is the rock granoblastic.

Prominent among the minerals present is very cloudy epidote. So turbid is the mineral that in places it is quite dark and almost opaque. In other places there is present a very clear variety of epidote. It shows strong pleochroism in lemon-yellow and colourless. The distribution of colour in any particular grain is usually irregular, reflecting the corresponding variability of iron content in the mineral.

Closely associated with this clearer variety of epidote which occurs exclusively in the clearer felspathic regions are three minerals, sphene, lawsonite and chlorite. The first is quite common in this rock. Small brown lozenges of the material regularly occur in chains throughout the epidote masses (sometimes in the more turbid variety as well). The lawsonite is found in colourless well-cleaved prisms which have a slight tendency to radiate grouping, thus forming a sector of a circle of small angle. The birefringence is not very high, about 0·019, the mineral is optically positive, extinction straight and elongation negative. The chlorite is pale green to colourless. It is derived partly from earlier biotite and possibly from hornblende as well. It is giving place to epidote. A transitional stage is the development of the circular fibres of tremolite, which in this rock are not very common.

The rest of the rock is comprised of an acidic plagioclase. Twinning is not prominent, but poorly developed albite twins and rare pericline twins are present. The latter in combination with the former produces a cross-hatching, which, in places, is much like the microcline peg-structure. The high (comparatively) refractive index of the mineral distinguishes it from the last-named substance. Alteration is indicated by early stages in perthitic texture development and the discontinuous development of the twin lamellae in the crystals. Saussuritisation, as a distinct alteration process, has also proceeded slightly.

No. 815. This is another gneissic rock in which bands of pink and white felspar are separated by a fine granular mass composed mainly of epidote ; some iron ore, however, is also present.

As has been indicated above, this rock is with difficulty placed in any of the groups of this classification. The amount of biotite, chlorite, actinolite is too small to allow of its being placed in group (E); it can hardly be placed in group (B) for similar reasons, and in consequence it has been placed in group (A) because of the predominance of felspar and epidote.

This rock, unlike No. 589, preserves its gneissic nature on the microscopic scale. Definite bands of felspar are separated from one another by bands consisting mainly of epidote, but which always carry a certain amount (occasionally a comparatively large amount) of biotite, which is altering to chlorite and actinolite.

The felspar is a little turbid, which results in the mineral appearing patchy under crossed nicols ; it is not saussuritized to any extent. There are two varieties of felspar present. These occur in equal proportions. One is the triclinic potash felspar microline ; the other is an acidic plagioclase, about $Ab_{80}An_{20}$. Both felspars show twin lamellae, those of the plagioclase being decidedly tapered.

The epidote presents the usual characteristics.

The chlorite-biotite is of a brownish yellow-green colour. In places it has altered more than in others, producing a patch-work appearance. The birefringence is quite variable, from ultra-blue and reds where chlorite predominates to second order colours where the biotite has not altered very much.

Akin to this biotite-chlorite material is some pale green pleochroic actinolite. This mineral has a tendency to fibrous and needle forms. It shows all the characteristic optical properties, viz., extinction about 18°, negative optical nature, negative elongation, optic axial angle about 80°.

Considerable sphene is present in large lozenges which show one cleavage particularly well developed, that parallel to 010 face. Appreciable apatite and a little zircon are present. The rock is singularly free from magnetite.

Sub-group (2).

The Saussuritized-Epidote Rocks.

The two members of this sub-group are Nos. 226, 249.

These two specimens are closely allied to the injection gneisses which are found in the moraines at Cape Denison and which are described in the present work. Each is a pegmatitic mass of felspar in which are set large hornblende crystals. Thus far the rocks are identical with some of the so-called intermediate gneisses referred to in an earlier sentence. In addition to these minerals there are veins of pale yellow-green epidote. These veins clearly represent the result of hydrothermal action on the earlier rock. Most probably the original amphibolite area was first intruded by the pegmatitic material producing lines and zones of weakness in the rock. Later, possibly as the last stage in this acid igneous attack, but more likely quite distinct from this, the material now appearing as zoisite was introduced into the rocks by hot solutions which were able to force their way into the gneiss along the lines of weakness mentioned above.

No. 226. Some idea of this rock is given in the previous paragraph. In addition, it may be mentioned that the epidote veins are most pronounced in the amphibolite portions of the rock, but thinner veins—continuations of the stronger ones in the hornblende—do cut through the felspathic portion. Some brownish biotite is also seen.

A basic plagioclase, labradorite with $Ab_{55}An_{45}$, is the commonest mineral present. As the title of the sub-group shows, the plagioclase is highly turbid and greatly saussuritized. Twin lamellae, of the albite kind, are seen, but in places are discontinuous because of the development of a rude perthitic texture. Bends in the twin lamellae are common and point to the part played by shearing stresses. Occasional micrographic intergrowths of quartz and felspar occur between large plagioclase crystals.

The earliest of all the minerals present is a pleochroic hornblende, which is considerably chloritised. The latter mineral shows typical ultra-blue interference colours.

The hornblende is cut by veins of epidote and plagioclase. This felspar is granoblastic ordinarily and of very small grain size. Rare laths are seen. Sphene is a prominent member of these veins, and frequently occurs plentifully and continuously enough to form subsidiary veins within the larger ones. It shows its usual features, and, in addition, multiple twinning, possibly parallel to (221). Such twinning is usually accompanied by a strongly developed parting which is distinctly visible in the present mineral; it is also strong evidence of the action of powerful shearing stresses, which, in this rock, are also manifested by bends in the twin lamellae of the felspar, the laths of chlorite and the prisms of hornblende.

The epidote veins not only cut the hornblende areas of the rock, but also the felspathic. They are then more compact and unaccompanied by appreciable quantities of the other minerals.

The epidote of the rock is not confined to veins, but larger concentration areas occur where the mineral is more massive. It then is frequently accompanied by zoisite. It, in these regions, shows strong pleochroism from honey-yellow to colourless. As is to be expected, the borders of these large areas are much less compact than the central parts. Smaller, and to some extent, separated crystals are here. These small crystals are idioblastic, usually prismatic, but not infrequently considerably elongated on the side near the felspar and then developing pronounced acicular forms.

No. 249.—The hand specimen is of a coarsely crystalline gneissic rock in which large pegmatitic-like felspar crystals of a faint rose-pink colour are set in a mass of dull green hornblende. The hornblende is, for the most part, a meshwork which serves as the containing structure which holds the felspar. In places, however, the fibres of hornblende have been forced apart and the pegmatitic matter has entered along the openings. Veins of epidote and quartz cross both amphibolic and felspathic regions and are thus seen to be of later formation than either of these two.

Under the microscope the whole rock is seen to be much lighter in hue than No. 226. This is true, first, in connection with the felspar. Whereas in No. 226 dark patches of indeterminate material were widely spread throughout the plagioclase, in this rock metamorphism has proceeded further—to the stage of the formation of two definite minerals, epidote and zoisite. These minerals form the larger inclusions which partly comprise the poikiloblastic aggregate known as saussurite. The smaller saussuritic component is a micaceous mineral, probably allied to sericite.

The epidote, which is widely distributed through the rock, is the second mineral whose colour is much lighter than in No. 226—reference is now made to those parts where the epidote occurs continuously, and not as a component of saussurite. Instead of being a golden-yellow colour and pronouncedly pleochroic, the epidote is uniformly light and non-pleochroic. It is also replaced, to a very large extent, by zoisite.

The hornblende, too, shows this falling-off in colour-intensity. In No. 226 chlorite and hornblende occurred alternately within a single individual prism, where the chlorite had a deep olive green colour, much like that of the hornblende. Here, in No. 249, there is no such close association. Chlorite occurs as independent crystals of a very pale green colour, and the hornblende very much reduced in quantity, occurs in pale, frail-looking masses like those found in feather-amphibolites.

Stress effects are not lacking in this rock, but rather do they seem to be more intense in this rock than in No. 226. The bends in the felspar lamellae are often bent back upon themselves. Similar general S-shapes are seen in the veins of epidote where small grains of this mineral, and more particularly zoisite, are so aligned as to trace out the shape of the S. The crystals of chlorite and hornblende are likewise lightly curved.

Sphene occurs in this rock, not in long veins, but as isolated grains which almost invariably have ilmenitic nuclei.

Quite a considerable quantity of scapolite occurs within the felspathic regions.

GROUP (B).

The Epidote-Actinolite-Felspar Rocks.

There are four members of this group, viz., Nos. 546, 368, 602 and 931. They are alike only in that the mineralogical composition is as indicated above.

No. 602.—This rock is very much like the members of sub-group (1) of Group (A). For this reason it is treated next so that the resemblances and differences will be the more readily seen. It is a pegmatitic rock consisting of pinkish felspar in which are found patches of the dark green acicular mineral actinolite, and a little less commonly, yellow-green grains of epidote.

The felspar is not at all saussuritized. It consists of plagioclase, $Ab_{70}An_{30}$, which is rather turbid, but which shows albite twins well developed. Some little bending of the lamellae is evident.

The amphibole is very pale green. At the ends of the long massive prisms where the mineral meets the plagioclase, are either epidote grains exhibiting idioblastic outline or a mass of fine needles of colourless tremolite. Where this tremolite is particularly abundant, the felspathic regions are quite clear, which shows that assimilation of some portion of the felspathic content has occurred. There are still visible faint albite twin lamellae in these areas.

The epidote of the rock is very massive. Much more regular zonal arrangements within the epidote are shown by the double refraction colours than is ordinarily the case with this mineral. Instead of epidote, zoisite is sometimes found. Multiple twin lamellae in this last material are of interest.

Sphene occurs in swarms of small grains in the epidotic areas. Apatite is present to an appreciable extent.

No. 546.—Unlike No. 602, this rock is very fine-grained, banded and of grey yellow-green colour. Epidote, amphibole and felspar are identifiable in the bands. Some quartzose bands are seen in the hand specimen. This rock is almost identical with No. 257, described by Stillwell.

The gneissic banding is even more pronounced under the microscope. Regions comprised mainly of granoblastic felspar alternate with those of granoblastic and idioblastic epidote. Neither region is absolutely homogeneous. The felspathic portion, which is mainly microcline, contains an occasional grain of bright honey-yellow pleochroic epidote, and more than occasional flakes of the pale green orthorhombic amphibole anthophyllite. The epidotic portion consists of crystals of epidote between and around which occur prisms of anthophyllite (Plate VIII, fig. 1). Sphene grains and more compact monoclinic amphibole masses are not uncommon in these regions. A very little apatite is found in the rock.

No. 368.—This is an amphibolite rock which has been penetrated by veins of epidote matter. In consequence of this, we find a dense, heavy, compact fine-grained amphibole rock crossed by yellow veins of granular epidote.

The same two major divisions are perceptable under the microscope. The amphibolitic portion is a low-grade plagioclase-hornblende-schist. The hornblende is pale green tremolite. The plagioclase is acid oligoclase. In addition to these determinative minerals are sphene which usually has an ilmenitic nucleus and sporadically-occurring grains of pleochroic epidote.

The main epidotic masses consist of a felty mass of elongated prisms. Very rarely a crystal of actinolite carrying a few grains of sphene is seen in this area. In one portion of the epidote area a small vein of calcite crosses the rock. Apatite and free ilmenite comprise the accessories of the amphibolitic areas.

GROUP (C).

The Hornblende (or Biotite)-Epidote-Felspar Rocks.

Included in this group are Nos. 379, 410, 425.

These rocks represent earlier amphibolitic species which have been subjected to epidotization at a subsequent stage in their history. They are naturally dark and dense. Moreover, vein-material of epidote (and of quartz in No. 379) criss-crosses the rocks. No. 415 has a surface coating of well-developed green prismatic crystals on one face.

No. 379.—This rock was originally a plagioclase-hornblende-schist, but subsequent intrusions of quartz and possibly epidote, too, have considerably modified it.

The original felspar now shows the strain effects, to which it has been subjected, by extensive development of mortar structures. The quartz, on the other hand, is entirely free from such textures. The explanation is that it was the forcing apart of the felspathic and hornblendic areas (for the latter likewise are granulated) by the incoming siliceous solutions which caused the shattering seen in the rock.

These more truly hornblende schist areas still retain many of their characteristic features. Other modifications than those mentioned already are chloritisation of the hornblende which is a retrograde effect, the presence of long-strings of sphene and veins of epidote.

The newer material is mainly quartz. This is quite clear except for evenly distributed magnetite specks. Associated with this quartz, and acting as a division between it and the earlier material is a remarkable development of epidote crystals. These crystals form definite coronas around earlier plagioclase and hornblende alike (Plate VIII, fig. 2). They are most likely the expression of the reaction which has occurred between the invading siliceous material and the calcic and argillaceous material originally present.

No. 410.—The rock in its present form is a biotite-plagioclase schist which has been affected by epidote-invasion. Whether the rock was originally a biotite-schist or a hornblende-schist is impossible to be decided. If the latter, then the hornblende, as in No. 379, has suffered a retrodgrade metamorphic change which probably is the result of the epidotizing solutions.

There is a fairly high percentage of sphene and apatite among the accessory minerals, and allanite, also, is somewhat more prominently developed than usual. The epidote itself is of a pale yellow colour, non-pleochroic and compactly arranged.

Textural features are mainly determined by stress conditions. Bent prisms of biotite, curved masses of the more brittle epidote and crushed areas in the felspar all show how potent this factor has been in shaping the rock.

A mineralogical change worthy of comment is the decided conversion to chlorite of the biotite which has been entrapped in the epidotic areas.

No. 425.—This rock is a epidote-albite-hornblende-chlorite schist in which a little more epidote than ordinary is present. For this reason the rock is placed in the present division and not that part of the work which treats of the epidiorites and their allies.

The actinolitic tendency of the amphibole, the elongation of the chlorite and the parallelism of the epidote impart a decided schistosity to the rock.

Other minerals, besides the above, which are present, are sphene, quartz and apatite.

GROUP (D).

The Epidote Rocks.

The members of this group are Nos. 254, 255, 415, 642. Of these, the first three are closely related to epidosites proper, while No. 642 is a highly epidotic intrusive of a pegmatitic felspar gneiss. The last-mentioned rock will be described first.

No. 642.—The major portion of the rock is a heavy dense mass of yellow-green epidote intimately knit-up with lustrous black hornblende. The lesser portion represents the original felspar pegmatite. It consists of a band from half an inch to an inch wide, of pink felspar which has been split into finer bands, perhaps as thin as 0·02 of an inch, by the epidote-bearing matter.

Little more is learnt of the rock by a microscopic examination. The epidote is mainly compact, but where it gives place to felspar, the individual crystals become separated and a meshwork of the two minerals is then visible. The felspar, where porphyroblastic, is greatly crushed. Sphene, hornblende and apatite are present.

The hand specimens of Nos. 254, 255, 415 are somewhat alike. The first is darker in colour than the other two, both of which show small (up to one-quarter of an inch in length) crystals of epidote. Some quartzose matter appears to be interstitial.

No. 254.—This rock consists of granulated epidote which is crossed by small veins of quartz and felspar. The epidote is mixed with some chlorite and sphene. The former, no doubt, is responsible for the dark hue of the rock, while the latter usually carries ilmenitic nuclei.

The quartz and felspar differ in the response they show to stress. The former has become very finely granulated, but the latter seems almost entirely unaffected. The epidote, like the quartz, has, in places, been reduced to a fine granulitic mass.

No. 255.—An unusual feature of this rock is the presence of vein-calcite. This matter, together with quartz and a very little hornblende and sphene, fills the interstices of the epidote-rock. The other characteristics of the rock are those of the normal members of the epidosites.

No. 415.—This rock, which was collected *in situ* east of Lake III, at Cape Denison, differs from normal epidosites in having interstitial oligoclase instead of quartz. Some sphene and pale blue-green chlorite are found among the massive epidote crystals.

Apart from these features there is nothing worthy of comment.

GROUP (E).

Rocks showing pronounced Cataclastic Effects.

The two members of this group are Nos. 727 and 1242. The former is a gneiss showing crush effects in epidote and felspar; the latter is a porphyritic rock which has suffered epidotisation and some granulation.

No. 727.—This is a mixture of large crystalline epidote regions and brecciated hornblende masses.

Microscopically, the hornblende is less obvious. It is considerably chloritised and has little colour. More prominent than this is vein-quartz which occupies a considerable portion of the rock. The individual particles show strain polarisation, sutured edges and some granulation. There is a little felspar in these parts of the rock.

The main part of the rock is occupied by epidote, which is greatly crushed. Small granulated particles, instead of large well-defined prisms, typify the rock.

No. 1242.—This rock is prominently banded. Green epidote, pink felspar and dull chloritised-epidote bands alternate.

Traces of the original porphyritic nature of the rock are seen under the microscope. Phenocrysts of slightly saussuritised acid plagioclase are present. Round them flow bands of highly crushed felspathic groundmass and granular epidote.

An occasional brownish red phenocryst of very low double refraction is possibly hematite-stained serpentine after olivine.

The groundmass proper of the original rock has been intensively crushed and now consists of very fine granular epidote and felspar. Some small shreds of pale green chlorite occur in these granulated areas.

III.—EXPLANATION OF PLATE VIII.

Fig. 1. *Epidote-anthophyllite-felspar-gneiss.* Specimen No. 546, erratic from the Moraines at Cape Denison.

Globular crystals of epidote around which are woven fibrous masses of anthophyllite and actinolite are shown. Some interstitial felspar and quartz are also present. Mag. 44 diams.

2. *Hornblende-epidote-felspar rock.* Specimen No. 379, erratic from the Moraines at Cape Denison.

The centre of the photo is occupied by a crystal of hornblende surrounded by a corona of epidote; the whole set in a matrix of felspar. Portions of other similar hornblende masses are to be seen. Mag. 38 diams.

Sydney: Thomas Henry Tennant, Government Printer—1940.

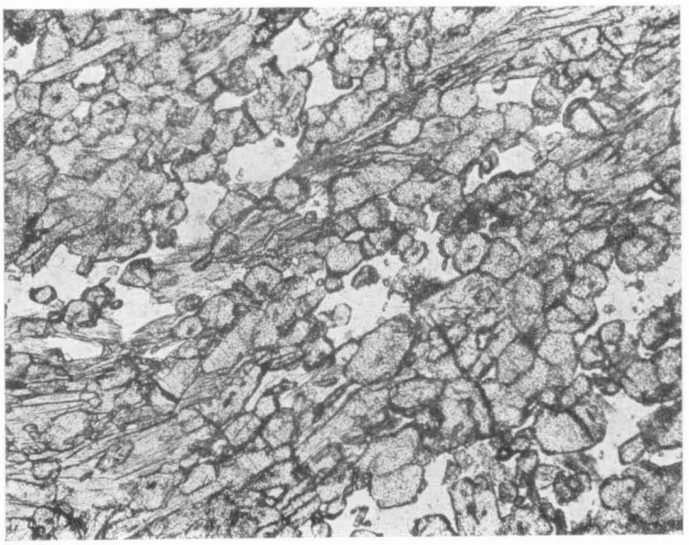

Fig. 1.

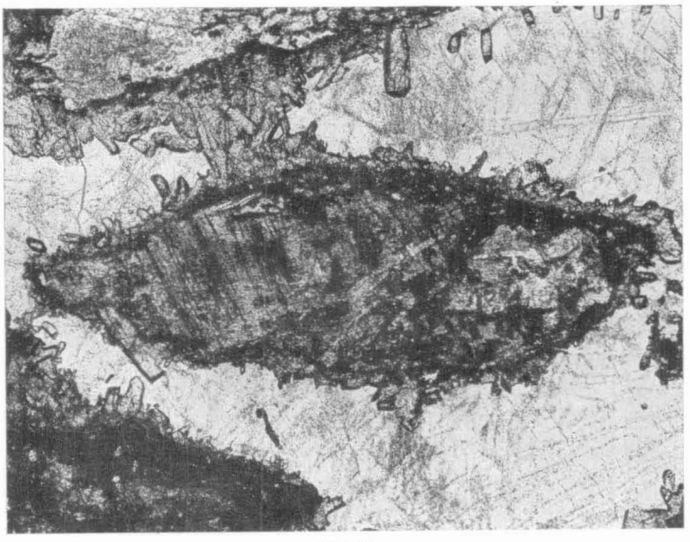

Fig. 2.

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