AUSTRALASIAN ANTARCTIC EXPEDITION

1911-14.

UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, Kt., D.Sc., B.E

SCIENTIFIC REPORTS.

SERIES A.

VOL. III.

**GEOLOGY.**

PART IV:

# AMPHIBOLITES AND RELATED ROCKS

FROM

# THE MORAINES, CAPE DENISON, ADELIE LAND.

BY

F. L. STILLWELL, D.Sc.

WITH TWO PLATES.

PRICE: TWO SHILLINGS.

Printed by Alfred James Kent, Government Printer, Phillip-street, Sydney.—1923.

ISSUED AUGUST, 1923.

## SERIES A—REPORTS.

HON. EDITOR: PROF. SIR DOUGLAS MAWSON, KT., D.Sc., B.E., O.B.E., F.R.S.

---

| VOL. | PRICE. £ s. d. |
|---|---|
| I. GEOGRAPHY AND PHYSIOGRAPHY. (*In preparation.*) | |
| II. OCEANOGRAPHY. | |
| PART 1.—SEA-FLOOR DEPOSITS FROM SOUNDINGS— By FREDERICK CHAPMAN, Ass. Linn. Soc. (Lond.), F.R.M.S., &c., National Museum, Melb. | 0 6 0 |
| III GEOLOGY. (*Adelie Land and King George Land.*) | |
| PART 1.—THE METAMORPHIC ROCKS OF ADELIE LAND— By F. L. STILLWELL, D.Sc., Aust. Antarc. Exped. Staff | 2 2 0 |
| „ 2.—THE METAMORPHIC LIMESTONES OF COMMONWEALTH BAY, ADELIE LAND. By C. E. TILLEY, B.Sc. ... ... ... ... ... ... ... | 0 1 6 |
| „ 3.—THE DOLERITES OF KING GEORGE LAND AND ADELIE LAND, By W. R. BROWNE, D.Sc., Lecturer, Geological Department, Sydney University | 0 1 6 |
| „ 4.—AMPHIBOLITES AND RELATED ROCKS FROM THE MORAINES, CAPE DENISON, ADELIE LAND. By F. L. STILLWELL, D.Sc., Aust. Antarc. Exped. Staff | 0 2 0 |
| IV. GEOLOGY. (*Will deal principally with Queen Mary Land.*) (*In preparation.*) | |
| PART 1.—THE ADELIE LAND METEORITE. By P. G. W. BAYLY, F.I.C., and F. L. STILLWELL, D.Sc. | 0 1 6 |
| V. GEOLOGY (*Macquarie Island*). (*In preparation.*) | |
| VI. GLACIOLOGY. (*In preparation.*) | |


QUEEN MARY LAND
PERTH
MELBOURNE
MACQUARIE ISLAND
ADELIE LAND
29
30
30
29
29
JANUARY
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

AUSTRALASIAN ANTARCTIC EXPEDITION

1911-14.

UNDER THE LEADERSHIP OF SIR DOUGLAS MAWSON, KT., D.Sc., B.E

SCIENTIFIC REPORTS.

SERIES A.

VOL. III.

GEOLOGY.

PART IV:

# AMPHIBOLITES AND RELATED ROCKS

FROM

# THE MORAINES, CAPE DENISON, ADELIE LAND.

BY

F. L. STILLWELL, D.Sc.

WITH TWO PLATES.

PRICE: TWO SHILLINGS.

Printed by Alfred James Kent, Government Printer, Phillip-street, Sydney.—1923.

ISSUED AUGUST, 1923.

# AMPHIBOLITES AND RELATED ROCKS FROM THE MORAINES, CAPE DENISON.

BY
F. L. STILLWELL, D.Sc.

WITH TWO PLATES.

## CONTENTS.



* The classification adopted is that proposed by U. Grubenmann in "Die Kristallinen Schiefer." Berlin, 1910.

## I.—INTRODUCTION.

A GREAT variety of metamorphic rocks were collected from the moraines at Cape Denison, in Adelie Land, and the following notes give some account of the amphibolites and related rocks. Three specimens, which are specifically mentioned, are fragments of erratics found at Cape Hunter, nine miles west of Cape Denison. The basis of the grouping of these rocks is Grubenmann's chemical classification, with its zonal subdivisions, and this section includes Groups IV, V, and III, the Amphibolites and Eclogites, the Magnesium Silicate Gneisses, and the Plagioclase Gneisses. Each group is subdivided into three divisions (based on mineral composition and on structure) called the Kata, Meso, and Epi divisions. In the Kata division of these groups the pyroxene is in excess of the hornblende; in the Meso division the hornblende is in excess of the pyroxene; and in the Epi division there is a pronounced development of saussurite, lawsonite, epidote or chlorite, and also of mechanical structures. These groups are defined by their chemical composition, and the use of the classification is therefore restricted by the absence of complete chemical analyses. The chemical composition is, however, reflected in the mineral composition, from which the divisions of each group have been in most cases recognised.

The term *amphibolite* is used with the same meaning adopted in the memoir on the metamorphic rocks occurring *in situ* at Cape Denison.[1] It may be defined as a completely recrystallised rock of basic igneous chemical composition, whose mineral content is essentially hornblende and plagioclase. The latter mineral can be replaced wholly or partly by other minerals, such as zoisite, epidote, garnet, or scapolite. When the amphibolite possesses a strongly-foliated character it has been called an *amphibolite-schist*. In many cases the schistose structure is accentuated by the partial replacement of hornblende by biotite or chlorite, and the term *amphibolite-schist* becomes equivalent to the terms *biotite, chlorite or mica-amphibolite*.

[1] "Metamorphic Rocks of Adelie Land." F. L. Stillwell. Scientific Reports, A.A.E., Vol. iii, pt. 1, pp. 24, 25.

This usage does not conform with the definition issued by the Joint Committee of the Geological Society of London and of the Mineralogical Society in the recent report on British Petrographic Nomenclature[1]. This Committee retain the term *amphibolite* for unfoliated or slightly-foliated metamorphic rocks of doubtful or other than igneous origin. It is composed essentially of hornblende and felspar, often containing various accessories, such as epidote and garnet. They distinguish *hornblende-schist* from amphibolite by the possession of a foliated texture.

On this basis completely recrystallised rocks, which consist of hornblende and felspar, and which possess a slightly-foliated structure, are excluded from the family of amphibolites when they are derived from igneous rocks. It would appear to be the intention of the Committee to include such cases among the *epidiorites* which are defined as unfoliated basic igneous rocks in which the augite is completely altered to hornblende. They seem to have overlooked the fact that two types of altered basic hornblende rocks, occurring in the form of a dyke or sill, can be recognised,—(1) those in which the ferro-magnesian has suffered recrystallisation, and (2) those in which both the ferro-magnesian and felspar have suffered recrystallisation. These two types may be encountered in one area, as at Broken Hill (New South Wales), where they are readily distinguishable from one another in the field, in the hand specimen and under the microscope. The term *epidiorite* covers the first type, and it is clearly undesirable to extend it to the second type, which is identical with *amphibolite*.

A typical amphibolite will contain 60 to 70 per cent. of hornblende and about 25 to 30 per cent. of felspar. Other metamorphic rocks occur which contain nearly all hornblende and practically no felspar, and it is necessary for precise description to distinguish these from the typical amphibolite. It is also desirable to distinguish between the foliated amphibolite and the hornblende schist with felspar in excess of the hornblende. These metamorphic types, in which hornblende is an important constituent, may be tabulated as follows :—

| Mineral composition. | With massive structure. | With foliated structure. |
|---|---|---|
| Mainly hornblende ... ... | Hornblende fels ... ... | Amphibole or hornblende-schist. |
| Hornblende in excess of felspar... | Amphibolite ... ... ... | Amphibolite-schist or mica-amphibolite |
| Felspar in excess of hornblende | Hornblende-plagioclase-gneiss | Hornblende-plagioclase-schist. |

The massive types pass by gradual transitions into the foliated types. It is obviously difficult to restrict the term *hornblende-schist* to foliated amphibolites, as recommended by the Joint Committee. It is more logical to use the term for the pure amphibole types as has been done by Grubenmann[2]. The term *amphibole-schist* includes rocks which contain more than one variety of amphibole, but those which contain anthophyllite are referred to as anthophyllite schists in the following pages.

[1] "Report on British Petrographic Nomenclature." Min. Mag., Vol. xix, No. 92, pp. 137-147, 1921.
[2] "Die Kristallinen Schiefer." U. Grubenmann. Berlin, 1910, p. 216.

## II.—Group IV.—THE AMPHIBOLITES AND ECLOGITES.

At Cape Denison the variety of types occurring *in situ* is considerably increased by a study of specimens collected from the moraines. The main occurrences *in situ* consist essentially of felspar and hornblende, with or without biotite. They have been looked upon as basic igneous dykes which have recrystallised under conditions varying from those of Grubenmann's Meso zone to those of the Epi zone. The moraine types include representatives of the Epi, Meso, and Kata divisions, and some are similar to members of the Cape Gray series, occurring 25 miles to the east.

### Kata Division.

The distinguishing feature of the Kata division of this group is the abundance of pyroxene. A representative is specimen No. 937, a hornblende-plagioclase-pyroxene-gneiss, which possesses similar features to the plagioclase-pyroxene-gneiss, No. 773, from Cape Gray, and to the plagioclase-pyroxene-gneiss, No. 935, from Stillwell Island[1]. Like Nos. 773 and 935, it possesses large relic crystals of augite, which have recrystallised partly as clear granular pyroxene and partly as hornblende. Like No. 773, it possesses traces of the original felspar laths of the original dolerite. Its felspar is a clear basic labradorite, appearing partly as lath-shaped crystals, but mostly as coarse granular crystals of the same average grain size as the hornblende and pyroxene. It contains a few flakes of biotite and a few disseminated and minute grains of ilmenite.

Related to this type are two erratics (Nos. 962 and 967), from Cape Hunter, 9 miles west of Cape Denison. These are hornblende-plagioclase-pyroxene-gneisses, in which the pyroxene is in excess of the hornblende. Garnet is absent, and the pyroxene includes both augite and hypersthene. Basic felspar is an important constituent, and, in addition, the rocks carry a little biotite and accessory apatite and ilmenite.

Numerous pink garnets are present in No. 595, a type closely related to the garnet-plagioclase-pyroxene-gneiss, No. 935, from Stillwell Island. Some of the garnets tend to form a zone between the pyroxene aggregates and the plagioclase. The felspar occurs as large crystals of basic labradorite and as granulitic aggregates of a less calcic felspar, probably andesine. Some of the larger crystals contain cloudy alteration products. Quartz is present, and has probably developed with the formation of garnet by the interaction of felspar and pyroxene. There is a considerable amount of hornblende, derived from the alteration of the pyroxene, which is associated with numerous large grains of ilmenite, probably derived from the same source. This garnet-bearing type is related to the eclogite family, but the clear omphacite of the typical eclogite is absent.

Specimen No. 227 is a dark, glistening schistose rock, showing abundant pink garnet and black biotite in the hand specimen. It also possesses a thin lenticle of segregated quartz along the schistosity, which may have developed with the formation

[1] Op. cit., pp. 169, 173.

of the garnet. In section, the rock has a coarsely-crystalline schistose structure, and the brown biotite is the most abundant mineral along some of the schistose bands. The plagioclase is mostly andesine, and varies towards labradorite. It is mostly clear, and only occasional grains show alteration. Pyroxene occurs in large crystals along one schistose band, and in smaller crystals in other parts of the rock. It includes hypersthene, augite, and fibrous diallage, from which ilmenite has separated out. Only occasional crystals of green hornblende are present. Garnet occurs in large pink crystals up to 6 mm. in diameter, with numerous inclusions, and also in small idioblastic crystals. A little quartz is present, and there are large accessory crystals of apatite and zircon. The rock may be called a garnet-biotite-plagioclase-gneiss. It differs from members of the eclogite family in the large development of biotite in place of pyroxene.

## Meso Division.

The conditions of the Meso zone metamorphism are considered to become more important in the formation of the augite-amphibolites. Several examples, including Nos. 380, 351, and 212, exist in the collection; and the percentage of hornblende in these is in large excess of the percentage of pyroxene. They resemble the pyroxene amphibolites described from the Cape Pigeon Rocks.[1] Of these specimens No. 212 is remarkable in possessing large, dark-green porphyroblasts of a very calcic felspar. Some of these crystals are over an inch in width, and possess well-defined crystal boundaries. The texture of the rock is massive, and the structure is typically granoblastic and porphyroblastic. The mineral composition of the rock, excluding the porphyroblasts and the accessory minerals apatite and ilmenite, is :—

| | | | | |
|---|---|---|---|---|
| Felspar ... | ... | ... | ... | 31·4 per cent. |
| Hornblende | ... | ... | ... | 64·8 ,, |
| Pyroxene | ... | ... | ... | 3·8 ,, |

The proportion of felspar to the ferromagnesian in this case is practically the same as in the Cape Denison amphibolites. The felspar is quite clear and unaltered. Most grains show lamellar twinning and are highly calcic. The hornblende is green and fresh, without the tinge of blue colour noticeable in many of the amphibolites with Epi zone features. The pyroxene includes both augite and hypersthene.

The porphyroblasts possess crystal outlines, and, like the felspar in the base, are perfectly clear and free from traces of decomposition. They show complex twinning, and, in addition to simple twinning, there are at least two sets of lamellar twinning. They contain small inclusions of pyroxene and hornblende. The pyroxene inclusions tend to occur in rounded grains, while the hornblende inclusions develop their crystalline form against the plagioclase. The inclusions in many places show a linear arrangement along cleavage lines and twinning planes. The presence of these inclusions and the fresh character of the plagioclase in the base of the rock indicate

[1] Op. cit., p. 180.

that these large crystals have developed during the recrystallisation, under the conditions of the formation of the amphibolite. The absence of any relic structure is important negative evidence that these porphyroblasts were not phenocrysts in the original igneous rock.

A sample of the porphyroblastic felspar was separated and freed as far as possible from the ferromagnesian inclusions by hand picking and by the use of heavy solutions. The sample was then analysed by Mr. J. C. Watson in the Victorian Geological Survey Laboratory.

| | |
|---|---|
| $SiO_2$ ... ... ... ... | 45·92 |
| $Al_2O_3$ ... ... ... ... | 35·34 |
| $Fe_2O_3$ ... ... ... ... | 1·05 |
| MgO ... ... ... ... | str. tr. |
| CaO ... ... ... ... | 16·39 |
| $Na_2O$ ... ... ... ... | 1·70 |
| $K_2O$ ... ... ... ... | ·20 |
| $H_2O$ ... ... ... ... | ·33 |
| $H_2O$ ... ... ... ... | ·00 |
| | 100·93 |

This analysis demonstrates the highly calcic nature of the porphyroblast which approximates to $Ab_1An_6$.

Specimen No. 547 is a remarkable quartz-pyroxene–amphibolite. It is distinguished as one of the very few specimens occurring on the moraine with a weathered crust. It is a heavy basic rock, and a rough determination of its specific gravity gave 3·25. It is rather coarse-grained, and possesses a slight schistose character. In section it is found to be similar in structure and character to the other specimens of pyroxene-amphibolites, except that the felspar is completely replaced by quartz. The amount of quartz is approximately the same as the amount of felspar in the typical amphibolites. No garnet is present in the section, but grains of ilmenite and pyrite are unusually abundant, and partly account for the high specific gravity.

The Meso division of the amphibolites is more typically represented by a number of amphibolites and biotite-amphibolites which are similar to some of the occurrences *in situ* at Cape Denison. In the typical examples the plagioclase is clear and often untwinned, and in Nos. 946 and 959 the hornblende crystals contain numerous clear inclusions of felspar and quartz, producing a " sieve " structure. In another case, No. 865, there are numerous porphyroblasts of felspar, which average about 5 mm. in width. This specimen was part of a large erratic in which the porphyroblasts were arranged in a linear manner and parallel with the schistosity—an occurrence in strong contrast with the scattered occurrences of metamorphic xenoliths in the amphibolite

*in situ* at Cape Denison[1]. Apart from the porphyroblastic character the rock is a typical amphibolite, with dominating hornblende and very little brown biotite. The felspar is clear andesine with indefinite and intermittent twinning.

A schistose variety is represented by No. 597, in which the light-coloured constituents are sufficient to produce a greyish colour in contrast to the black colour of the normal amphibolite. It is a biotite-amphibolite-schist, carrying lawsonite, epidote, and coarse crystals of apatite. The epidote and lawsonite are interlaminated with biotite, and the development of these minerals indicate an approach to the Epi division of this group.

### Epi Division.

Specimen No. 985 is a jet black schistose chlorite-amphibolite, similar in most respects to the preceding variety, No. 597. The biotite of No. 597 has been mostly converted into chlorite in No. 985, and most of its felspar has been saussuritised. These changes are considered to be Epi features, superimposed upon a typical amphibolite. Large vein-like segregations of saussurite are present in the hand specimen of No. 985.

Another chlorite-amphibolite is specimen No. 520. Biotite is completely replaced by chlorite, and the alteration is accompanied by the separation of a little quartz. An interesting feature in this case is the separation of the blue glaucophane constituent from the complex molecule in a manner similar to the schiller inclusions that are sometimes found in hypersthene. The result is a mottled green and blue crystal of hornblende (Pl. XL, fig. 1). Apatite and ilmenite are abundant minor constituents, and most of the felspar is cloudy and saussuritised except for small areas of clear albite.

The same mottling of blue and green hornblende is developed in a lesser degree in the amphibolite No. 965. This specimen possesses a pronounced "sieve" structure, in which the hornblende is highly perforated with colourless inclusions. The plagioclase is cloudy. Some of it possesses prominent diablastic structure, representing one stage of its development, but most of it forms a fine granulitic aggregate of acid plagioclase. Crystals of apatite and ilmenite are large and unusually abundant. A little chlorite is present, derived from biotite, and pyrite is also present.

Another variety of chlorite-amphibolite is No. 247. This specimen is a schistose rock, in which abundant lenticles or porphyroblasts of felspar are set in a dark matrix of hornblende, mica, and felspar. The base of the rock is similar to the biotite-amphibolites, except that biotite is replaced by chlorite. In this and the preceding examples the chloritisation does not extend to the hornblende. Quartz is present showing cataclasis, and, together with the abundant felspar, indicates a gradation towards the more acid group of the plagioclase gneisses. Some of the felspar lenticles consist of large saussuritised plagioclase, partly surrounded by clear, recrystallised felspar. Others consist of granoblastic masses of andesine felspar, with a little quartz.

[1] Op. cit., p. 48.

Scattered grains of epidote, chlorite, and muscovite occur in the felspar areas. In this case, the features of the Epi division include the presence of epidote and the cataclastic structures, in addition to the presence of saussurite and chlorite.

Specimen No. 828 is a similar porphyroblastic chlorite-amphibolite, but the cataclasis and mortar structure are much more pronounced. The margins of the hornblende crystals have been crushed and converted into chloritic selvages. The porphyroblasts of felspar are elongated along the schistose planes, and are surrounded by chlorite and finely-granulitic quartz and felspar. This rock also contains occasional large crystals of allanite.

Specimen No. 961 is an Epi-amphibolite, in which the hornblende crystals display a remarkable mortar structure. It is a highly schistose rock, containing a a larger percentage of hornblende than the typical amphibolite. The fracturing and grinding of the fragments of hornblende have produced zones and films of green chlorite around islands of unaltered hornblende. A blunt hornblende crystal often assumes a lenticular shape where the chloritic brash is drawn out along the schistosity. The clear mineral is an acid plagioclase, frequently drawn out into lenticular shapes along the schistosity. Some crystals show a mortar structure, while others have been reduced to finely-pulverised aggregates.

Specimen No. 233 is a chlorite-amphibolite, in which the alteration of hornblende into chlorite has been extensive. It contains large pale green to colourless crystals of hornblende, which are all partly converted into chlorite. The greater proportion of the chlorite, which is the most abundant mineral in the rock, has been formed in this way. A subordinate quantity of chlorite appears to be pseudomorphous after biotite. The felspar is cloudy, and occurs in granular crystals. Though mostly untwinned, it is probably an acid plagioclase. In a vein that traverses the section, it has recrystallised as clear albite. Ilmenite, granular sphene, and apatite are distributed freely through the rock. Epidote is a minor constituent, except in the neighbourhood of the vein, where it is associated with chlorite and clear albite.

Specimen No. 210 is an interesting relative of the epidote-biotite-schist, No. 153, which occurs as an altered dyke rock at Cape Denison[1]. Its structure is more massive and less schistose than No. 153. The biotite of No. 153 is replaced by a green pleochroic chlorite, and epidote crystals are more numerous than in No. 153. The clear felspar is an acid plagioclase, and no basic felspar is present. Sphene and magnetite (or ilmenite) are important minor constituents, and are associated together in the same manner as in the typical amphibolites. Apatite is an accessory mineral, and there are occasional grains of calcite. The amount of felspar appears to be less in this rock than in No. 153, tending to make this specimen a typical member of the family of epidote-chlorite-schists.

An interesting specimen is the lawsonite-chlorite-schist, No. 936. It is one of the few specimens from this region which shows surface weathering, being covered with a brown iron-stained skin. A brown colour also appears on the fractured surface,



[1] Op cit., p. 30.

and is due to the presence of the golden-brown mica on the schistose surface, such as is characteristic of the lawsonite-amphibolites at Cape Denison. The ferromagnesian constituents include pyroxene, hornblende, biotite, and chlorite. The pyroxene, which constitutes 5 per cent. of the rock, has the granular character and pale colour common in the plagioclase-pyroxene-gneisses. In some cases it passes over directly into chlorite, but its alteration to green hornblende is more common. Green hornblende forms about 14 per cent. of the rock, and the remaining four-fifths of the rock consists chiefly of biotite with lawsonite and chlorite, saussuritised felspar, and clear acid plagioclase. Biotite possesses the curious reddish-brown colour previously seen in the lawsonite amphibolite (No. 635), occurring *in situ* at Cape Denison, and shows various stages of decolouration in its alteration to chlorite. Colourless lobate lenticles of lawsonite are interlaminated with both biotite and chlorite. Lawsonite is also well developed in the chloritic and saussuritised areas. The saussuritisation of the plagioclase has been fairly complete. The albite molecules have reappeared as clear acid plagioclase, while the anorthite molecules have combined with water and produced lawsonite and granular epidote. Fibrous chlorite is also abundant among these aggregates, and there is a little quartz and white mica. Sphene, ilmenite, and pyrite are important accessory minerals, and isolated grains of allanite and apatite are present.

Lawsonite, chlorite, and epidote indicate the relationship of this rock to the Epi division. The presence of pyroxene indicates that the rock was previously subjected to Kata zone metamorphism, being probably a plagioclase-pyroxene-gneiss. These conditions are superseded by the hornblende-producing conditions of the Meso zone, which were finally superseded again by the Epi zone conditions of recrystallisation which now characterise the specimen.

### Gabbro Schists and Gneisses.

In addition to the typical amphibolites, the collection contains a number of handsome hornblendic rocks of apparent coarse grain. They possess the same mineralogical variety and composition as the amphibolites. In many cases they possess the same average grain size, but the minerals are grouped in clusters, so that the hand specimen assumes a mottled black-and-white character, with the appearance of a coarse-grained rock. In these cases they are amphibolites, with the glomeroplasmatic structure described by Lœwinson-Lessing, and Holmes.[1] The mineral grouping indicates either (1) that each cluster has been derived from an original crystal unit, or (2) that each cluster is a minute metamorphic differentiation. The average regularity of the areas throughout the hand specimens renders the first explanation the more probable. In some cases this explanation is confirmed where the white areas have retained the form of felspar crystals, and the rocks are metamorphic representatives of gabbros. Some of the types may have been placed in order among the amphibolites, but the " relic " gabbro structure of the hand specimens has favoured their consideration under the heading of gabbro schists and gneisses.

[1] Trav. Soc. Nat. St. Petersb., vol. xxv (1900), p. 208; A. Holmes, Q.T.G.S. lxxiv, 1918, p. 55.

Specimen No. 915 is an example of a garnet-biotite-amphibolite with glomeroplasmatic structure, and is similar to No. 50 (Pl. XLI, fig. 1). In section, it is found that the dark areas of hornblende crystals consist of small lenticular clusters, together with biotite and ilmenite. The white areas are granoblastic aggregates of basic plagioclase. A similar specimen is No. 990, in which the brown biotite is replaced by green chlorite, and more of the felspar is saussuritised.

No. 339 is a garnet-bearing gabbro-gneiss (Pl. XLI, fig. 2). It possesses a coarse gneissic structure, and has a mottled appearance. The black areas consist of aggregates of hornblende and augite, or garnet and biotite, but the four minerals are contained in some aggregates. The white areas, which are slightly discoloured by weathering, consist of aggregates of labradorite, partly saussuritised, and a little quartz. The biotite aggregates contain a little lawsonite, and their rounded form suggests their derivation from garnet[1]. The suggestion is supported by the presence of quartz, which can be formed with the change from garnet to biotite. The hornblende has been derived from augite, while the granular form of the metamorphic pyroxene suggests its derivation from large platy pyroxene crystals. Ilmenite and apatite are accessory minerals. The microscopical features are similar to those of the hornblende-pyroxene-gneisses, with the addition of the glomeroplasmatic structure.

A specimen in which the gabbro structure is very prominent is No. 593, whose character would be well described as a hornblende-gabbro. It is a coarse, handsome rock, containing some large crystals of labradorite, though consisting for the most part of coarse hornblende and felspar. Occasional crystals of green augite are associated with the hornblende, and a few fragments of garnet are found near plates of biotite. In thin section the labradorite has a tendency to idiomorphic outlines—a contrast to the granoblastic aggregates of many metamorphic rocks. The twin lamellæ of the labradorite are very broad and much more abundant than in previous types, but there is a small amount of untwinned sodic felspar. The hornblende forms large crystals, but in other respects is similar to the smaller crystals in the amphibolites. Augite is present, and in one case forms the nucleus of a large hornblende crystal. Large crystals of ilmenite, with sphene rims, accessory apatite, and zircon are present. While the nature of the rock is understood by the name "hornblende-gabbro," the rock possesses metamorphic traits in the presence of relic garnet, of secondary felspar, saussuritised felspar, and the characteristic relation of sphene and ilmenite.

In specimen No. 367 some of the felspar areas are 2 cm. wide, and the rock has the appearance of an augen gneiss. The section shows that the felspars have recrystallised as granoblastic aggregates of calcic andesine, fairly free from saussurite. Coarse crystals of epidote are present. Some of the biotite is replaced by chlorite and is intergrown with lawsonite. The Epi zone features are, however, subordinate in this example, and the rock may be called a plagioclase-gabbro-gneiss. The plagioclase is thoroughly saussuritised in a somewhat similar specimen, No. 969 (Pl. XLI, fig. 3).

[1] Op. cit., p. 157.

Specimen No. 317 is a coarse-grained rock, with a mottled black-and-white appearance, due to glomeroplasmatic areas of hornblende and felspar of average width of 3 to 4 mm. Each dark hornblende mass resolves itself on examination into clusters of small crystals, associated with crystals of chlorite, ilmenite, and apatite. This ilmenite may have been discharged from the original pyroxene in the manner recorded in the garnet-plagioclase-pyroxene-gneiss, No. 935, from Stillwell Island[1]. Biotite is replaced by chlorite and epidote. In the white areas are large saussuritised felspars, in which sericite, white mica, epidote, chlorite, and zoisite are found, in addition to clear albite. There are also areas of clear labradorite, and a few scattered fragments of garnet. The rock may be distinguished as a saussurite-gabbro-gneiss.

Specimen No. 728 is another variety of saussurite-gabbro-gneiss. Its felspar is completely saussuritised, and there is a little garnet and a small development of secondary quartz in the hornblende, probably associated with the development of epidote and chlorite. The specimen is not schistose, and the outline of the original felspar crystals is discernible in the hand specimen, averaging about 6–7 mm. long and 2–3 mm. wide. The form of the felspar is even better preserved in No. 861, where it is sufficiently obvious to suggest that the hand specimen is a hornblende-felspar-porphyry. There is, however, complete saussuritisation of the felspar, while the biotite and some of the hornblende is converted into epidote and chlorite. Scattered garnets occur around the fringe of some of the hornblende clusters, and are suggestive of the garnet roms around the pyroxene in the garnet-pyroxene-gneisses of Stillwell Island.

The conversion of hornblende into chlorite is further advanced in specimen No. 515, another saussurite-gabbro-gneiss. The chloritisation of the hornblende proceeds from the edges and cleavage cracks. The section is crossed by branching veins of lawsonite (Pl. XL, fig. 2), which have developed during the saussuritisation of the felspar. These veins cross hornblende as well as felspar areas. Zoisite occurs with the epidote in the altered areas. There are, however, considerable areas of unaltered basic felspar.

Apart from the gabbro gneisses and the amphibolites that have been described, there are a number of coarse-grained hornblendic rocks. With the segregation of the lighter-coloured constituents, these rocks become representatives of the hornblende-plagioclase-gneisses of Group III. With the segregation of the darker constituents, they grade towards the hornblende schists of Group V. Specimen No. 721 (Pl. XLI, fig. 4) illustrates a segregation assuming the form of a vein. The vein contains large crystals of hornblende, some of which are 3 cm. long, together with felspar and a little quartz. A similar vein occurs on the edge of another specimen, No. 25, in which there is a noticeable increase in grain size of the amphibolite as it approaches the edge of the vein.

[1] Op. cit., p. 174.

## III.—Group V.—MAGNESIUM SILICATE GNEISSES.

As the percentage of felspar decreases the members of the Amphibolite Group grade into the rocks of Group V, the magnesium silicate gneisses.

### Kata Division.

Assigned to the Kata division of Group V is Specimen No. 527, an apple-green rock, consisting essentially of granular green pyroxene. It consists, in section, of a granulitic mass of clear pyroxene, resembling omphacite, with a subordinate amount of very pale green to colourless hornblende, together with a little interstitial quartz. Garnet is absent; and, otherwise, the rock would be classed as an eclogite in Group IV. The development of hornblende is irregular, and sometimes is accompanied by a little biotite. Portions of the specimen possess a distinctly dark-green shade, due to an increased amount of hornblende. One portion of the specimen possesses a noticeable percentage of red felspar, indicating the relationship with the amphibolite group. This particular specimen is traversed by a vein of quartz and plagioclase, 2 cm. wide, in which the quartz is mostly confined to the centre of the vein, and the plagioclase to the walls of the vein.

In Specimen No. 963 the hornblende is much more important, and the hand specimen possesses a corresponding dark colour. This specimen was obtained from an erratic on Cape Hunter. The main constituent of the rock is pyroxene, including both augite and hypersthene. Some of the crystals are clear and granular, and others are fibrous. All show more or less alteration to hornblende. There is a small development of brown biotite accompanying the hornblende, subordinate plagioclase, and scattered grains of ilmenite and pyrite.

These rocks are unfoliated, and therefore possess resemblances to the ultra basic igneous rock "pyroxenite"; but the pyroxene possesses the distinctive character of the granular pyroxene of metamorphic origin commonly observed in the Cape Gray series of altered basic dyke rocks.

### Meso Division.

As hornblende becomes the essential constituent the types are grouped in the Meso division of Group V. Among these is Specimen No. 594, a garnet-hornblende-schist. It is a coarse-grained, dark-green rock, which consists of green hornblende and scattered pink garnets. In addition, there is a little interstitial felspar, as well as scattered grains of ilmenite and apatite.

Specimen No. 513 is a heavy, dark-green, slightly schistose rock, consisting essentially of amphibole, with scattered specks of pyrite visible in the hand specimen. In thin section there are large talcose areas produced by the decomposition of some

pre-existing crystals. These contain numerous inclusions of magnetite and amphibole. The magnetite appears to have been a separation product, accompanying the formation of the talc. It is distributed as fine particles along traces of former cleavage planes, and along a system of cracks more or less at right angles to the cleavage. In many places these particles have coalesced to form irregularly-shaped inclusions of magnetite. The arrangement of the discharge of magnetite suggests that the original crystals were olivine, though the nature of some of the included amphibole indicates the possibility of pre-existing pyroxene, partly altered to hornblende before the curious alteration to talc. The amphibole is the most abundant mineral, and includes green hornblende and anthophyllite. The latter has developed in long prismatic crystals, which possess faint pleochroism from colourless to very light brown. The cross sections show the usual hornblende cleavage and outline, and the prismatic sections possess straight extinction. Sometimes there is a green core of hornblende, with a colourless border zone of anthophyllite. Sometimes the hornblende is decolourised, and there appears to be a gradation from hornblende to anthophyllite. In addition to these minerals, the rock contains a minor amount of biotite, with pleochroism from a pale-straw brown to a bright green, and of magnetite with accessory grains of pyrite, apatite and quartz. The rock is an anthophyllite-schist, on which has been superimposed some of the features of the Epi division. These features include the development of talc, the bent and crushed appearance of some of the biotite crystals, and the occasional fracturing and mortar structure in the amphibole.

Specimen No. 516 is another representative of the anthophyllite-schists, and, as in No. 513, there are only occasional grains of felspar. It is a dark-green schistose rock, showing a brownish tinge on the weathered surface, due to the slight oxidation of anthophyllite. In thin section, the green hornblende is the most important mineral, and the colourless to light-brown anthophyllite is intergrown with it. The talcose areas of the preceding specimen are absent, but some of the anthophyllite crystals show decomposition around their edges and cleavages to a talcose material. Brown biotite is much more abundant than in No. 513, and helps to produce the schistose structure. Accessory grains of apatite, ilmenite, pyrite and quartz are present.

Another representative of the anthophyllite-schists is Specimen No. 109, in which the green hornblende is absent. This specimen is a light-brown rock, in which the prisms of anthophyllite are arranged with their long axes in the plane of schistosity. Some of these crystals are over 2cm. long, and they lie in all positions in this plane. Plagioclase can be observed in the hand specimen in a proportion which makes the inclusion of this specimen in this group doubtful. In section the anthophyllite is slightly pleochroic from colourless to pale brown, showing the well-developed cleavage and outline of the amphiboles. The plagioclase is labradorite, and there are odd flakes of biotite and a few grains of magnetite (or ilmenite). The rock could possibly be placed in the group of the amphibolites.

A typical hornblende-fels is No. 548, a black, heavy, massive rock. It is fairly coarse-grained, and in the hand specimen appears to consist wholly of hornblende. In section, it is composed chiefly of fresh green hornblende, containing a few inclusions of rounded quartz blebs. Quartz is the more important minor constituent, and there are, in addition, accessory flakes of biotite, grains of felspar, calcite, apatite, and ilmenite.

Specimen No. 950 is a biotite-hornblende-schist, which is closely related to the biotite-amphibolites. It contains felspar and a little quartz, but in less amount than in the typical amphibolites. The brown biotite is abundant, but not uniformly distributed through the rock. It forms clusters, in which some of the micaceous laminæ are bent and twisted. Occasional grains of epidote are associated with the biotite. Green hornblende is the most abundant constituent, and both the hornblende and biotite possess pleochroic haloes, which surround minute inclusions.

A curious hornblende-fels is No. 941. It is a dark-green, massive rock with a porphyroblastic appearance, due to platy crystals of hornblende, which are set in a fine matrix. The examination reveals the large hornblendes as relic crystals which have for the most part broken down into granulitic aggregates of a similar pale-green hornblende (Pl. XL, fig. 3). The latter forms the bulk of the thin section. A little colourless chlorite and a little brown biotite are mixed with the granulitic hornblende. Embedded in these aggregates are a few long, slender prisms with ragged terminations, which are feebly pleochroic from colourless to pale green. Some show lamellar twinning, and they possess straight extinction with yellow and grey polarisation colours of the first order. They show cleavage, and appear to be a form of orthorhombic amphibole. The remaining constituents are ilmenite dust, and grains of pyrite and apatite. It would appear as if the original platy hornblende had been chloritised and the reaction had then been reversed, reproducing the fine granulitic hornblende from the chlorite.

Another dense hornblende-schist is No. 209, in which a subordinate amount of biotite, for the most part converted into chlorite, is associated with the pale bluish green, granular hornblende. It contains large talcose areas, similar to those in No. 513, produced by the decomposition of pre-existing olivine or pyroxene. These areas form about half of the section, and contain magnetite in a similar manner. They are studded with inclusions of hornblende and chlorite, but there is no trace of the original mineral.

The family of actinolite-schists is represented by specimen No. 246, which displays in the hand specimen a bright green mass of acicular crystals. Its appearance forms a distinct contrast to that of the dark greenish black hornblende-schists. In thin section it consists almost entirely of a mass of long thin actinolite prisms, which are pale green to colourless. A few flakes of biotite and a few scattered grains of ilmenite are the only other minerals present.

### Epi Division.

A larger development of chlorite occurs in specimen No. 229, which may be called a chlorite-hornblende-schist. The formation of chlorite has been accompanied by the development of a little epidote, and the separation of a little quartz. In places the ends of the hornblende crystals are frayed out into needles embedded in quartz. Some of the hornblende crystals show the effects of crushing, with an alteration toward chlorite. Ilmenite is disseminated through the section, and there are occasional grains of untwinned felspar. The marked development of chlorite is a feature associated with the Epi division of this group, in which this rock has been included.

Another specimen of hornblende-schist, No. 888, contains a curious plate of chlorite, which is composed of layers of chlorite. In each layer the micaceous laminæ of chlorite are arranged more or less at right angles to the trend of the layer; but the laminæ in adjoining layers are set at varying angles in one another. Both chlorite and hornblende in this specimen possess a very pale green colour, being nearly colourless.

A specimen that can be placed in this division is No. 916, a dense, dark green pebble bearing glacial striæ. It is a close relative of the epidote-chlorite-schists of Group IV, but it is distinguished by its very subordinate amount of clear felspar. It consists chiefly of epidote and chlorite. The iron, which has been discharged during the conversion of biotite and hornblende into epidote and chlorite, is disseminated throughout as numerous small particles of ilmenite. A little zoisite is associated with the epidote. Sphene and apatite are not observed, but white mica is a minor constituent. The rock is an epidote-chlorite-schist; and, since chlorite is the more important constituent, it is included in the family of chlorite schists. If epidote had been more important, the rock would be related to the epidosites of the Epi division of Group IX, the lime silicate gneisses.

Specimen No. 931 is a fine grained, dark-green, schistose type with thin bands of light green epidote. The percentage of felspar and quartz is very small, and even less than in the preceding type No. 916. The main mass of the rock consists of epidote and hornblende, chlorite being a very minor constituent. In addition to the more important pale green hornblende, there is a clear colourless hornblende, and both varieties are intergrown in one crystal. The colourless hornblende shows the brighter polarisation colours and a slightly larger extinction angle. A colourless pyroxene is present, partially altered to hornblende, and more prominent in some layers than others. Granular epidote is abundant through the section, and has in part segregated into layers. The small percentage of felspar and quartz is mostly confined to these layers. Associated with the epidote crystals are a number of zoisite crystals, possessing grey and ultra-blue polarisation colours. Sphene is an important accessory, and forms thin strings of crystals in the layers of epidote. One corner of the section is crossed by a narrow vein of serpentine. The rock is an epidote-hornblende-schist, and the development of epidote, almost to the exclusion of chlorite, produces a resemblance towards the epidosite family.

## IV.—GROUP III.—THE PLAGIOCLASE GNEISSES.

With a decreased percentage of hornblende and an increased percentage of felspar, the amphibolite types pass into less basic rocks which correspond to the plagioclase gneisses of Group III. In many specimens quartz becomes a more important constituent and a considerable variety of rocks, including some transitional varieties between Groups I and IV., are placed here.

### Kata Division.

None of the specimens examined appear to fall into this group.

### Meso Division.

Among the hornblende-plagioclase-gneisses are specimens Nos. 169, 170, which are light-coloured, coarse-grained rocks, in which the hornblende appears as small schlieren in the light-coloured base, and forms about 16 per cent. of the rock. The base contains quartz and alkali felspar in addition to the plagioclase. These specimens also contain fragments of much larger schlieren composed of dark amphibolite or green pyroxene. In the proximity of the amphibolite schlieren there is a band containing epidote, calcite and lawsonite along which the hornblende is partially altered. The alteration (Pl. XL, fig. 4) takes place first to a colourless hornblende and then into an aggregate of epidote, lawsonite and calcite. The pyroxene in the pyroxenic schliere shows alteration to hornblende, and there is in addition a separation of calcite when fragments of pyroxene are set in a network of calcite.

Specimen, No. 378, is a pink hornblende-felspar-gneiss, whose colour is due to the pink felspar modified by the dark crystals of hornblende and mica. In section, it has a granoblastic structure and a schistose texture. The colourless constituents include quartz, clear microcline, plagioclase with accessory apatite. The dark constituents are green hornblende, greenish-brown biotite, which is partly altered to chlorite and epidote, while sphene is an abundant accessory mineral. The rock may be called a hornblende-felspar-gneiss, and on account of its content of quartz and alkali felspar it probably has a chemical composition grading towards that of Group I, the alkali felspar gneisses.

No. 259 is a hornblende-plagioclase-gneiss, which is more basic than No. 378, and probably grades in the opposite direction towards the group of amphibolites. No. 378 contains pink felspar in the hand specimen, but No. 259 possesses more hornblende and white felspar. No. 259 also possesses a coarser grain size, and some of the hornblende crystals are 4mm. wide. In section, the large hornblende crystals are green and bluish-green in colour, ragged in outline, and frequently contain inclusions of biotite. Some are partially broken across the biotite inclusions, and epidote has developed in places along the strained portions of the hornblende. Biotite is very

subordinate to hornblende, and epidote has developed from the crushed biotite. Some of the epidote is finely granular, and some of it occurs in grains and crystals. Quartz is subordinate to felspar, which consists of an acid oligoclase and untwinned felspar. The felspar possesses myrmekitic structure, but it is free from products of decomposition. Quartz and some of the felspar shows strong undulose extinction. Accessory grains of apatite, allanite, and sphene are present.

Specimen No. 240 is a biotite-plagioclase-gneiss, and another example with affinities to the amphibolite group. It is a grey schistose rock, in which the dark constituents, biotite, and hornblende are subordinate to the white minerals. In section, the flakes of brown biotite are arranged parallel with the schistosity, and are in large excess over the green hornblende. There is a small amount of green chlorite and colourless lawsonite interlaminated with the biotite. Quartz is present, and the andesine felspar is quite clear, except for a few crystals which possess cloudy micaceous alteration products.

An exceptional biotite-hornblende-felspar-gneiss is specimen No. 956. The hand specimen is a dark schistose rock, showing glistening biotite, and is finer grained than most of these rocks. In section, the hornblende is quite distinct from the granular green variety of the typical amphibolites. It occurs in ragged, acicular crystals, and the colour of the prisms is mostly green and pale green. Some prisms show a pleochroism from greenish-blue to blue, indicating a change to glaucophane. In addition to the large crystals, it also occurs as fine acicular needles. Its polarisation colours are unusual. In many cases there is no position of absolute extinction between crossed nicols; but a position of 30° to 40° to the cross wires shows ultra-blue colours. While the polarisation colours appear to be low, they are interfered with by the colour and dispersion of the crystal. The biotite possesses an unusual colour, which changes in cross-section from a reddish-brown to a biscuit-brown. The crystals possess an unusually ragged outline, and contain minute dots of discharged ilmenite. The amount of felspar appears to be a little greater than in the typical amphibolites. The felspar crystals are mostly untwinned, some possess traces of microcline twinning and some are lamellar twinned crystals of acid oligoclase. Calcite, ilmenite, and epidote are minor constituents, and pyrite and apatite are accessory minerals. While the rock is more basic than typical members of this group, it is at the same time distinct from the amphibolites.

A different type of hornblende-quartz-plagioclase schist is No. 51. This is a grey schistose rock, in which numerous prismatic needles of hornblende and occasional small crystals of ilmenite are set in a grey groundmass. In section, the rock consists of thin, elongated crystals of green hornblende, set as porphyroblasts in a finely granulitic groundmass of quartz and felspar. The hornblende crystals are ragged with the pronounced prismatic habit. Its colour is dark green to bluish-green. Numerous small and isolated flakes of biotite have developed along some of the schistose layers. The ground mass, in which the quartz appears to predominate is

very fine; and there are thin lenticles of felspar arising from it. Some of this felspar is untwinned; but some lamellæ show an extinction angle of 33° indicating a labradorite. There are scattered crystals of ilmenite and apatite. This type of schist is distinct from the other hornblende-plagioclase-gneisses, and the quartzitic nature of the ground mass suggests its derivation from a sedimentary rock.

Specimen No. 924 is another type of hornblende-plagioclase-schist, which is also more basic than typical members of this group. The base of the rock consists of densely-packed acicular needles of hornblende, with grains of epidote set in a colourless base of clear felspar and quartz. The hornblende needles have a pale green colour and an extinction of 20°. The rock also possesses relic phenocrysts of quartz and felspar, and in this way resembles a "porphyroide." Some of the felspars have an extinction of 27° indicating labradorite and some are studded with numerous small crystals of epidote. These relic crystals indicate that the rock has developed from a porphyritic igneous rock, probably a felspar porphyrite. The abundance of epidote is a feature belonging to the Epi division of this group.

### Epi Division.

This division includes the group of the epidote felspar gneisses. Some of these appear to grade into the Epi division of Group I, the Alkali-Felspar Gneisses, while others grade toward the Epi divisions of Groups IV, V, and IX, the Amphibolites and Edogites, the Magnesium Silicate Gneisses and the Lime Silicate Gneisses.

Typical of these epidote gneisses is specimen No. 257, in which the colour of the specimen is dominated by the green epidote. It is a green schistose rock with a banded structure and a much finer grain than preceding types. It possesses a distinct crystallisation-schistosity, and some of the bands possess a darker green colour than the average, on account of the association of chlorite and hornblende with the epidote. In section, the light coloured bands consist of granoblastic masses of clear felspar, with scattered flakes of pale chlorite and epidote. The felspar consists of microcline felspar and albite. In some bands epidote (with a little zoisite) is the most important mineral; while in others a pale green hornblende is as abundant as the epidote. The hornblende represents the residual mineral, which has survived the general alteration into epidote and chlorite. Its colour is bleached prior to this alteration; and areas of residual green mineral are observed, surrounded by colourless hornblende partly converted into chlorite. Sphene and apatite are present, and a few epidote grains possess a reddish-brown nucleus of allanite.

In a similar specimen, No. 157, some of the bands of pink felspar are broader, being as much as 5mm. wide, while others are darker and possess a larger percentage of hornblende. In this case, and in No. 522, quartz is present. In No. 522, the pale green hornblende changes into a colourless hornblende prior to its alteration to epidote and chlorite. Many of the epidote grains contain a reddish-brown nucleus which is probably allanite.

A coarser-grained type of the same class of rock is No. 726, in which the pink bands of felspar are 2½ cm. wide. No. 726 is a handsome rock, whose colour is dominated by the pink felspar, but contains disseminated patches of bright green epidote. In addition to the pink bands, there are bands of green chloritised hornblende with a silky sheen. In section, there is a little cloudy untwinned felspar, which may be orthoclase, and lamellar-twinned oligoclase-albite. The development of epidote within some of the plagioclase indicates that it has been partly derived from felspar. Pale decolourised hornblende is present, and the abundant chlorite and some of the epidote has been derived from it. Quartz is absent in this case, but large grains of apatite and zircon are present.

Of different appearance is specimen No. 598, a pink and green massive boulder containing large porphyroblasts of pink microcline up to 3cm. in length and over 1cm. in width, set in a rather coarsely-crystalline base of pink felspar, bright green epidote, and dark-green chlorite. The general appearance is somewhat similar to a pink porphyritic granite, except that there is a general absence of quartz. The resemblance is more strictly to a felspar-porphyry, from which it has probably been derived. The large porphyroblasts show the irregular wedge-shaped twinning of microcline, with small inclusions of quartz, plagioclase and sphene. The character of porphyroblasts has been confirmed by a determination of the alkalies by Mr. J. C. Watson, in the Victorian Geological Survey laboratory, which gave:—

| | | |
|---|---|---|
| $K_2O$ | ... ... ... ... | 14·04 per cent. |
| $Na_2O$ | ... ... ... ... | ·66 ,, |

The felspar in the base of the rock consists of lamellar-twinned plagioclase and subordinate untwinned felspar. Sometimes it shows cataclasis and a partial development of myrmekitic structure, and sometimes bent lamellæ. Its extinction angle measures up to 14° and it is probably an oligoclase. The green chlorite and epidote are bunched together in aggregates, and of these two minerals, epidote is the more abundant, forming large idiomorphic crystals. Sphene and apatite are accessory minerals, and the rock can be classed as an epidote-felspar-gneiss. The presence of large crystals of microcline indicate a gradation towards the group of the alkali felspar gneisses (Group I).

A related rock is No. 954, in which the porphyroblasts of microcline are much smaller. The grain size is less than half that of No. 598, and the appearance is more granulitic. The epidote and chlorite are more or less evenly distributed through the section, producing the darker colour as opposed to the pink colour of the preceding specimen. The aggregated amount of epidote and chlorite is less than in previous examples, and the chlorite is more abundant than epidote. Crystals of sphene accompany the epidote. Microcline occurs in base as well as forming the porphyroblasts, and contain numerous inclusions of albite, with a ragged and irregular shape, after the manner of graphic structure. There is a considerable amount of untwinned

orthoclase, and a subordinate amount of plagioclase. The abundance of microcline and the decreased amount of epidote bring the rock into the group of the alkali-felspar gneisses, and it may be called a chlorite-microcline-gneiss.

Another porphyroblastic epidote-felspar-gneiss is No. 590; but it differs from the two preceding specimens in possessing a marked schistose structure. It consists of porphyroblasts of pink felspar, set in a base coloured green by epidote. The porphyroblasts consist of granoblastic aggregates of untwinned and microcline felspar. The clear base consists of felspar with a few grains of quartz and a subordinate amount of plagioclase. Coarse crystals of epidote are abundant and grouped in clusters with chlorite and a little zoisite. Ilmenite has been altered to leucoxene.

Specimen No. 910 is a different type, and may be described as an epidote-felspar-breccia. It is a very dense, fine-grained, pale-greenish rock studded with minute porphyroblasts of felspar. The thin section possesses a uniform pale-green colour, and consists of angular crystals of felspar set in a dark semi-opaque mass of epidote. The general appearance is that of a breccia and the felspar is water clear, partly twinned and partly untwinned. Some of the lamellar-twinned individuals have an extinction angle of 16°. Here and there are larger crystals of epidote, which are more transparent than the base, and consequently show brilliant polarisation colours. Under high powers the base of the rock is seen to consist of closely packed minute grains of epidote set in a base of clear felspar.

Specimen No. 592 is a massive, pale-greenish rock, somewhat similar in appearance in section to the coarse-grained variety, No. 726. It contains coarse crystals of partially altered hornblende, epidote (sometimes intergrown with allanite), chlorite and felspar. The rock is brecciated, and the fragments are separated by veins of quartz and felspar, darkened by finely granular epidote.

Specimen No. 591 is an epidote-felspar-gneiss, which has a pale-green colour and a schistose structure. In section, it shows the helical structure commonly seen in phyllites and mica-schists. There are a few small felspar porphyroblasts, some of which are cracked and broken, and show various stages in breaking down into a finely granulitic mass. Some felspars are untwinned, and some are acid plagioclase. There are also a few porphyroblasts of allanite. The bulk of the rock consists of the finely granulitic base enveloping the wavy bands of dark granular epidote, similar to that in No. 910. Chlorite is present, and interwoven with the granular epidote, and there are occasional crystals of sphene. The specimen assumes a dark colour on the one side, where the amount of felspar decreases and the rock passes into an epidosite.

A further stage of epidotisation exists in specimen No. 589. This specimen retains the schistose structure and possesses traces of green hornblende. The felspar is subordinate, and there are bands of well crystallised epidote, as well as bands of finely granular epidote. Lawsonite is also present, and has been derived from the felspar. In addition there is a little zoisite and abundant sphene.

With the decrease in the percentage of felspar, the colour of the rock deepens, and a dark-green type, like No. 599, is produced. It differs from Nos. 157, 257, and 522, in possessing a massive structure. It has an increased percentage of chlorite, and possesses relationships with the epidote-chlorite-schists of Group IV. Epidote is the most abundant mineral, and, together with the decrease in felspar, indicates a transition towards the epidosites, the Epi division of Group IX, the lime silicate schists. Chlorite is much more abundant than in previous specimens, and there is only a trace of hornblende. Quartz is present, but subordinate in amount to the felspar. Both quartz and felspar show cataclasis, and some crystals appear in polarised light as fine granulitic aggregates. Ilmenite is present, and its association with sphene is another point of resemblance with the amphibolite group.

With the decrease of both chlorite and felspar, a massive green rock of epidosite is produced. No. 255 is an example of this class, consisting chiefly of epidote. The section has a uniformly yellowish-green colour, due to the epidote. Quartz is present but very subordinate. A little pale hornblende exists as relic crystals, and a little chlorite is intergrown with the epidote. Sphene, with associated magnetite, is an abundant accessory mineral, and a little calcite is present. This rock is a member of the Epi division of Group IX, the lime silicate rocks.

---

## V.—DESCRIPTION OF PLATES.

### Plate XL.

Fig. 1.—No. 520, an amphibolite in which the hornblende shows a mottled appearance, due to the separation of blue hornblende from the green hornblende. Mag. 35 diams.

Fig. 2.—Veins of lawsonite traversing a gabbro gneiss No. 515. Mag. 35 diams.

Fig. 3.—Amphibolite No. 941, in which granulitic hornblende has developed from large crystals of hornblende. The nicols are crossed, and the large crystal which occupies most of the field is nearly in a position of extinction, while the granulitic hornblende appears light due to its bright polarisation colours. Mag. 35 diams.

Fig. 4.—No. 169, in which a crystal of hornblende is partially altered to a mixture of calcite, epidote, and lawsonite. Mag. 35 diams.

### Plate XLI.

Fig. 1.—No. 50, hornblende-plagioclase-gabbro gneiss.

Fig. 2.—No. 339, garnet-hornblende-plagioclase-gabbro gneiss.

Fig. 3.—No. 969, saussurite-gabbro gneiss with augen of saussurite.

Fig. 4.—No. 721, segregation vein of hornblende, felspar and subordinate quartz in amphibolite.

[With Two Plates.]

Sydney: Alfred James Kent, Government Printer—1923.

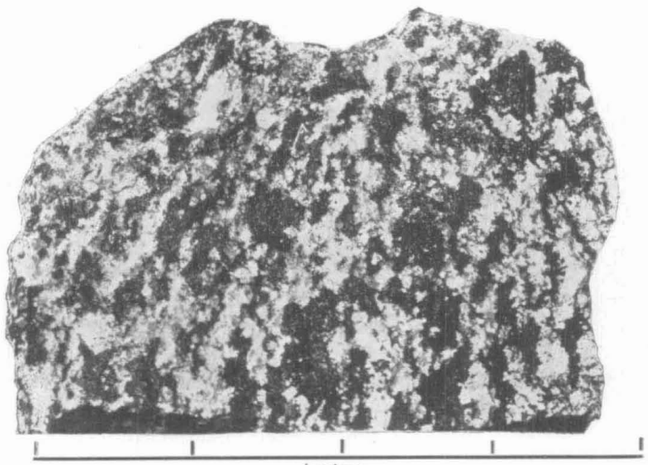


Fig. 1.

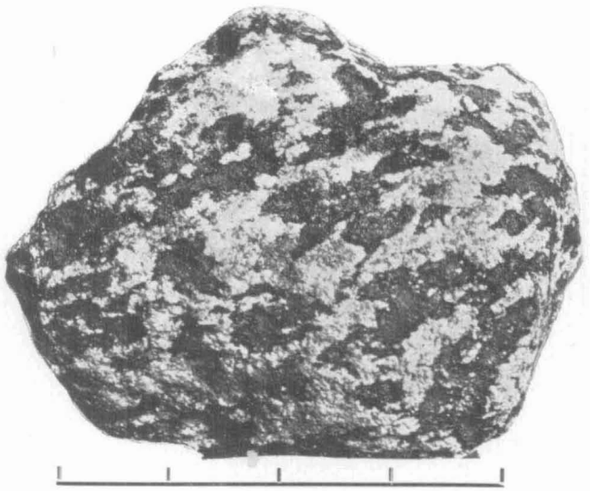


Fig. 2.

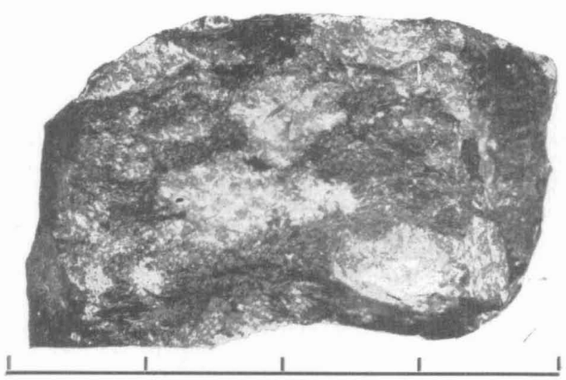


Fig. 3.

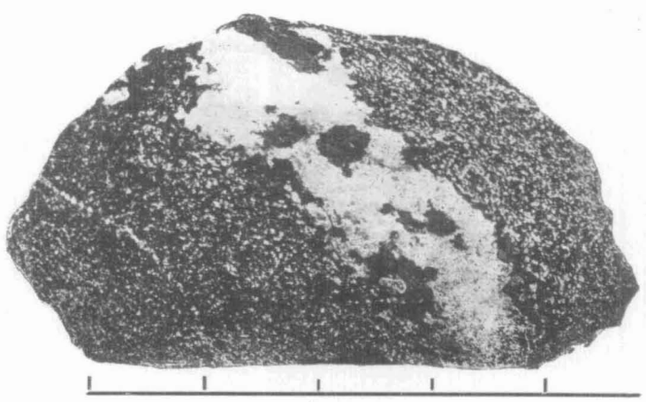


Fig. 4.

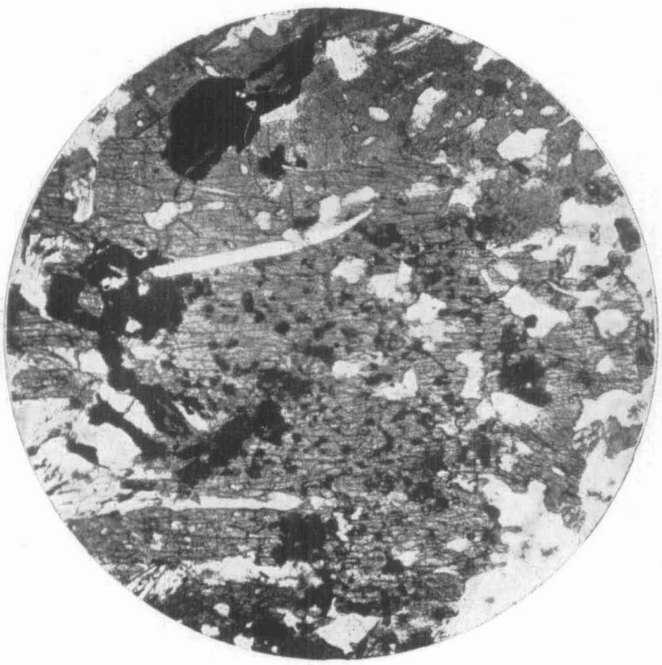

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.