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PART 9.

SOME HYBRID GNEISSES
FROM
THE MORAINES, CAPE DENISON.

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

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SOME HYBRID GNEISSES FROM THE MORAINES.

BY

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

(Adelaide).

I. INTRODUCTION.

ALTHOUGH it is impossible because of the lack of field characters definitely to assign relationships between the gneisses of the kind dealt with in this section, nevertheless it is possible to make a logical arrangement into divisions whose properties are serially related and which correspond with those of similar gneisses found elsewhere, but particularly with those of the Small Isles of North West Scotland.* It will be seen that the classification of the next paragraph allies these rocks with those described† from Loch Choire Complex, and shows them to have some affinities with the diopside-plagioclase-hornfelses of Hirasawa.‡

The gneisses of the collection here described fall into several well-marked groups. As we proceed from augen gneisses through banded-gneisses to gneisses low in ferromagnesian we can suppose that we are dealing in turn with the least affected country rock, the intermediate zone and the least affected acidic magma. Here the original country rock was an earlier igneous rock, the ancestor of the amphibolitic masses now present. The intruding rock was such an earlier igneous rock, acidic, being aplitic in fact. The three main types of gneisses thus represented can be classified as:—

1. Hornblende-felspar (augen) gneisses.
2. Injection gneisses.
3. Pegmatitic rocks containing ferromagnesian constituents.

The correctness of this suggested classification is attested to by the presence of a number of specimens intermediate between groups (1) and (2), and of specimens which show three forms of pegmatitic base, viz., those in which quartz preponderates, those in which felspar preponderates and those in which there is an approximately equal distribution of these two minerals.

In view of these modifications the treatment of these rocks will be as follows:—

1. Hornblende-felspar (augen) gneisses.
2. Rocks intermediate between groups (1) and (3).
3. Banded injection gneisses.
4. Pegmatitic rocks containing ferromagnesian.
 - (a) The rocks which have predominating felspar.
 - (b) The rocks which have predominating quartz.
 - (c) The rocks which have approximately equal quantities of felspar and quartz.

* Harker, 1908, Geol. of Small Isles, pp. 105-7.

† Read, 1931, The Geol. of Central Sutherland, Min. Geol. Surv. Scot., pp. 133-139.

‡ Sugi, 1930, Jap. Jour. Geol.

The validity of the assumptions made here is confirmed by the observations of Goldschmidt of the imbibition and injection metamorphism which has occurred in the Stavanger district* of Norway. The observations which he made of the rocks near the igneous margin are pertinent here. He observed the following progression from more distant parts to those nearest the igneous mass: hornblende and clinozoisite are formed; then closer in micropertthite begins to appear, and along with the albite forms streaks, folia and augen. The innermost contact zone consists of an injection gneiss in which the magmatic residues have been forcibly injected into the parting planes of the rock.

II. PETROLOGY.

(1) THE HORNBLLENDE-FELSPAR (AUGEN) GNEISSES.

The rocks which fall under this heading are Nos. 367, 367A and 1235. These rocks have a close resemblance to one another, and as No. 1235 is the better specimen we shall confine our description, to it.

The rock is definitely gneissic, parallel masses of streaked-out felspar are set within parallel lines of lustrous black hornblende. The streaks of felspar are not uniformly wide, however, some having a lenticular form so well developed that the augen nature of the gneiss is at once apparent.

Fine veins at right angles to the foliation filled with secondary calcic matter and frequently highly puckered indicate that after the intrusion of the acidic magma the rock underwent intense dynamic metamorphism.

(2) THE ROCKS INTERMEDIATE BETWEEN GROUPS (1) AND (3).

The members of this division are Nos. 120, 243, 717 and 1236.

As is suggested by the general classification of the whole suite of rocks here described the members of this subdivision do not possess the augen structure of the members of Group (1) nor the banded nature of those of Group (3), but rather have they approximately equal quantities of ferromagnesian and leucocratic constituents. In places what may be called incipient injection banding is seen, and in other places poorly shaped globular felspathic matter is found. The dark mineral matter is usually massive, but in some of the specimens there is a feeble schistosity developed.

The actual mineral contents of these rocks are much alike. The lighter minerals are quartz and felspar, the darker is a handsome lustrous hornblende or a dull green chlorite derived from it. In some specimens (notably Nos. 120, 1236) the amount of the chlorite is considerable, approximately equal to that of the amphibole, in fact.

* "Die Injection metamorphose in Stavanger—Gebeite," Videnskapsselsk. Skr., 1, Math-Nat Kl., Kristiania, 1921, No. 10, 142 pp., quoted Tyrrell, "The Principles of Petrology," 1930, p. 327.

(3) THE BANDED INJECTION GNEISSES.

The members of this group are Nos. 50, 387, 1241.

These rocks are all characterized by an excellently developed separation of the light and dark minerals into clearly defined bands. The dark mineral matter is typically a lustrous hornblende, but in places it gives way to a dark brown to black biotite. The light mineral matter consists essentially of quartz and felspar which usually form veins of pegmatitic material between the bands of hornblende. So well developed is this banding that one is tempted to call it *lit-par-lit*, but the original igneous nature of the injected rock prohibits the use of this term.

No. 50 gives some support to the classification which has been adopted in this present work. The banded section of the specimen occurs together with a contact portion of purely pegmatitic matter. This shows that nearest to the injecting acidic magma is the injection gneiss itself; in this way we have a piece of evidence afforded us which could have been provided in no other way save by an actual examination of the field relationships.

The mineral compositions resemble closely those of similar rocks described by Read and Sugi and referred to above.

In No. 1241 there is a considerable quantity of felspar and some quartz in bands microscopically (as well as macroscopically) distinguishable from hornblende and biotite areas. The felspar is mainly plagioclase, $Ab_{85} An_{15}$, showing both albite and pericline twins which are usually bent and frequently knicked. Sugi* refers to similar features in a biotite granite from Fudosaka and later (p. 42) to similar effects being produced in biotite plates. There is a little very turbid orthoclase. The quartz is clear and granular. There is a very considerable amount of massive green hornblende. Practically every crystal is surrounded by pellucid quartz grains, which shows that this mineral has been introduced under sufficiently great pressure not merely to force apart layers of hornblende matter but actually to wedge its way between the grains themselves. This intimate contact of hot, high-pressure quartz with the hornblende has been effective in forming reaction products. In some few places there are myrmekitic (or more properly here, dactylitic) intergrowths of silicic matter and felspar near the hornblende; and invariably where quartz grains are in contact with the hornblende this mineral is bordered by a region of much lower D.R. which reflects the alteration which has occurred. Biotite, which is usually massive and of a very reddish brown colour, contains occasional lenticles of lawsonite. Apatite, zircon, magnetite, allanite and hæmatite are also present.

In No. 387, while the mineral composition as a whole is much the same as in No. 1241, there are peculiarities of texture and detailed mineral character which render the rock distinguishable from No. 1241 and also from No. 50.

* *Op. cit.*, p. 35.

Myrmekitic intergrowths not more than 0.08 mm. wide, often border orthoclase crystals. The plagioclase feldspar, which is about $Ab_{60} An_{40}$, is also somewhat perthitic. The quartz has a strongly pronounced undulose extinction. Now, these are all features which characterize rocks of the kind dealt with here. Some of them, indeed, are referred to by various authorities as diagnostic.

The biotite is seen in some places to be derived from hornblende. It is associated with a little epidote.

The hornblende of the rock is massive and strongly pleochroic. Z is deep olive-green, Y blue-green, X straw-yellow. The absorption is $Z > Y > X$.

No. 50 again is somewhat similar to the other rocks of this group, but its peculiarities definitely characterize it.

The most remarkable feature is the striking development of lenticular masses of lawsonite within the biotite which is found in strongly pronounced veins of pleochroic matter (Z is deep red-brown, X light brown; the absorption is strong with $Z > X$). The lawsonite crystals are distinguished from prehnite by the following properties. It has an invariably negative elongation in prismatic sections, whereas prehnite is sometimes positive; it has more marked and a greater number of cleavage lines than prehnite, $2V$ is about 80° , whereas it is about 60° for the other mineral. This occurrence of lawsonite, a mineral with close affinities to prehnite, allies the rock to those described by Read* where he refers to lobate masses of prehnite within biotite crystals. The biotite has ejected titanium in some places. The ejection matter is present as highly complicated networks of rutile needles.

The hornblende, although usually massive, is sometimes poikiloblastic, the included matter is ordinarily quartz.

A feature of this rock is the presence of some sphene, a mineral characteristically absent from Nos. 1241 and 387, although it is frequently mentioned in the literature dealing with similar rocks.

Plumose chlorite is rarely associated with hornblende and biotite.

There is some lawsonite in the saussuritization products of the plagioclase.

Johannsen† refers to the change of biotite to chlorite and when the stage of ultra blues has been reached by the chlorite there is frequently a separation of epidote, usually between lamellæ of the biotite, where it forms elongated lens-like patches. There thus seem to be at least three closely associated minerals which occur as lenticular patches of alteration matter in biotite. They are prehnite, lawsonite and epidote. The determinative factors for the formation of the particular mineral developed are very obscure, further research needs to be carried out before a pronouncement can be made.

* Op. cit., p. 116.

† "Petrography" (1932, vol. II, p. 153).

In another section cut from the pegmatitic portion of the crystal there are no ferromagnesian minerals at all. The chief components are highly sericitized orthoclase and quartz. The patchy nature of the potassic feldspar is suggestive of anorthoclase. There is a tendency in places toward micrographic intergrowths of quartz and orthoclase.

A little albite is present.

Some original muscovite is also found.

(4) PEGMATITIC ROCKS CONTAINING FERROMAGNESIAN MINERALS.

(a) The rocks which fall in this group are Nos. 226, 970 and 1238.

The hand specimens of these rocks are much alike. Each has a crystalline felspathic base in which is set larger or smaller masses of ferromagnesian material (usually hornblende, but occasionally actinolite or chlorite). The ferromagnesian is most abundant in No. 226, it is of intermediate amount in No. 970 and least in No. 1238. In the last rock the size of the hornblende masses is smallest; they are ovate to lenticular in shape and average 2 cm. long x 3 cm. wide. Some epidote is macroscopically visible in a vein in No. 226.

The most interesting feature of No. 970 when viewed under the microscope is the presence of parallel tongues of acid feldspar which thread through the original more calcic plagioclase and continue uninterruptedly into hornblende masses. These tongues are microscopic veins along which the injected matter from the later acidic magma has been forced. They are microscopic equivalents of sills, for they lie along parallel cleavage lines which are the counterparts of bedding planes on the larger scale.

The most abundant mineral is a saussuritized derivative from an earlier highly calcic plagioclase. The saussuritization products which have completely obliterated the original twin lamellae consist of much epidote, some zoisite and a little calcite. The prevalence of these minerals rich in calcium indicates that the lime content of the original plagioclase must have been high.

The hornblende of the rock is not so massive as in many of the rocks of this suite; it more closely resembles the less dense hornblende of feather amphibolites.

Occasional flakes of sericite are seen.

No. 1238 is totally different, in that the felspathic content is almost entirely microcline, and, in comparison with that of No. 970, is particularly clear and unaffected by saussuritization or sericitization.

Indeed, the most noticeable and characteristic features of the rock are the invariably perthitic nature of the microcline and the frequency of myrmekitic intergrowths. The regions between large microcline crystals are filled by mosaics of smaller rounded grains of this mineral or by somewhat circular and elliptical masses of quartz and feldspar in myrmekitic intergrowth.

A little original muscovite is present.

Apatite occurs in a few, large, isolated grains.

The little hornblende present is giving place to biotite which in turn is becoming chloritized with an accompanying formation of prehnite or lawsonite. These ferromagnesian minerals are invariably separated from the main feldspathic mass by a region of myrmekite.

(b) *The rock which has predominating Quartz.*

The member of this group is No. 32.

This specimen is taken from a contact region between a red feldspathic quartz pegmatite and amphibolite.

The amphibolite closely resembles those from these moraines described by Stillwell (1918, 1923) and the present writer (1940). Some little highly saussuritized calcic plagioclase is present. Most of this portion of the rock, however, consists of massive hornblende. An interesting occurrence is that of prochlorite which is present to about 8%. Associated with this prochlorite is other chlorite which shows ultra-blue interference colours normally characteristic of this mineral. In the chloritic masses small grains of ilmenite and sphene are found.

The pegmatitic part of this rock consists of a great deal of quartz and some orthoclase in a contact zone with basic feldspar and hornblende. The hornblende has the same characteristics as in the purely amphibolitic portion of the rock. The products of saussurization in the basic feldspar have very frequently given place to a light green biotitiferous chlorite. Little need be said of the orthoclase and quartz except that the first is greatly kaolinized and the second has a very undulose and indifferent extinction. There are regions where myrmekitic textures are evident.

(c) *The rocks which have approximately equal quantities of feldspar and quartz.*

The members of this group are Nos. 1239, 384A, 878.

It is only the relatively large amount of quartz in No. 1239 which prevents it from being included in group (a). In the hand specimen it looks very much like the members of group (a), particularly No. 1238A. Nos. 384A, 878 are more closely related to one another. Each has a white feldspathic mineral which is typically saccharoidal. Each contains bronzite, although the amount of this mineral in No. 878 is much greater than that in No. 384A. This latter rock, on the other hand, carries a larger amount of hornblende than the former.

Under the microscope No. 1239 is seen still more to resemble No. 1238A for there is considerable microcline-microperthite present. In addition to this felspar there is felspar which shows albite twin lamellae which taper towards the ends of the crystal and eventually disappear. Crush zones between large crystals of felspar and quartz are quite common. They are usually filled with myrmekitic matter. The large quartz grains have undulose extinction.

Apatite and muscovite are the only other colourless minerals present.

The dark minerals are hornblende, biotite and sphene. The hornblende is pleochroic in deep blue, bottle green and yellow green. The biotite is associated both with the hornblende and with the silicic matter of the rock. In the second circumstance it seems as if some of this matter has been assimilated; a similar reaction has been observed in connection with some of the charnockite like rocks from this area (*antea*, Vol. III, Part 6.) A little allanite and a few grains of magnetite and zircon are also present.

There is no microcline in specimen No. 384A. The felspar is acid plagioclase $Ab_{85} An_{15}$ which shows tapering albite twins. Occasionally pericline twin lamellae have also been developed. Perthitic structures and myrmekitic intergrowths are almost completely absent.

The more interesting points are the presence of distinctly pleochroic hypersthene, Z pale green, X pale pink, with $Z > X$. Associated with this mineral, and to a large extent derived from it, are massive green hornblende and biotite. In this rock, too, as in the above mentioned charnockite series is a development of biotite along cleavage lines and cracks in felspar. This change is a characteristic one in rocks of this nature. Apatite and zircon (the latter frequently as nuclei of intense pleochroic haloes) comprise the accessory minerals.

In specimen No. 878 the pyroxenic mineral is clino-enstatite. Two varieties of alteration of this mineral are seen. In one a mesh-work of cracks filled with serpentine and talc has developed but in the other variety the change has been confined more to the edges of the mineral where the biotite has been produced.

The presence of a large number of deep red brown crystals of biaxial brookite in this rock is of interest.

The greater part of the rock consists of undulose quartz and acidic plagioclase about $Ab_{90} An_{10}$. Perthitic and myrmekitic textures are lacking.

Appreciable quantities of apatite, zircon and magnetite make up the rest of the rock.

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