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Dedicated to Professor Atsuo Harumoto in Commemoration of his Retirement on the 16th November of 1959

On the Hida Gneiss in the Vicinity of the Kamioka Mine, Gifu Prefecture, Japan

By

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Abstract

Granodioritic gneiss widely distributed in the Hida Gneiss area has every possibility of having been derived from acid igneous rocks of magmatic origin.

Metamorphic rocks (crystalline limestone, melanocratic gneiss, etc.) of mainly sedimentary origin were probably formed by the metamorphism previous to the intrusion of the granodioritic magma, though modified by some later movements of the earth's crust The metamorphism and the intrusion, however, might have been of consecutive occurrence in one orogenic movement: the metamorphic rocks including granodiorite were under the control of the orogenic stress during or after the intrusion.

Introduction

For the past two years the writer has had a chance to make inquiries into the Hida Gneiss both at the Kamioka Mine of Yoshiki province, Gifu Prefecture and at Tsunokawa, the western part of the same province. As for the metamorphic rocks of this group, excellent detailed studies were made respectively by ISHIOKA[1], IWAFUNE[2], KOBAYASHI[3], NOZAWA[4], SATO[5], etc..

Referring to their studies on the metamorphic rocks, the writer will in this paper express his opinion which is in some parts different from those of the above-named authors.

The Abstract of Petrography

(i) Crystalline Limestone

It contains, besides calcite of sacchaloidal texture, small quantities of Ca-rich monoclinic pyroxene, garnet, olivine, chondrodite, chlorite, prehnite, etc.. The foliation of this limestone is perceivable to the naked eye on account of the parallel arrangement of graphite crystals.

(ii) Fine and/or coarse-grained melanocratic Gneiss

This term implies all sorts of the gneisses consisting of a few of the following minerals: monoclinic pyroxene, hornblende, biotite, plagioclase, alkali-feldspar, quartz, garnet, etc.. They are fine-grained, generally foliated, stratiformed and concordant with limestone, being considered to be gneisses presumably, of sedimentary origin. The most numerous of them all are gneisses consisting mainly of green hornblende, plagioclase ($An_{40\sim50}$) and also containing small quantities of biotite and quartz; they may be ascribable to basic tuff or basic lava origin. Where this rock either comes in contact with or is surrounded by granodiorite and/or granodioritic gneiss, a kind of dioritic gneiss rather melanocratic is formed between the two rocks, as is referred to later on.

(iii) Medium-grained hornblende-monoclinic pyroxene granodiorite (medium-grained migmatite—miner's classification)

It consists mainly of quartz, plagioclase (An_{30}-An_{45}), diopsidic—hedenbergitic pyroxene and green hornblende and contains very small quantities of biotite, microcline, sphene, apatite and iron ore. It is noteworthy that among the colored minerals monoclinic pyroxene is most abundant and remarkable. It sometimes happens that around this pyroxene is formed green hornblende, to which biotite flakes are partly attached. The texture is, in most cases, granitic or dioritic, and scarcely foliated.

(iv) Coarse-grained facies (Coarse-grained migmatite—miner's classification)

This is a little more leucocratic than medium-grained facies, notwithstanding their mutual resemblance: there is little difference in their mineral components. It is no exaggeration to say that the rock has no foliation.

The rocks of (iii) and (iv) are, the writer considers, of the same group.

(v) Biotite-hornblende-granodioritic gneiss (the same as that of Nozawa's classification)

This mainly comprises quartz, plagioclase ($An_{28\sim35}$), biotite and hornblende, and slightly microcline, sphene, apatite, etc., the latter group of minerals being larger in quantity than in the cases of (iii) and (iv). Moreover, in this rock there develop chlorite, epidote, prehnite, etc., while its hornblende sometimes contains other minerals to show sieve texture, and it very rarely happens that the hornblende has monoclinic pyroxene as a relict mineral in its core and biotite attaches partly around it. The rock has a texture in which granoblastically-formed fine-grained microcline, plagioclase, quartz, etc. are surrounding relatively larger crystals of hornblende and plagioclase. The fine-grained plagioclase is generally Ab-richer in its composition than the coarse-grained.

(vi) Biotite granodioritic gneiss (Nozawa's classification)

It consists mainly of quartz, biotite, plagioclase ($An_{28\sim30}$), and miclocline, containing, in small amount, apatite, sphene and iron ore, too. In this rock, also, there are seen chlorite, prehnite, etc., presumably altered minerals from biotite. The rock bears, except for scantiness of hornblende, a strong resemblance to that of (v).

Table 1. Monoclinic pyroxenes in gneisses.

Sample number	Index of refraction $n_{1'(110)}$	2V (+)	Chemical composition	Rock containing
A. 3	1.725±0.003		$Di_{19}Hd_{81}$	coarse-grained monoclinic pyroxene granodiorite
A. 11	1.683±0.003		$Di_{76}Hd_{24}$	"
A. 11′	1.683±0.003 (n_2=1.703±0.003)	60°±5°	$Di_{76}Hd_{24}$	limestone adjacent to coarse-grained granodiorite (Sample A. 11)
A. 8	1.695±0.003		$Di_{61}Hd_{39}$	medium-grained hornblende-monoclinic pyroxene-granodioritic gneiss
A. 8′	1.702±0.003		$Di_{65}Hd_{35}$	fine-grained, melanocratic hornblende-monoclinic pyroxene-quartz-dioritic gneiss adjacent to granodioritic gneiss (Sample A. 8)

Some Observations and Considerations of the Rocks

I. Hornblende-monoclinic pyroxene granodiorite and its relation to other rocks assumed as of sedimentary origin

This rock as well as biotite-hornblende granodioritic gneiss is found most widely distributed in this district, especially in the underground part of the mine.

(a) Medium-grained granodiorite

When we examine the relation of the rock of this facies to crystalline limestone, we find that the former is generally arranged rather concordantly with the foliation of the limestone, but sometimes cuts it dykewise. Besides, limestone in a lens-like shape often exists inside the granodiorite, and the latter in the form of layers inside the former. Often on the limestone side of the contact boundary of the two rocks there is formed wollastonite, and its inner part is composed of such skarn minerals as garnet, monoclinic pyroxene, scapolite, chondrodite, etc.. About the boundary between granodiorite and limestone there frequently exists leucocratic dioritic or syenitic rock, but the writer will dwell on it on another occasion.

Where this granodiorite contacts with melanocratic gneiss, there exists a rather melanocratic quartz-dioritic gneiss which has either the outline suggestive of its bygone boundary of the melanocratic gneiss block in the pre-reaction stage or a ghost-like shape suggesting that the gneiss is being absorbed into the granodiorite, and there are frequently the instances in which the melanocratic gneiss is still retained in the dioritic gneiss (Fig. 1). This dioritic zone is rich in colored minerals and has the same essential minerals as the granodiorite does, though scanty

Fig. 1. A ghost-like xenolith of melanocratic gneiss (2) in the granodiorite (1). The former is digested strongly into the latter. (In the gallery of 0-meter level directed to Yoshigahara).

of quartz. Where the melanocratic gneiss remains as a relic in the dioritic one, there these two rocks have foliation in common. And where the reaction zone is poorly developed, granodiorite often intrudes in vein into melanocratic gneiss and the boundary is noticed either clearly or obscurely as the case may be (Fig. 2 and Fig. 3).

(b) Coarse-grained granodiorite.

This develops in the rock of the medium-grained facies, generally with a transitional relation, or partly with a relatively clear boundary. For instance, at the gallery of 0 meter level (with the direction 120° from N; toward Yoshigahara) this rock runs for tens of meters; it generally does not form very small mass; say, about the size of several meters, though smaller in mass than the medium-grained type of it.

The relation of this rock to limestone and melanocratic gneiss is characterized by the far greater discordancy of foliation than the relation of the rock of medium-grained facies to those gneisses. It cuts melanocratic gneiss in random directions as dykes and apophyses (Fig. 4 and Fig. 5) and sometimes it contains complicatedly-folded mass of melanocratic gneiss as a digested block (Fig. 6). Again sometimes it xenolithically contains several mutually adjacent blocks of melanocratic gneiss—the foliations of which are running toward diverse directions, to suggest the independent and random movement of each block (Fig. 7).

Such observations convince the writer of the facts that once a granodioritic magma intruded into melanocratic gneiss, limestone, etc., and that where the assimilation was left incomplete, there alone remains melanocratic dioritic gneiss. The writer is of the opinion that, in the earlier stage of the magma intrusion the medium-grained granodiorite was formed out of that magma which intruded into

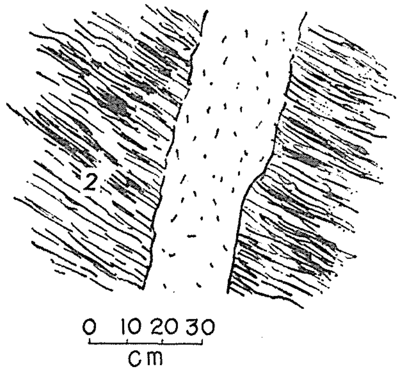

Fig. 2. A dyke of medium-grained granodiorite (weakly foliated: strike N78°W, dip N70°) (1) injecting into fine-grained meranocratic gneiss (strike N50°W, dip SW70°) (2).
(In the gallery of 0-meter level directed to the North, between the 1st and the 3rd ore-bodies)

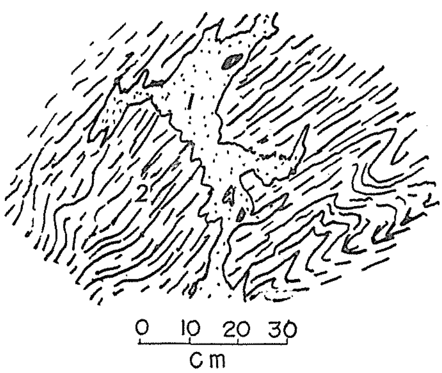

Fig. 3. Irregularly-formed dyke of medium-grained granodiorite (1) injecting into melanocratic gneiss (2).
(On the road from Tochibora to the Inishi Pass).

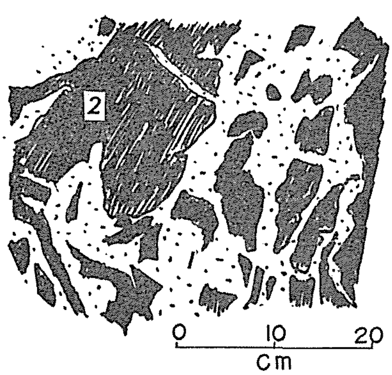

Fig. 4. Melanocratic gneiss (2) cut by many irregularly-formed dykes of coarse-grained granodiorite (1). The former is strongly digested by the latter.
(In the gallery of 0-meter level directed to Yoshigahara).

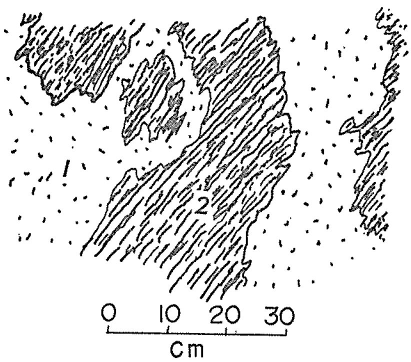

Fig. 5. Coarse-grained granodiorite (1) irregularly injecting into folded melanocratic gneiss (2). The latter is digested strongly into the former.
(In the gallery of 0-meter level, between the 2nd and the 4th ore-bodies).

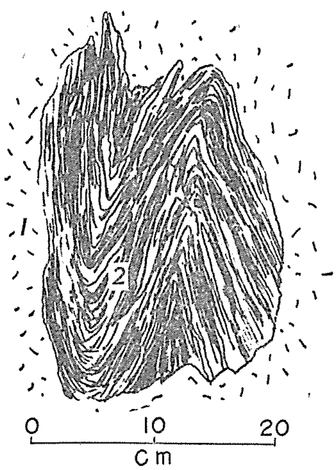

Fig. 6. A complicatedly-folded mass of melanocratic gneiss (2) digested into coarse-grained granodiorite (1).
(In the gallery of 0-meter level directed to Yoshigahara).

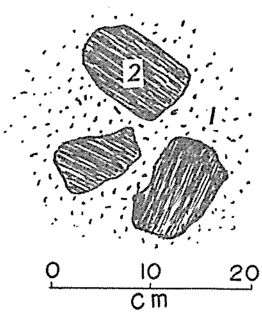

Fig. 7. Some xenoliths (2) of melanocratic gneiss contained in the coarse-grained granodiorite (1). Each foliation of the xenoliths is of random arrangement.
(In the gallery of 0-meter level directed to Yoshigahara).

the gneisses in the direction almost parellel to their foliations. In the later stage of it, and as the volatile matters got concentrated, the coarse-grained granodiorite was made to occur out of the residuals intruding rather regardless of the gneiss foliation.

II. Hornblende-granodiorite and its relation to biotite-hornblende granodioritic gneiss and biotite-granodioritic gneiss

(i) It is clear from observations of these two rocks at the Maruyama Mine that the perfect transition from non-foliated granodiorite to foliated granodioritic gneiss is traceable.

(ii) Granodiorite is characterized by the fact that it contains monoclinic pyroxene as its essential colored mineral. As stated before, such a pyroxene is occasionally seen, as a reaction relic, in hornblende of granodioritic gneiss.

(iii) Granodioritic gneiss contains deep green hornblende of sieve texture wherein plagioclases are developed like so many islands in the green sea of hornblende. As the result of the metamorphism, colorless amphibole (tremolite?) is sometimes seen in the gneiss. Also such metamorphic minerals as epidote, chlorite, prehnite, etc. are contained therein.

(iv) Quartz, Na-richer plagioclase* microcline, biotite, etc., in granoblastic texture are developed surrounding larger-grained plagioclase, hornblende, etc., in the gneiss. And it is due to this mineral arrangement that the rock has a kind of gneissose texture.

(v) So far as its chemical composition is concerned, similar are the larger grained plagioclase in this gneiss and every plagioclase in the granodiorite. But in the plagioclase in the gneiss, alteration is often very remarkable and twin plane is so curved as to be suggestive of its having undergone a stress or stresses.

Conclusion

To sum up, it cannot but be concluded, therefore, that this granodioritic gneiss was certainly metamorphozed from the already consolidated granodiorite, in a deeper zone of the earth's crust, under the stress given during or after the stage of granodioritic magma consolidation; and then the non-foliated granodiorite was formed out of the yet unconsolidated part of the magma.

The difference of mineral composition between granodiorite and granodioritic gneiss was due mainly to the different conditions before and after this metamorphism. Emanations (mainly alkalic) probably from the yet unconsolidated part of the granodioritic magma acted cooperatively upon the metamorphism of the already consolidated granodiorite.

It follows from the above-mentioned inference that granodioritic gneiss (Nozawa's classification), that is, migmatite (at least the greater part of what miners call migmatite) was produced, in the strict sense of the term, never by granitization

* Na in this plagisclase is richer than that in the larger-grained one.

or metazomatism of rocks in solid state, but by granodioritic magma in liquid state and by its emanation and afterwards modified by orogenic stress.

Furthermore, if compared with the Ryoke Metamorphic Zone, limestone is as remarkably developed in this zone as it is self-evident that the above said magma was much contaminated by limestone. The remarkable existence of monoclinic pyroxene in granodiorite is a datum to suport this conjecture stress.

That the existing limestone, melanocratic gneiss, etc. underwent metamorphism before the formation of the granodiorite or granodioritic gneiss, is, the writer considers, seen not only from the fact that they were injected by the non-foliated granodiorite, but also by the other fact that the parallelism of rock foliation is not always found between sedimentary gneiss and granodioritic gneiss derived from granodiorite. That is to say, there were at least two different stages in the metamorphism: before and during or after the magma intrusion, even if these two stages were of one orogenic movement: the metamorphism of sedimentary gneiss seems to have been renewed by the intrusion of the granodiorite and by the crustal movement in the stage of that intrusion—polymetamorphism, and all kinds of gneisses have been further affected by the intrusion of Funatsu granite and afterwards also by the movement, owing to which mylonites were formed.

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