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The Metagabbroic Rocks Bearing Ferriferous Minerals in the Ryoke Zone, Japan

By

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With 1 plate and 4 figures in the text

Abstract

There have been found two metagabbroic rocks bearing ferriferous minerals having a subparallel arrangement with the Ryoke metamorphics. The one is characterized by fayailte, orthoferrosilite, ferroaugite, and andesine, and the other by ferrohypersthene, and andesine. The mafic minerals in the former resemble those of eulysites and collobrierites, and the latter rock is similar to those once reported by Dr. S. Iwao. It seems to the writer that these rocks are the recrystallization products due to granitization, and the ferriferous olivine and pyroxenes are not relict minerals which preexisted before the granitization, but are of the granitization phase. Ferruginous schalsteins, or basic igneous rocks are considered as the originals of these rocks.

Introduction

There are, at least, two main groups of metagabbroic rccks having remarkable differences with each other, in the Ryoke granite intruded in the Jurassic Age,* in West Japan. The one has comparatively large xenolithic masses of several kilometers in diameter, considered as forerunner of the batholithic granite, and the other is bedded or sheet-like masses of small scale compared with fhe former, being characterized by ferriferous varieties of mafic minerals and plagioclases of intermediate compositions. These two kinds of basic groups and their associated Chichibu palaeozoic system have suffered granitization due to the granite.

This paper will be written on the petrological studies of the bedded metagabbroic rocks mentioned above.

Geology and Petrography

A. The fayalite-bearing metagabbroic rocks of Hiiruba, Nagano Prefecture

The rocks crop out in the Hiiruba Valley, the upper stream of the Yonegawa River being a left-side tributary of the Tenryu River.

In this district, generally speaking, the Chichibu System coexists with the granitic rock intruded in subparallel directions to the bedding plane of the former,

* infered by Dr. T. Kobayashi formerly.

and there various schists and gneisses have been constructed by the mutual reactions among each other. The granitization[1] of the sedimentaries is of the properties that the granitic emanations (fluids) having migrated prior to the intrusion of the granitic magma itself, have acted upon the sedimentaries; the metamorphism, except the thermal one, along the very contacts between the granite itself and various sedimentaries, is insignificant, and generally the degree of granitization has only slight relations with the distance from their contact. The original arrangements of the preexisting sedimentaries are slightly disturbed by the granitization. After the granitization, the porphyritic granodiorite intruded as clean-cut dyke in the granitization-products.

The metagabbro consists of the concordant mases in the garnet-cordierite-biotite-quartz-schist, having the strike NE, and the vertical, or high angle dip to SE, and being separated in a few horizons by the interbeds of the schist and the occurrences of the granitic rock.

In the schist nearer to the very contact with the metagabbro, there is generally a traditional rock bearing hornblende porphyroblasts, which frequently turned to mylonite by the dislocation in time of the tectonic movements after the granitization and the granite intrusion, by which the metagabbro itself had fissility. The contact parts of these two rocks, therefore, might have been weak for the tectonic movement.

The largest mass of the metagabbro extends about 150 meters in length, and frequently smaller ones form lenticular bodies for a few meters in the granodioritic rock, but even in the case of a small mass its bedding horizon is maintained, because in pursuing over a mass to its strike direction, one will encounter another mass on the same horizon. The total extension reaches 180 meters. Thickness of each mass is 5 meters in maximum, and 1 meter in minimum, The total thickness reaches about 8 meters.

The boundary between the metagabbro and the leucocratic granodioritic rock is sometimes linear, but the latter diffuses divergently in the former through rather broad areas at the northern part, where the formation of the melanocratic granodioritic rock is observed (See PL. 1).

The melanocratic rock, too, scatters in patches in the metagabbro itself.

The relations between the leucocratic granodioritic rock and the schist are tranditional along both striek-and dip-sides.

Judging from the field observations, both the melanocratic granodioritic rock and the leucocratic granodioritic rock are the products of the granitization due to the permeation of the granitic fluids. The permeation, perhaps, have started along the bedding plane of the preexisting rocks. Thus it can be said that they are the members of " Banded Gneiss ".

On the other hand, the inner part of the metagabbro, too,is distinctly metasomatized by the granitic fluids, judging from the microscopical investigations, so the melanocratic dioritic rock is possibly of the advanced stage (later stage) of the granitiztion of the metagabbro. The leucocratic granodioritic rock, mainly, is of the mutual reaction origin between the argillaceous sediments and the granitic fluids.

The biotite porphyritic granodiorite is of intrusive origin, not of permeation origin. The metasomatic action of this rock seems to be very weak, because this rock forms a clean-cut dyke in the other ones. After the granitization finished, this rock seems to have appeared.

The plagioclase-hornblende-granulite of the southern part is intruded by the granite, and is one of the metasomatized basic rock. The metasomatic action on this rock, too, is of the kind that happened prior to the granitic intrusion.

Summary of the microscopical observations of the rocks

a) The fayalite-bearing metagabbroic rock

This is coarse- or medium-grained melanocratic rock, consisting of plagioclase, hornblende, olivine, biotite, quartz, also frequently orthoferrosilite, and rarely ferroaugite as essential minerals ; and zircon, allanite, sphene, and garnet, almandine, as accessory ones.

The average mode of this rock and its bulk composition are shown in Table 1.

Table 1. The chemical analysis and the mode of the fayalite-bearing metagabbroic rock from Hiiruba.

SiO_2	53.12	plagioclase	60.6
TiO_2	1.18	quartz	13.3
Al_2O_3	16.60	amphiboles	12.8
Fe_2O_3	1.10	biotite	6.0
FeO	13.16	fayalite	4.1
MnO	0.45	pyroxenes	2.0
MgO	1.20	(mainly rhomb.	
CaO	6.39	variety)	
Na_2O	3.20	accessories	1.2
K_2O	0.81		100.0
P_2O_5	0.26		
$H_2O(+)$	1.55		
$H_2O(-)$	0.28		
Total	99.30		

Analyst : The writer

There are two varietis in the feldspars, one of which forms large and subhedral, sometimes porphyroblastic crystals, and the other smaller and granular ones. The former have irregular zonal structure, in which parts of An 49–51 are surrounded by more acidic periphery of An 39–40. The small and granular crystals are An 40 and less frequently zoned. These two varieties of the feldspars are altogether fresh through all parts of the crystal bodies.

The fayalite in general is bordered by the amphiboles, and shows irregular and corroded appearance : the fayalite is replaced directly by cummingtonites showing polysynthetic twin, and furthermore brownish green hornblende crystallizations occur arround them. In other words, the fayalite has a reaction rim of amphiboles. But rarely the fayalite * without such a reaction structure moulds ophitically in the interstices of the subhedral feldspars having zonal structure. Therefore, it is certain that the fayalite is of later formation than, or contemporaneous with the plagioclase (An40).

The orthoferrosilite is more euhedral than olivine, but both are bordered by amphibole. There are faintly noticiable the oriented plates of monoclinic

* This fayalite has the same chemical composition as that with the reaction-structure.

pyroxene in its body.

The ferroaugite is a very rare mineral, occuring with ophitical texture in the interstices of feldspar crystals, and being surrounded by brownish green hornblende, but cummingtonite is not observed in this case. There are scattered many small and irregular crystals of brown hornblende showing sieve-texture in the augite crystals.

The brownish green hornblende and the biotite replace the other minerals except for quartz, and the crystals of these two minerals, respectively, have the same orientation with each other through fairly broad areas in the rock section, even if they are separated in different bodies by the existence of other associating minerals: namely, they seem to be a kind of porphyroblast.

The quartz is a cementing material of the interstices of hornblende, and feldspar, and appears fresh.

Garnet, almandine, frequently occurs in the parts rich in quartz.

The optic propertits of these minerals are shown in Table 2.

Table 2.

Sample No.	Fayalite	Ortho-* ferrosilite	Ferroaugite	Grunnerite	brownishgreen Hornblende	Biotite	Almandine
(Ina) 62	2V=55° Fa85(2)	$\gamma=1.769$, 2V=(-)85° $\rho<, v$ OF84	none	$n_2(110)=$ 1.712 2V≒(-)88°	$n_2(110)=$ 1.713 2V=(-)63°	$\gamma=1.693$	$n≒1.809$
(″) 128 (1)	2V=55°	undeterm	none	$n_2(110)=$ 1.715 2V≒(-)90°	$n_2(110)=$ 1.718 2V=(-)63°	$\gamma=1.693$	none
(″) 126	2V=54°	2V=(-)84°	none	$n_2(110)=$ 1.717	$n_2(110)=$ 1.720 2V=(-)63°	$\gamma=1.694$	none
(″) 128 (2)	2V=54°	2V=(-)85°	$n_2(110)=1.724$. 2V=(+)53° Wo35 En23 Fs 42(2)	$n_2(110)=$ 1.710	$n_2(110)=$ 1.711	undeterm.	none
(″) 149	none	2V=(-)84°	none	$n_2(110)=$ 1.720	$n_2(110)=$ 1.720 2V=(-)64°	$\gamma=1.693$	none

b) Melanocratic granodioritic rock.

This occurs as irregular patches in the fayalite-bearing metagabbro, or as narrow contact facies between the metagabbro and the leucocratic granodioritic rock. It is composed of plagioclase, hornblende, biotite, quartz, iron ore, garnet, apatite, sphene, and allanite.

The garnet, almandine, associates with quartz and biotite as large porphyroblast.

The hornblende is of brownish green varie'y, in which cummingtonite patches, considered as pseudomorph after olivine, or rhombic pyroxene, are contained.

The mode of the constituent minerals is similar to the fayalite-bearing metagabbro, except for the absence of olivine and pyroxenes.

This rock is the representative of the more advanced granitized facies than

* It is eulite, according to Poldervaart's classification.

the fayalite-bearing one, judging from its constituent minerals and their optical properties.

The optical data of the minerals are shown in Table 3.

Table 3.

Sample No.	Cumming-tonite	green Hornblende	Biotite	Plagio-clace	Garnet
(Ina) 144	n_2 (110) =1.708	n_2 (110) =1.712	$\gamma=1.690$	outter zone of zonal structure: An 44	undeterm

The garnet porphyroblast may have a genetical relation with the rhombic pyroxene, or the olivine, as follows:

$$\begin{Bmatrix} 3[FeO.\ SiO_2] \\ 3[MgO.\ SiO_2] \end{Bmatrix} + 2Al_2O_3 = \begin{Bmatrix} 3\ FeO.Al_2O_3 \cdot 3SiO_2 \\ 3\ MgO.Al_2O_3 \cdot 3SiO_2 \end{Bmatrix}$$

This Al_2O_3 may be of the origin of the alkali-alumina-emanation from the granitic fluids.

c) Leucocratic granodioritic rock

This is allotriomorphic granular, and consists of plagioclase, quartz, green hornblende and biotite as essentials, and apatite, iron ore, zircon, allanite as accessories. Among the plagioclases of this rock, there are noticed porphyroblastic ones infrequently.

The optic data of the minerals are shown in Table 4.

Table 4.

Sample No.	green Hornblende	Biotite	Plagio-clase	Garnet
(Ina) 129	undeterm. (very small amounts)	$\gamma=1.674$	An 40, rarely zoned	none
(″) 161	n_2 (110) =1.720	$\gamma=1.686$	(1) porphyro-blast zoned: core: An 49 cell: An 40 (2) granular: An 40	contained

d) Garnet-cordierite-biotite-quartz-schist

This is fine-grained and granular, consisting of plagioclase (An40—Ad27), quartz, microcline, biotite ($\gamma=1.648-1.665$), cordierite, garnet, iron ore, zircon, and apatite.

Where the schist contacts with the fayalite-bearing metagabbro, the green hornblendes crystallilze out in the schist-part, and form porphyroblasts which are surrounded by biotite flakes accompanied by quartz. It appears to the writer that the porphyroblast is the product of the metamorphic differentiation in time of the granitization due to the reactions between the schist and the metagabbro.

e) Porphyritic granodiorite

This consists of porphyritic microcline, quartz, biotite, oligoclase, iron ore, zircon, apatite and allanite, being somewhat gneissose.

f) Amphibolitic granulite

This consists of porphyroblasts of brownish green hornblende (n_2 (110) = 1.670 – 1.675, 2V ≒ (–) 80° of brownish green variety, n_2 (110) = 1.660 — 1.665, 2V ≒ (—) 80° of greenvariety), biotite (γ = 1.635 – 1.645), iron ore, plagioclase (generally zoned : core — An64, cell — An47), quartz sphene, and apatite.

Table 5 shows the bulk composition of this rock.

Table 5.

SiO_2	49.97	
Al_2O_3	17.34	
TiO_2	0.65	
Fe_2O_3	1.50	
MgO	8.21	
FeO	7.31	
MnO	0.11	
CaO	11.49	
Na_2O	1.96	
K_2O	0.19	
$H_2O(+)$	1.39	
$H_2O(-)$	0.28	
P_2O_5	0.41	
Total	100.81	Analyst: The writer

This rock seems to be of the origin of basic sediments, and may have any connection with the fayalite-bearing metagabbroic rock.

B. The ferrohypersthene-bearing metagabbroic rock of Nishitani, Nara Prefecture

There is the outcrop of this rock on the roadside leading to Nishitani from the station of Sanbonmatsu of Kinkinittetsu R. R. Line.

In this area there are granodiorite, banded gneiss, and schists of the Ryoke zone, which underlie the dacites ef Muro Volcanic Group of Cainozoic Era.

The geological and petrological environments of this region are similar to that of the fayalite-bearing rock area above mentioned, except for the existence of volcanic rocks.

At the outcrop, the metagabbroic rock associates in parallel with leucocratic granodioritie rock, garnet-biotite-quartz-schist, and crystalline limestone with many skarn minerals. These rocks extend to the NW direction with vertical dip.

The sketch of this outcrop is shown in Fig. 1.

The leucocratic granodioritic rock is of metasomatized character similar to that of Hiiruba. The marginal part, 5 – 10 centimeters wide, of the Ferrohypersthene-bearing rock along the granodioritic one is somewhat leucocratic.

Summary of the microscopical observations of the rock

a) Ferrohypersthene-bearing metagabbroic rock

This is medium-grained and melanocratic, having weak gneissosity, and is

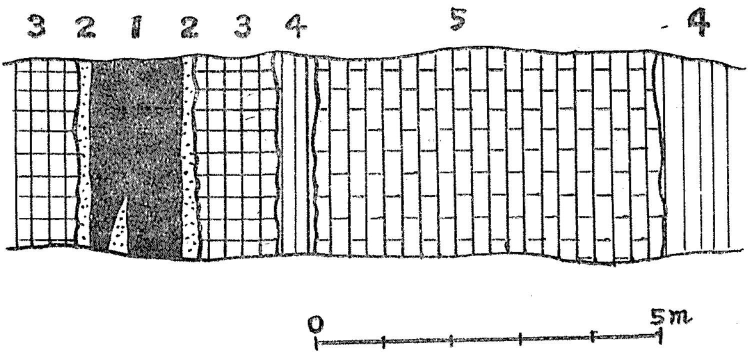

Fig. 1. The outcrop of tho ferrohypersthene-bearing metagabbroic rock of Nishitani
1. ferrohypersthene-bearing metagabbroic rock
2. melanocratic granodioritic rock
3. leucocratic granodioritic rock
4. garnet-biotite-quartz-schist
5. limestone with many skarn minerals

composed of, mainly, feldspar, quartz, biotite, and brownish green hornblende, being accompanied by small amounts of ferrohypersthene, allanite, magnetite, apatite,and zircon.

Feldspars consist of two varieties, porphyroblastic crystals and granular ones. The former has zonal structute with tranditional boundary, peripheral part being An40 and core part An47, and moreover, the remarkably decomposed core having the composition of An74, is observed frequently.* The fine grained and granular feldspar is of An40, doubtlessly being of granitization origin.

Hypersthene has reaction-rim of amphiboles, inner part of which is cummingtonite and outter part brownish green hornblende.

Amphiboles in general replace the other minerals.

Biotite is reddish brown, and quartz fills the interstices of other minerals.

The arrangement of biotites has the influence upon the gneissosity of this rock. This rock is petrologically the equivalent to the fayalite-bearing metagabbro of Hiiruba.

The optical data and the bulk composition, respectively, of this rock are shown in Table 6, and Table 7.

b) Melancocratic granodioritic rock

This consists of mainly plagioclase, quartz, and biotite, and rarely, apatite, magnetite, garnet, and zircon. Amphibole appears very rarely.

Feldspars are of the same character as those of the ferrohypersthene-bearing facies.

Biotite is brown.

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* This decomposed plagioclase core appears to the writer to be a relict mineral from the original rock of this metagabbroic one.

Table 6. The optical data and the inferred chemical compositions of the constitueut minerals in the granitized rocks of Nishitani.

	ferrohyper-sthene-bearing metagabbroic rock	melanocratic granodioritic rock	leucocratic granodioritic rock	garnet-biotite-quartz-schist
Biotite	reddish brown $\gamma = 1.675$	brown $\gamma \fallingdotseq 1.669$	brown $\gamma \fallingdotseq 1.670$	reddish brown $\gamma = 1.650 - 1.655$
brownish green hornblende	$C \wedge Z = 16°$ $n_2(110) = 1.693$ $2V = (-)72°$	very small amounts	$n_2(110) \fallingdotseq 1.690 - 1.693$ $2V \fallingdotseq (-)70°$	none
cumming-tonite	$n_2(110) \fallingdotseq 1.690$	rare	none	none
ferrohy-persthene	$\gamma \fallingdotseq 1.742$ $2V = 58°$ $\rho < v$ OF 62	none	none	none

Table 7. The chemical compositions of the granitized rocks of Nishitani

	ferrosilite-bearing metagabbroic rock	melanocratic granodioritic rock	leucocratic granodioritc rock
SiO_2	57.36	65.60	66.91
TiO_2	1.04	0.17	0.58
Al_2O_3	16.28	15.60	15.58
Fe_2O_3	1.15	0.86	1.12
FeO	8.35	4.56	3.81
MnO	0.34	0.18	0.14
MgO	2.89	1.95	1,58
CaO	7.29	4.23	4.65
Na_2O	3.02	3.66	3.17
K_2O	1.25	1.99	1.66
P_2O_5	0.29	0.33	0.20
H_2O (+)	1.45	0.56	0.55
H_2O (−)	0.27	0.42	0.44
	100.98	100.11	100.39
Analyst:	The writer	The writer	Y. Yamamoto

Interstitial quartz is in greater amounts than that of the ferrohypersthene-bearing facies.

Garnet, almandine, occurs as porphyroblast associated with biotite and quartz.

This rock correlates with the similarly named one at Hiiruba.

Table 6, and Table 7, respectively, show the optical data and the bulk composition of this rock.

c) Leucocratic granodioritic rock

It is allotriomorphic and granular, consisting of plagioclase, quartz, biotite, and brownish green hornblende as the essentials, and apatite, magnetite, zircon, and sphene as the accessories, in which plagioclase (An 40) generally does not show zonal structure, but rarely has the core (An 47).

The optical data of the minerals and the bulk composition, respectively, are shown in Table 6, and Table 7.

d) Garnet-biotite-quartz-schist

It is fine-grained and granular, being mainly composed of biotite, quartz, plagioclase of An40, and rarely of apatite, magnetite, microcline, and zircon.

Genetical Considerations of These Metagabbroic Rocks

Judging from the geological, and the petrographical conditions, these metagabbroic rocks evidently belong to a rock-series of the same character, and the similar facies to the metagabbro of Nishitani are observed in part at Hiiruba. On the other hand, the rock of Nishitani seems to be the same as the granitized granulites of Tenryûkyô [3], and other places formerly reported by Dr. S. Iwao.

It is shown from Fig. 2 that the indices of refraction of the mafic essentials in all these rocks change regularly and continuously among each other, and therefore, there exists a close and genetical relation among the mafic essentials in all these

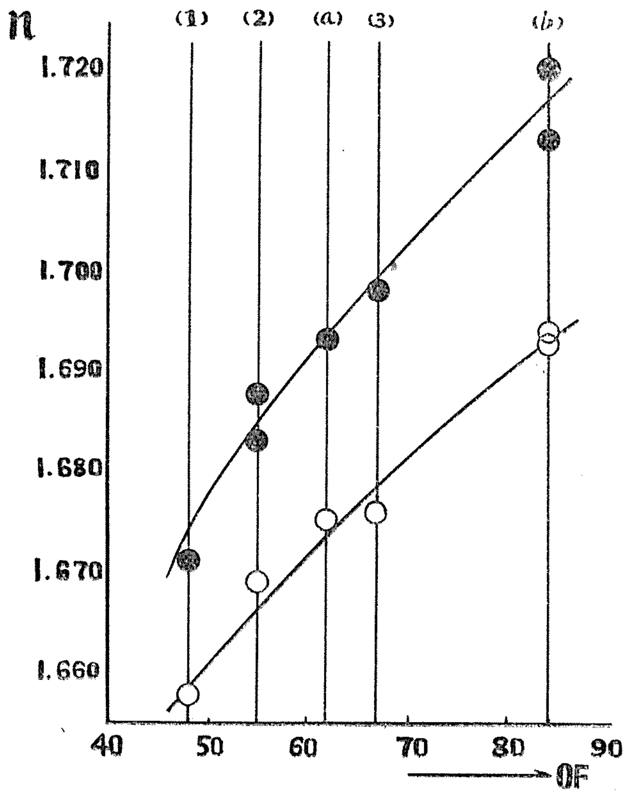

Fig. 2. The mutual relation between the ferriferous minerals in these metagabbroic rocks
n. index of refraction
{for brownish green, or green hornblende, n_{γ}(110)
{for biotite, γ.
OF. orthoferrosilite (mol%) in rhombic pyroxene
● hornblende ○ biotite
(a) from Nishitani (1) from Obatake, Yamaguchi Pref.[3]
(b) from Hiiruba (2) from Mukunô, Yamaguchi Pref.[3]
(3) from Tenryukyo, Nagano Pref.[3]

rocks. So it may be understood that all these minerals have appeared under the same genetical conditions.

The fayalite occurs ophitically in the interstices of the porphyroblastic crystals of plagioclase (An 40) which evidently recrystallized out due to the granitization. Therefore, the former also is certainly of the same genetical relation, judging from the manners of the coexistence of the two minerals. As the ferriferous orthorhombic and monoclinic pyroxenes seem to be nearly contemporaneous with the fayalite, judging from the microscopical observations, the pyroxenes also may be said to be recrystallization products.

From the facts above mentioned, the writer comes to the conclusion that the fayalite and the pyroxenes in these rocks are not relict minerals which preexisted before the granitization, but are the products of the granitization. So from the microscopical observations, feldspar An 40 – 50, fayalite, and pyroxenes will be of earlier recrystallization, and ampoiboles, micas, garnet, and quartz of later recrystallization. Among the minerals of the earlier stage and the ones of the later stage, it seems that there has happened a mineral-evolution in the course of the matasomatism, which may be of retrogressive character.

On the other hand, there have been reported igneous rocks bearing similer mineral assemblages. The studies on such volcanic groups have been greatly promoted by Dr. Kuno(4) and other authors, but those of such plutonic ones seem to be comparatively scanty. As far as the writer knows, the remarkable examples of the latter are of the layered series of Skaergaards gabbro(5), Queensland, and of Karoo dolerite(6). At the ferriferous gabbro stage, the former has fayalitic olivine and monoclinic pyroxene, but no rhombic pyroxene, and the latter has fayalitic olivine and rhombic pyroxene which is of later formation than the monoclinic one. The contaminated gabbro, say, the one of Aberdeenshire(7), has only ferriferous rhombic Pyroxene.* Two pyroxenes seem to be not crystallized in the ferriferous gabbro of the later stage of the magmatic differentiation of the common mafic magma.(8) So it seems to the writer that the fayalite and the ferriferous two pyroxenes in these rocks in question cannot be the relict minerals, not having crystallized in magmas before the granitization.

According to the studies of the binary systems, $MgSiO_3$ — $FeSiO_3$, and $CaSiO_3$—$FeSiO_3$,(9) the recystallization of fayalite, orthoferrosilite, hedenbergite, and quartz may be possible in some parts rich in $FeSiO_3$ under the lower temperature-condition than that of magma.

In respect to the assemblages of the mafic minerals and their chemical compositions, these rocks in question bear the striking resemblance to eulysites,(10) or collobrierites(11) which are considered as the recrystalline metamorphic rocks of iron ores, or ferruginous sediments. But there is a marked difference between the two rock groups in amounts of feldspar; eulysites, or collobrierites have little plagioclase, but the rocks in question have great amounts of it.

In the metagabbros, on the other hand, the relict feldspar (An 74) remains, so it appears to the writer that the original rocks of there metagabbros are

* It is ferrohypersthene.

Fe-rich volcanic sediments, say some schalsteins, or some kinds of basic igneous rocks * which were injected in the form of sheet before the granitization, and almost lost the original texture due to the recrystallization or metasomatism.

The aspects of the chemical change due to granitization of these rocks in respect to the ferromagnesian compositions are shown by Fig. 3 plotted from the numerical values calculated from their bulk chemical compositions in accordance with the method advocated by Dr. Tomita.[12]

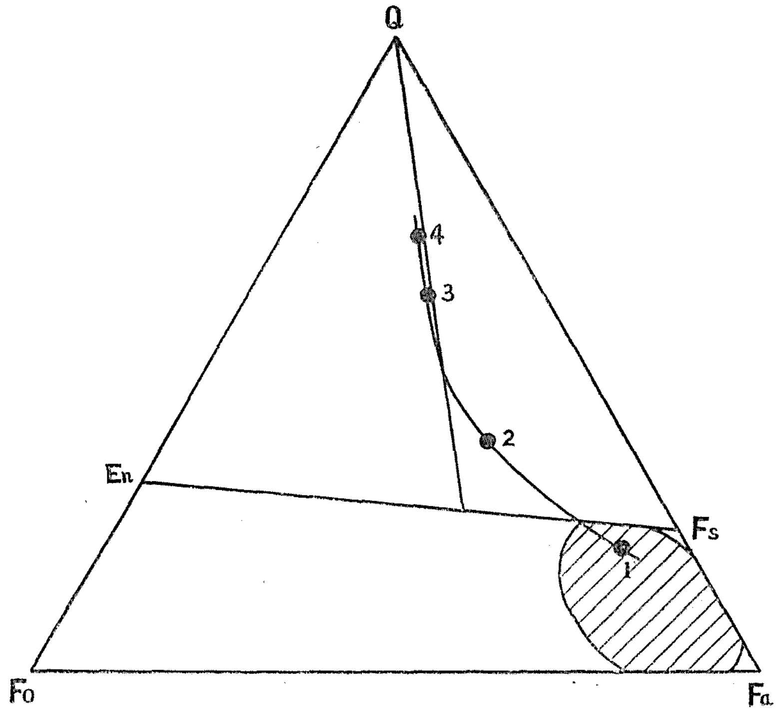

Fig. 3 The Forsterite-Fayalite-Quartz-Diagram
1 fayalite-bearing metagabbroic rock, Hiiruba
2 ferrohypersthene-bearing metagabbroic rock, Nishitani
3 melanocratic granodioritic rock
4 leucocratic grandioritic rock
hatched part···Eulysites and Collobrierite

It is shown that the fayalite-bearing rock of Hiiruba is derived from the more basic and Fe-rich original than that of the ferrosilite-bearing rock of Nishitani, and the former resembles strikingly eulysites in respect to the ferromagnesian compositions. Considering from Fig. 3, in respects to ferromagnesian components, the course of the chemical change due to granitization of these rock-series seems to have proceeded from any point nearer to the Fa-corner to the eutectic line connecting

* It appears to the writer that the original igneous rock suitable for the above condition is the basic one of contaminated origin, judging from recent studies.

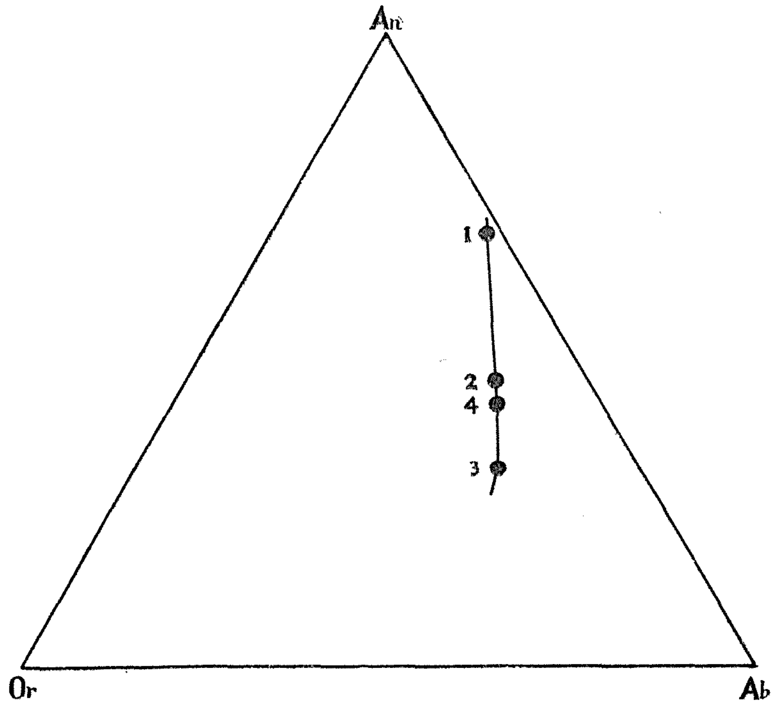

Fig. 4 The Or–Ab–An–Diagram
1~4=The same as those in Fig. 3.

the pyroxene eutectic and the Q-apex, then following on the line to the Q-apex.

On the other hand, considering from Fig. 4, the feldspar-components seem to change their compositions in the direction of the eutectic between Or and Ab.

In the case of normal metagabbros poor in Fe, the metasomatic change of the ferromagnesian components in general begins from any area near the Fo-corner in granitization.

Table 8. The two examples of the schalsteins rich in Fe in the Chichibu System.

	(1)	(2)
SiO_2	47.14%	43.91
Al_2O_3	16.82	15.91
Fe O_3	4.23	13.73
FeO	4.69	3.02
TiO_2	1.08	2 12
MnO	0.42	0.14
CaO	11.45	3.91
MgO	3.83	6.00
$H_2O(-)$	1.07	0.95
K_2O, Na_2O, $H_2O(+)$	undetermined	〃
	(90.73)	(89.69)

Analyst: T. Ueda

(1) From Ioto, Kitayama Village, Gifu Prefecture.
(2) 〃 〃 〃

In the Chichibu System, there are frequently the associations of limestones and schalsteins. The schalsteins, in general, are considered to be rich in MgO, but poor in $FeO+Fe_2O_3$. But as shown in Table 8, it is certain that ferriferous schalsteins were deposited.

Judging from the above table, reduction of Fe_2O_3 to FeO seems to be neccessary in order to assume that the original rocks of these metagabbro are schalsteins.

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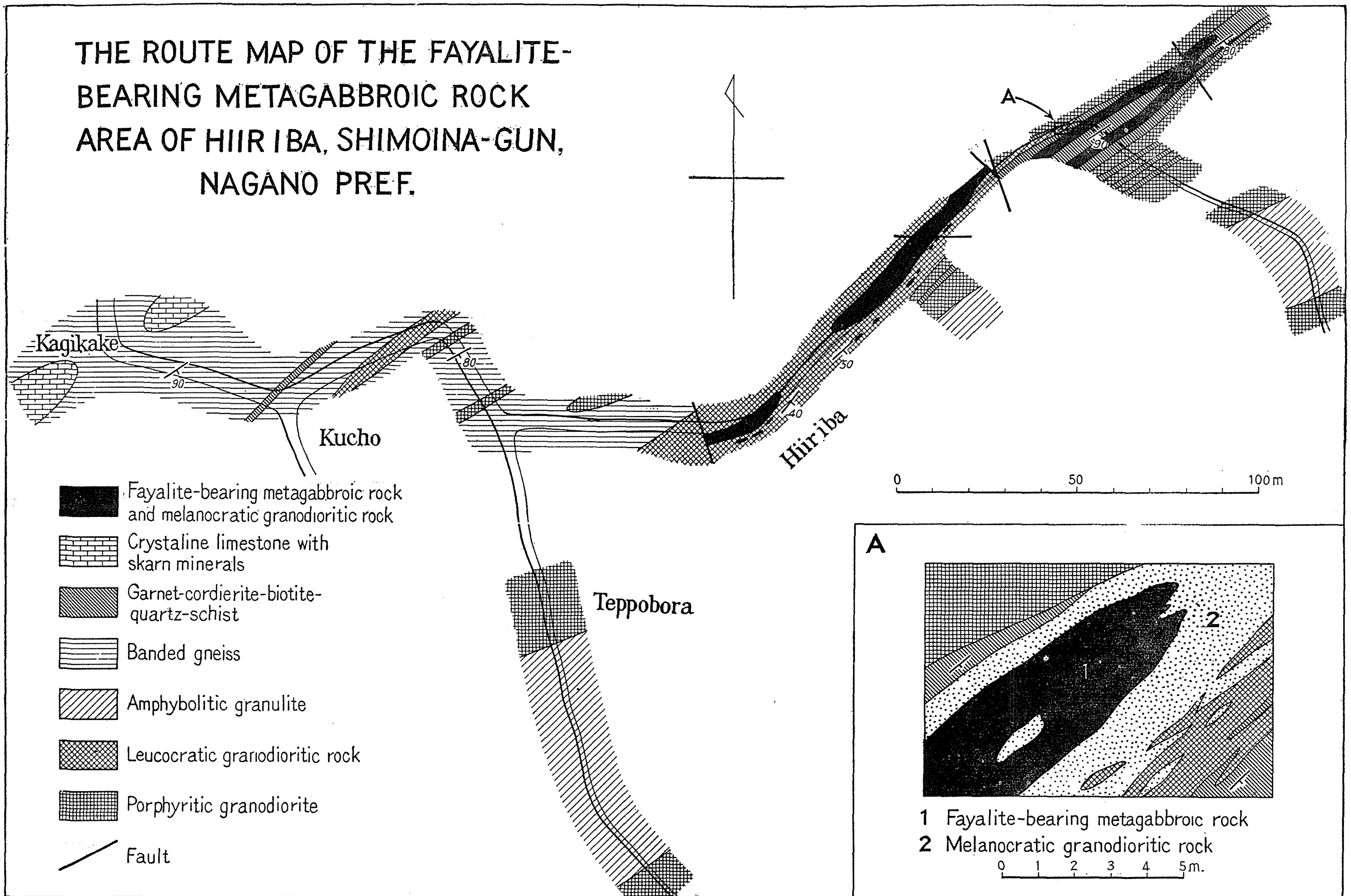
THE ROUTE MAP OF THE FAYALITE-BEARING METAGABBROIC ROCK AREA OF HIIRIBA, SHIMOINA-GUN, NAGANO PREF.
Kagikake
Kucho
Teppobora
Hiiriba
A
90
80
50
40
0
50
100m
Fayalite-bearing metagabbroic rock and melanocratic granodioritic rock
Crystaline limestone with skarn minerals
Garnet-cordierite-biotite-quartz-schist
Banded gneiss
Amphybolitic granulite
Leucocratic granodioritic rock
Porphyritic granodiorite
Fault
A
1
2
1 Fayalite-bearing metagabbroic rock
2 Melanocratic granodioritic rock
0 1 2 3 4 5m.