Magnesioriebeckite in Crystalline Schists of Bizan in Sikoku, Japan

by

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Abstract. Magnesioriebeckite (the magnesium-analogue of riebeckite) was found to occur in aegirine-bearing crystalline schist of the Sanbagawa-Mikabu zone at Bizan in the City of Tokusima. The mineral generally resembles glaucophane in optical properties, but is distinguished therefrom by a large extinction angle and a marked departure of two of the absorption axes from the indicatrix axes. (Amphiboles having such optical properties were called torendrikite by certain writers. Torendrikite appears to range from magnesioriebeckite to magnesioarfvedsonite in chemical composition.)

Probably magnesioriebeckite and contiguous amphiboles are common in the schists of the Sanbagawa-Mikabu zone.

The magnesioriebeckite has a large excess of alkalies, but the host-rock is deficient in alkalies. The formation of magnesioriebeckite in schists appears to be largely due to simple recrystallization under the conditions of glaucophanitic metamorphism and not necessarily due to alkali metasomatism.

I. Glaucophanic Amphiboles with Large Extinction Angles

In ordinary glaucophane and riebeckite (including crossite), the extinction angle in the vertical zone ($c \wedge Z$, $c \wedge Y$, or $c \wedge X$) is smaller than 15°. However, it is well-known that glaucophanic amphiboles having extinction angles larger than 15° are common in crystalline schists of the Sanbagawa-Mikabu zone in Japan. For example, HORIKOSI (1936) described nine glaucophanic amphiboles from the zone, and they all had extinction angles larger than 15°. The maximum value reached 23°. The cause of the large extinction angles was not clarified.

MIYASHIRO paid attention to the fact that a similar amphibole with a still larger extinction angle (about 30°) was described from metamorphic radiolarites associated with glaucophane-schists of Celebes by DE ROEVER (1947) under the name *torendrikite*. Then, he examined samples of glaucophanic amphiboles that were accessible to him. Soon he found that the optical properties of a glaucophane-like amphibole in a schist collected by IWASAKI at Bizan in Sikoku are practically identical to those of the Celebes torendrikite. It shows a large extinction angle (about 28°) and relatively low refractive indices. The most remarkable property of the amphibole is that two of the principal axes of the absorption ellipsoid show a marked departure from axes of the indicatrix (X, Y, Z).

Torendrikite is an alkali-amphibole, originally described by LACROIX (1920) from a syenite in Madagascar. In chemical composition, the original torendrikite belongs to *magnesioarfvedsonite*, the magnesium-analogue of arfvedsonite. Later

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investigators such as DENAEYER (1924) and DE ROEVER (1947) called optically-resembling amphiboles torendrikite without any chemical analysis. It was not clear whether these torendrikites also belonged to magnesioarfvedsonite or not. The present amphibole of Bizan also has the optical properties of torendrikite. It was analyzed and was found to belong to *magnesioriebeckite*, the magnesium-analogue of riebeckite. Then, torendrikite may be regarded as representing a series of alkali-amphiboles which was defined by certain optical properties and ranges from magnesioriebeckite to magnesioarfvedsonite in chemical composition.

As was described by SHODA (1956), two of the absorption axes of a certain arfvedsonite (called heikolite) also are not parallel to axes of the indicatrix. However, torendrikite has much lower refractive indices than arfvedsonite (and riebeckite also).

For the chemical compositions, optical properties and origin of the alkali-amphiboles in general, refer to another paper by MIYASHIRO (1957).

II. Optical Properties and Chemical Composition of a Magnesioriebeckite from Bizan

(a) General Statement

The magnesioriebeckite from a schist at Bizan will be described in detail in this chapter. Bizan (sometimes called Otakisan) is the name of a hill in the City of Tokusima (Tokushima) in Sikoku (Shikoku) and is one of the most famous localities of glaucophane and piedmontite in Japan (KOTO, 1887a, b). It belongs to the porphyroblastic albite-bearing part of the Sanbagawa-Mikabu zone. IWASAKI has been studying the geology and petrography of the district for the last several years (IWASAKI, 1955; etc.).

The host-rock of the magnesioriebeckite under consideration is a garnet-aegirine-amphibole-muscovite-quartz-schist with some quantities of hematite and apatite. In the aegirine, $c \wedge X = 8° - 25°$, 2V over $X = 64° - 84°$, and $\beta = 1.74$. In the muscovite, $Al_2O_3 = 22.60$, $Fe_2O_3 = 7.43$, $FeO = 0.82$ and $MgO = 3.52\%$ (Anal. H. HARAMURA). Larger crystals of the amphibole are strongly zoned with a nearly colorless core and colored rim, as is shown in Fig. 1. The colored rim is pleochroic from blue to purple. On the other hand, smaller amphibole crystals are usually nearly homogeneous and are identical in optical properties to the rim of the zoned crystals. The boundary between the core and rim is rather sharp in most cases, and shows a Becke line not rarely. The rim is higher in refractive indices than the core.

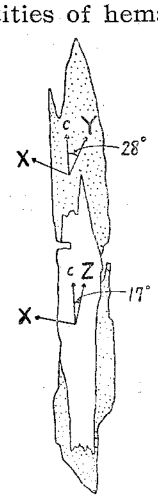

Fig. 1. The (010) section of a zoned amphibole crystal, having a nearly colorless core (white) and colored rim (stippled). The angular values indicated are for yellow light.

The colored amphibole of the rim is the magnesioriebeckite to be described in detail. The nature of the nearly colorless amphibole of the core will be discussed in the next section.

(b) Nearly Colorless Amphibole of the Core

In this amphibole, the optic plane is parallel to (010) with b=Y. For yellow light, $c \wedge Z=17°$. As the dispersion of the optic orientation is weak, any section of the mineral shows practically complete extinction between crossed nicols for white light. The optic constants are shown in Table 1.

Table 1. Optic properties of the nearly colorless amphibole of the core

b=Y; optic plane parallel to (010).
$c \wedge Z=17°$ for yellow light, 18° for green, and 18.3° for blue.
2V over X=30° for yellow light and 25° for green.
Thus, $\rho > v$.
$\alpha=1.640$, $\gamma=1.650$, $\gamma-\alpha$=about 0.010, all for yellow light.

The optic properties as well as the close association with the colored magnesioriebeckite suggest that this mineral also belongs to magnesioriebeckite or contiguous amphibole, having a smaller iron content than the rim.

(c) Colored Amphibole (Magnesioriebeckite) of the Rim

In this amphibole, the optic plane is normal to (010) with b=Z. For yellow light, $c \wedge Y=28°$. As the dispersion of the optic orientation is strong, the (010) section does not show extinction between crossed nicols for white light. For monochromatic light, the extinction is complete in any section. The optic constants are shown in Table 2.

Table 2. Optic properties of the magnesioriebeckite of the rim

b=Z; optic plane normal to (010).	
$c \wedge Y=28°$ for yellow light, 31° for green and 35° for blue.	
2V over X=43° for yellow light and 51° for green.	
Thus, $\rho < v$.	
(In some crystals, the outermost part of the rim has 2V=about 80°.)	
$\alpha=1.660$, $\gamma=1.670$, $\gamma-\alpha$=about 0.010, all for yellow light.	
Pleochroism:	parallel to b=purple,
	practically parallel to c=blue,
	normal to the above two=very pale yellow.
Absorption:	purple=blue>very pale yellow.

Note: The measurements were carried out for colored light (not monochromatic) that was obtained by filtering of white light.

Owing to the requirement of the crystal symmetry, one of the principal axes of the absorption ellipsoid is parallel to the b-axis, and hence to one of the principal axes of the indicatrix (Z). However, the remaining two axes of the absorption ellipsoid show large departures from the remaining axes of the indicatrix. One is practically parallel to the c-axis, and the other is practically normal to both b and c. In other words, under the microscope with the lower nicol only, the (010) section becomes darkest when the c-axis is practically parallel to the vibration direction of the nicol, and it becomes lightest when the c-axis is practically normal to the same. The pleochroism is also given in Table 2.

The colored amphibole was separated by means of the isodynamic separator and Clerici solution. The obtained sample for chemical analysis was composed of the colored amphibole with a small amount of the nearly colorless amphibole of the core. The sample was analyzed by Hiroshi HARAMURA. The result is given in Table 3. This table shows that the composition of the colored amphibole is very close to the idealized formula of magnesioriebeckite which follows:

$$Na_2Mg_3Fe_2'''Si_8O_{22}(OH)_2$$

Table 3. Composition of the magnesioriebeckite of Bizan

	Weight %	Metal atoms on the anhydrous basis of 0=23	
SiO_2	55.62	7.80	8.00 (7.80 + 0.20)
Al_2O_3	4.54	0.75 {0.20, 0.55}	
TiO_2	0.26	0.03	1.94 (0.55 + 0.03 + 1.36)
Fe_2O_3	12.99	1.36	
FeO	3.53	0.41	3.06
MnO	1.25	0.15	
MgO	11.98	2.50	
CaO	1.95	0.29	1.88
Na_2O	5.58	1.52	
K_2O	0.36	0.07	
H_2O_+	1.96	H_2O_+ =0.92	
H_2O_-	0.00		
P_2O_5	0.07		
	100.09		

Note: Fe'''/R'''=0.702, Fe''/R''=0.13. (In this case, R''' and R'' represent trivalent and divalent atoms, respectively, both in 6-coordination.)

III. Mode of Occurrence of Magnesioriebeckite in the Bizan District

Fig. 2 shows a geologic sketch map of the Bizan district.

Glaucophanic amphiboles occur mainly in glaucophane-schists of basic compositions, which are exposed in the central zone of the district, as shown in the map. In addition, such amphiboles are found also in beds, 1~3 meters thick, of quartzose schists containing muscovite, garnet, epidote (or piedmontite in some cases), aegirine, and amphibole. Generally the beds are found at places in the neighborhood of the zone of basic glaucophane-schists, but they are too thin to be shown in the map. The host-rock of the analyzed magnesioriebeckite is one of such quartzose schists. The locality of the host-rock is shown by a cross in the map. The magnesioriebeckite-bearing quartzose schists tend to contain usually larger amounts of muscovite and garnet than the associated magnesioriebeckite-free quartzose schists.

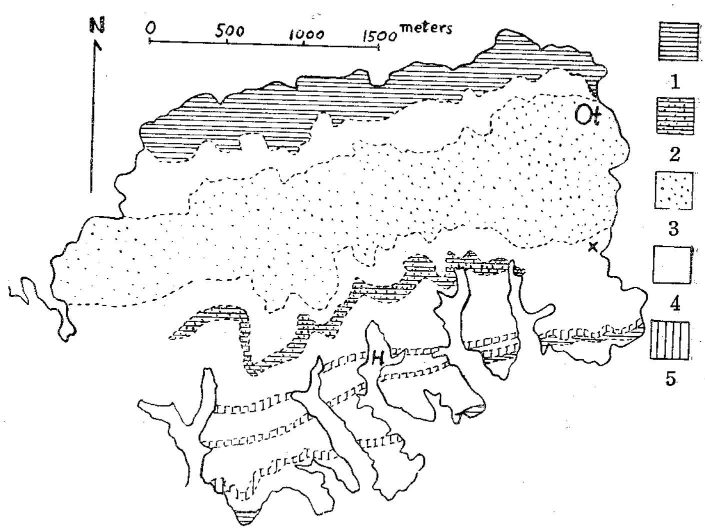

Fig. 2. Geologic sketch map of the Bizan district. Ot=Otaki Park; H=Hukumandani. 1=actinolite-greenschists, 2=glaucophane-green amphibole-schist, 3=glaucophane-schists of basic compositions, 3=black schists, 5=quartz-schists.

IV. Origin of Magnesioriebeckite and Aegirine in Schists

Glaucophanic amphiboles whose extinction angle is smaller than that of magnesioriebeckite but is larger than that of ordinary glaucophane would be subglaucophane close to magnesioriebeckite in composition. Then, magnesioriebeckite and contiguous amphiboles are probably common in the schists of the Sanbagawa-Mikabu zone. The significance of magnesioriebeckite in glaucophanitic metamorphism is discussed in another paper (MIYASHIRO and BANNO, 1958).

The (Na+K)/Al ratio of magnesioriebeckite is much larger than that of alkali-feldspars. In other words, magnesioriebeckite has a large excess of alkalies. In many cases, the host-rocks of magnesioriebeckite also would have an excess of alkalies in bulk composition. Such compositions of rocks would promote the formation of magnesioriebeckite. However, in the present case, the analyzed magnesioriebeckite occurs in association with large amounts of muscovite and pyralspite garnet, which both are deficient in alkalies. So far as such associated minerals are very abundant, the host-rock may become deficient in alkalies in bulk composition. Table 4 shows the calculated composition of the host-rock, which is really deficient in alkalies (Na+K/Al=0.66).

Table 4. Estimation of the bulk chemical composition of the host-rock from the modes

	Quartz	Muscovite	Garnet	Aegirine	Amphibole	Hematite	Total (wt%)
SiO_2	35.0	9.9	4.2	5.2	5.6		59.9
Al_2O_3		4.6	2.4	0.5	0.3		7.8
Fe_2O_3		1.5	0.6	3.0	1.3	14.0	20.4
FeO		0.2	3.4		0.5		4.1
MgO		0.7	0.4	0.1	1.3		2.5
CaO				0.1	0.1		0.2
Na_2O		0.1		1.1	0.6		1.8
K_2O		2.0			0.1		2.1
H_2O		1.0			0.2		1.2
Total	35.0	20.0	11.0	10.0	10.0	14.0	100.0

Note: (Na+K)/Al=0.66.

The deficiency in alkalies of the rock is revealed clearly when we calculate the probable mineral compositions which the rock would show, if it were subjected to igneous or high-temperature metamorphic conditions. The result of one of such calculations involving partial reduction of ferric iron is as follows: quartz 35%, feldspars (K : Na : Ca=42 : 54 : 4) 29%, hypersthene 6%, cordierite 6% and magnetite 24%. Thus, this imaginary rock is composed of feldspars and alkali-free minerals.

It follows that the formation of magnesioriebeckite and aegirine in the present case is not due to the special richness in alkalies of the host-rock, but is due to the situation that under the physical conditions prevailing during the present metamorphism the assemblage of magnesioriebeckite, aegirine, muscovite, garnet, etc. was more stable for the rock than the magnesioriebeckite- and aegirine-free assemblages, such as the above imaginary one. The formation of alkali-deficient minerals, muscovite and garnet, must have been essential for the formation of the associated magnesioriebeckite and aegirine. It is interesting in this connection that the magnesioriebeckite-bearing quartzose schists tend of contain usually larger amounts of muscovite and garnet than the associated magnesioriebeckite-free quartzose schists in the Bizan district, as stated before.

The formation of magnesioriebeckite in the present case was due largely to the adjustment of the mineral assemblage under the conditions of the glaucophanitic metamorphism. Metasomatic introduction of alkalies into the rock was not necessary for it.

If metamorphic differentiation takes place under such conditions, the resultant rock may become specially enriched in magnesioriebeckite and aegirine, and hence may become to have an axcess of alkalies in bulk composition. Thus, apparent alkali-metasomatism leading to the formation of rocks with excess alkalies during glaucophanitic metamorphism may actually be a kind of metamorphic differentiation in some cases at least.

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四国眉山の結晶片岩のなかの magnesioriebeckite

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(摘　要)

四国徳島市眉山の三波川変成岩のなかに magnesioriebeckite (リーベック閃石のなかの Fe″ が Mg によつて置換された化学組成をもつ角閃石) が見出された．それは，一見したところ藍閃石に似ているが，消光角がずつと大きく，また，光の吸収軸のうちの2つが光学的弾性軸から甚しく外れていることによつて容易に識別される．この種の角閃石は，おそらく三波川・御荷鉾変成岩のなかにしばしば含まれていて，ふつうは藍閃石と見誤られているものと思われる．

この magnesioriebeckite は，アルカリ交代作用によつてではなくて，藍閃変成作用の物理条件下における単なる再結晶によつてできたものと解せられる．そのような条件の下における変成分化によつて過剰のアルカリをもつ変成岩のできる可能性もある．