22. Sapphirine from Metamorphosed Layered Complex of Mt. Poroshiri, Hidaka Metamorphic Belt, Hokkaido

By Sumio MIYASHITA,^{*)} Masayuki KOMATSU,^{**)}
and Seiji HASHIMOTO^{*)}

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Introduction. Although sapphirine is not uncommon constituent of high grade silica poor and high alumina metamorphic rocks, no occurrence has been reported in Japan despite the presence of higher grade metamorphic rocks formed under the physical condition allowing the formation of sapphirine. However, the authors have realized the first occurrence in Japan during the survey of metamorphic rocks in the Hidaka metamorphic belt occupying the axial part of Hokkaido extended for about 150 km in the N-S direction. The sapphirine-bearing rock is found in metamorphosed troctolite belonging to the Mt. Poroshiri layered gabbroic complex included in the Western zone of metamorphic belt (Hashimoto, 1975).

Here the preliminary report on the chemical and optical properties of sapphirine is made with brief description on mode of occurrence.

Geological setting. Mt. Poroshiri is situated in the northern part of the Hidaka Mountains. The Mt. Poroshiri layered complex comprises three stratified zones according to the original lithology (Miyashita and Maeda, 1978), though massive metamorphic rocks with various degrees of recrystallization occur very irregularly. The lower zone of the complex given in Fig. 1 was originally composed of anorthosite, troctolite, wehrlite and dunite. Fine rhythmic layering is well developed in these rocks (Miyashita and Hashimoto, 1975). The middle zone of the complex consists of olivine gabbro with faint layering, and the upper zone is composed of massive gabbro. Two steps of metamorphism are distinguished in the Mt. Poroshiri complex. The earlier metamorphism was of retrogressive nature and occurred under a static condition. It yielded sapphirine in an altered anorthositic troctolite belonging to the lower zone of the complex. The second step occurred dynamically due to uplift of the Western zone (Grapes *et al.*, 1977).

Mode of occurrence. The sapphirine-bearing rock found from

^{*)} Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, Sapporo, Japan.

^{**)} Department of Geology and Mineralogy, Faculty of Science, Niigata University, Niigata, Japan.

Fig. 1. Simplified geologic map of Mt. Poroshiri area. 1: Hidaka Super Group. 2: Greenschist and Epidote amphibolite. 3: Green-hornblende amphibolite and Plagioclase blastoporphyritic amphibolite. 4: Plagioclase-olivine cumulate (Troctolite) and its metamorphosed equivalent. 5: Olivine cumulate and its metamorphosed rock. 6: Mylonite. 7: Locality of sapphirine. P is the top of Mt. Poroshiri.

three outcrops (Fig. 1) is composed of hornblende with subordinate amounts of sapphirine and plagioclase. Corundum, spinel, gedrite, chlorite and clinozoisite occur as accessories. The sapphirine-bearing rock has a heterogeneous texture (Fig. 2), which is probably due to its original igneous texture. Small domains consisting of mosaic hornblende are enclosed within a cluster of very fine hornblende and sapphirine. Anhedral plagioclase (An 85–95) occur in the latter. Both hornblendes are colorless to pale green under the microscope and have a pargasitic composition. Corundum generally occurs as scattered pod up to 10 mm, but rarely occurs in vein together with spinel and chlorite.

As shown in Table I, bulk compositions of the sapphirine-bearing rock and unmetamorphosed troctolite are almost the same. The compositional similarity and textural characteristic suggest that the sapphirine-bearing rock is derived from troctolite.

Sapphirine. $(\text{Mg}, \text{Fe}^{2+}, \text{Fe}^{3+}, \text{Al})_8\text{O}_2[(\text{Al}, \text{Si})_6\text{O}_{18}]$. The sapphirine is fine-grained, 0.5 to 0.02 mm in diameter, and is colorless to light blue under the microscope. Pleochroism is very weak. Optical

properties of the sapphirine are tabulated in Table II. The $2V_x$ of observed sapphirines ranges from 55° to 65° . X-ray diffraction data are given in Table III.

Fig. 2. Texture of sapphirine-bearing rock. Hb: Hornblende. Sap+Hb: Sapphirine and hornblende. Chl: Chlorite. C: Corundum.

Table I. Bulk compositions of troctolite and sapphirine-bearing rock

	1	2		1	2
SiO ₂	44.23	43.28	CaO	11.32	10.00
TiO ₂	.08	.07	Na ₂ O	1.62	1.14
Al ₂ O ₃	22.66	22.75	K ₂ O	.01	.14
Fe ₂ O ₃	.67	.90	P ₂ O ₅	.04	.09
FeO	4.09	3.58	H ₂ O(±)	1.08	1.29
MnO	.06	.09			
MgO	14.15	15.37	Total	100.11	99.00

1: Sample no. KK2-3, troctolite; plagioclase 65, olivine 35%. 2: Sample no. Sf-1, Sapphirine-bearing rock; hornblende 83, plagioclase 3, sapphirine 9, corundum 3, spinel 1, chlorite 1%.

Table II. Optical properties of sapphirine

α	1.711	Twinning	Penetration twin
β	1.713	Color	Light blue
γ	1.717	Pleochroism	Very weak,
δ	0.006		α : Colorless
$2V\alpha$	55° – 65°		β : Colorless
$\beta=\gamma$:O.A.P. (010)			γ : Pale blue

Three types of sapphirine are distinguished in terms of its form; very irregular anhedral crystal, prismatic crystal with numerous inclusions of hornblende and prismatic crystal free from inclusion. It may be worth nothing that cruciform twin is observed in the sapphirine of the prismatic crystal containing inclusion as shown in Fig. 3, since

polysynthetic twin has been reported from many localities (e.g., Lensch, 1971) but the occurrence of penetration twin is very rare. Herd *et al.* (1969) stated presence of penetration twin in sapphirine, however detailed description on the twin has not been done. A preliminary study with the universal stage shows that the crossing angle between the symmetrical plane and (010) of each individual is about 60° .

Table III. X-ray powder data for sapphirine

Poroshiri		Fiskenaesset		Poroshiri		Fiskenaesset	
d.Å	I/I ₁	d.Å	I/I ₁	d.Å	I/I ₁	d.Å	I/I ₁
3.61	15	3.600	10	2.13	20	2.127	12
		3.361	20			2.072	11
3.28	15	3.277	10	2.03	45	2.023	60
3.00	70	2.990	65	2.02	60	2.015	90
2.85	40	2.844	50			1.5517	10
2.78	20	2.762	25	1.544	25	1.5403	25
2.70	15	2.695	10	1.439	50	1.4401	30
		2.647	10	1.423	50	1.4353	65
2.58	30	2.576	30	1.412	25	1.4192	65
2.45	100	2.447	100			1.4073	30
2.36	30	2.347	35				

Fiskenaesset: Moore (1969).

Fig. 3. Cruciform twin of sapphirine. Hb: Hornblende. Sap: Sapphirine. C: Corundum. Sp: Spinel. Sapphirine contains numerous inclusions.

Selected microprobe analyses of anhedral and prismatic sapphirine free from inclusion are shown in Table IV. SiO_2 and Al_2O_3 contents of the sapphirines range from about 11 to 14 wt% and from 66 to 62 wt%, indicating $\text{MgSi} \rightleftharpoons \text{AlAl}$ substitution. Vogt (1947) had suggested a general formula for sapphirine as $\text{Mg}_{16-n}\text{Al}_{32+2n}\text{Si}_{8-n}\text{O}_{80}$ with n vary-

ing from 0 to about 2.5. Recently many analyses of sapphirine have been published and confirmed the formula by Vogt (1947). The minimum n value ($n=0$) is given by Segnit (1957) and the maximum value ($n=2.8$) is reported by Cameron (1976). The n value of the Poroshiri sapphirine ranges from 1.20 to 2.70 and those poor in SiO_2 of the Poroshiri sapphirine have close value to the maximum value. It is interesting that prismatic sapphirine free from inclusion is rich in SiO_2 , on the other hand anhedral sapphirine and prismatic sapphirine with inclusion have more aluminous composition.

Table IV. Selected analyses of sapphirine

	1	2	Numbers of cations; O=20		
SiO_2	13.28	11.53	Si	1.573	1.363
Al_2O_3	62.92	66.02	Al	8.783	9.196
Cr_2O_3	n.d.	.13	Cr	n.d.	.012
FeO^*	3.95	3.79	Fe^{2+}	.391	.375
MgO	18.61	17.50	Mg	3.286	3.083
CaO	.02	.03	Ca	.003	.004
Total	93.78	99.00	Total	14.036	14.033

* Total Fe as FeO. 1: Prismatic sapphirine free from inclusion, sample PU-7. 2: Anhedral sapphirine, sample 2U-8. Analysis has been made at 15 kV accelerating potential and $0.03 \mu\text{A}$ specimen current using JXA-5A electron microprobe. The corrections were made by the method of Bence and Albee (1968).

Discussion. Sapphirine is an important mineral indicating high-grade metamorphism from the granulite to the upper amphibolite facies (Turner, 1968). The occurrence of sapphirine is rare because it usually appears in the rocks with unusual chemical composition. In general, sapphirine-bearing rocks are rich in Al_2O_3 , MgO , and poor in SiO_2 and FeO (Deer *et al.*, 1978). In many sapphirine localities, metasomatism (e.g., Herd *et al.*, 1969) or partial melting (e.g., Clifford *et al.*, 1975) has been assumed for the production of such unusual bulk composition. However, the sapphirine-bearing rock in the present study is considered to be derived from anorthositic troctolite through the isochemical reaction introduced by an influx of water. The influx of water from the exterior has an important role for the reaction of olivine and plagioclase leading the formation of sapphirine and hornblende.

Sapphirine-bearing rocks with the same mineral assemblage as those of the Poroshiri complex have been reported from several localities, and their metamorphic conditions have been deduced to be of the low granulite or the high amphibolite facies (e.g., Forestier and

Lasnier, 1969). Therefore, it is considered that the lower part of the Mt. Poroshiri complex suffered from metamorphism of the same conditions.

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