Short Communication

Johannsenite from the Koryu mine, Hokkaido, Japan

Asahiko SUGAKI*, Arashi KITAKAZE* and Kiyoshi ISOBE**

**Institute of Mineralogy, Petrology and Economic Geology, Tohoku University, Sendai 980, Japan*

***United Resources Industry Co., Ltd., Kyobashi 3-1-3, Tokyo 104, Japan*

Abstract

Johannsenite from the Koryu mine, a gold-silver vein deposit of epithermal type, occurs as a principal constituent of gold-silver quartz veins. It is found as crustified bands in the form of aggregates of very fine crystals, less than 1 μm in length, and sometimes as acicular or fibrous crystals about 10 μm or less in length. Its unitcell parameters are $a = 9.875(4)$, $b = 9.044(4)$, $c = 5.274(2)\text{\AA}$, and $\beta = 105.54(9)^\circ$. Its chemical composition ranges from 57.7 to 75.6 mole% $\text{CaMnSi}_2\text{O}_6$, 14.0 to 23.9 mole% $\text{CaMgSi}_2\text{O}_6$, and 10.4 to 18.4 mole% $\text{CaFeSi}_2\text{O}_6$.

Introduction

Johannsenite commonly occurs in contact metasomatic deposits or in manganese rich metamorphic rocks (Schaller, 1938; Schiavinato, 1953; Allen and Fahey, 1953; Hutton, 1956; Mankov and Andereva, 1964; Momoi, 1964; Padera *et al.*, 1964; Frondel, 1965 etc.). During our studies of gold and silver ores from the Koryu mine, Hokkaido, Japan, an epithermal vein-type deposit, johannsenite was found to be one of principal vein minerals. Although johannsenite is very rare in such hydrothermal vein-type deposits, it has been reported from several other epithermal deposits; Venetia in Italy, Puebla in Mexico, Oregon in USA (Schaller, 1938), and Yatani (Taniguchi, 1969), Yugashima (Tanida *et al.*, 1977) and Kawazu (GSJ, 1970) mines in Japan. However, the occurrence, crystallographic data and chemical composition for johannsenite from these deposits have not been established except for the Italian and Yugashima deposits. The occurrence and mineralogical data of johannsenite from the Koryu mine are described in this paper.

Occurrence

Ore deposits of the Koryu mine, located about 24 km south of the Sapporo city, Hokkaido, Japan, are epithermal gold-silver quartz veins. They occur in Miocene black mudstone, and are composed mainly of quartz and some amounts of adularia, johannsenite, chlorite, vermiculite, calcite, magnetite, hematite, pyrite, chalcopyrite, sphale-

FIG. 1. Photographs of samples including johannsenite from the Koryu mine.
 A: Crustified bands of johannsenite (jh) and quartz (qz), No. 1 vein, Hanging Branch, 60 m level. B: Banded johannsenite overgrowth of fragments of mudstone (ms), No. 1 vein, Hanging Branch, 60 m level.

FIG. 2. Photomicrographs of johannsenite from the Koryu mine.
 A, B: Crustified bands of johannsenite, No. 1 vein, Hanging Branch, 60 m level. C: Aggregates of acicular or fibrous crystals of johannsenite, No. 1 vein, 45 m level. D: Secondary electron image of johannsenite, No. 1 vein, 45 m level.

rite, galena, electrum and silver minerals (such as aguilarite, pyrargyrite, proustite, miargyrite and arsenamayoite etc.). Johannsenite occurs as crustified bands, 3 to 10 mm in width, in intimate association with quartz, adularia and calcite as found in the No. 1 vein and No. 1 Hanging Branch (Fig. 1-A), and appears sometimes as rims or ring structures surrounding black mudstone fragments in quartz veins (Fig. 1-B). It is pale yellowish brown or pale brown in color on fresh surfaces, but is easily oxidized to dark brown or dark gray colors.

Under the microscope, johannsenite is observed as aggregates of very fine crystals, less than 1 μm in length, and occurs as fine crustified bands or rims in close association with quartz, adularia, sphalerite and pyrite (Fig. 2-A). It is also found as aggregates of acicular or fibrous crystals, about 20 μm in length, in quartz and calcite (Fig. 2-B and C). Its occurrences and mineral assemblages are similar to those of johannsenite from Venetia, Italy and Puebla, Mexico, as described by Schaller (1938). Manganese silicate minerals except johannsenite such as rhodonite, pyroxmangite and tephroite etc. have not yet been found in the Koryu mine.

Optical properties

As mentioned above, johannsenite from the Koryu mine is found as aggregates of very fine crystals less than 20 μm in length. Under the microscope, it may occur as aggregates of acicular or fibrous crystals elongated along the *c* axis and showing a weak pleochroism from colorless to pale brown in color. The extinction angle ($Z \wedge c$) is 42° to 50° . The optical sign is positive. Its indices and optical angle of $2V$ could not be measured.

Crystal data of johannsenite

Fine-grained aggregates of johannsenite from the 60 m level of the No. 1 vein, Koryu mine were used for X-ray analysis: small amount of calcite were removed with HCl (1:1) aqueous solution. Its X-ray powder diffraction data were obtained with a Guinier camera using monochromatized $\text{CuK}\alpha_1$ radiation and are given in Table 1 with those of johannsenite from the Madan mine, Bulgaria and Teragouchi, Japan (Momoi, 1964) for comparison. Pure silicon powder was used as internal standard and intensities were measured by microphotometry. Indexing was made referred to the cell constants of johannsenite obtained by Ito *et al.* (1982). Observed and calculated *d*-values are in good agreement. Cell parameters of johannsenite from the Koryu mine were obtained by a least-squares calculation using all the reflection data. They are mean values for the aggregates having various chemical compositions described below and $a = 9.875(4)$, $b = 9.044(4)$, $c = 5.274(2)\text{\AA}$ and $\beta = 105.54(9)^\circ$.

TABLE 1. X-ray powder diffraction data of johannsenite from the Koryu mine. Those of johannsenite from other localities are given for comparison.

h	k	l	I	Koryu mine		Madan, Bulgaria		Teraguchi*	
				d(obs.)	d(calc.)	I	d(obs.)	I	d(obs.)
1	1	0	7	6.60	6.56	30	6.59	14	6.592
2	0	0	7	4.78	4.76	30	4.78	9	4.779
0	2	0	6	4.54	4.52	5	4.55	5	4.553
2	2	0	18	3.284	3.278	25	3.300	33	3.292
-2	2	1	100	3.022	3.020	55	3.033	100	3.020
3	1	0	15	2.998	2.993	100	3.011		
-3	1	1	18	2.922	2.922	5	2.929	16	2.925
-1	3	1	30	2.596	2.593	15	2.607	20	2.605
2	2	1	65	2.547	2.548	20	2.561	31	2.564
0	0	2			2.541	30	2.547	25	2.547
4	0	0	4	2.377	2.379	3	2.390	6	2.390
3	1	1	10	2.332	2.334	3	2.342	10	2.348
1	1	2	12	2.236	2.234	3	2.240	8b	2.240
3	3	0	5	2.183	2.185	5	2.197	11	2.1986
-3	3	1	16	2.159	2.157	12	2.166	17	2.1664
-4	2	1	17	2.131	2.132	8	2.136	12	2.1380
4	2	0	—	—	—	—	—	4	2.1170
0	4	1	7	2.064	2.066	10	2.075	6	2.0794
2	0	2	20	2.028	2.028	5	2.039	2	2.037
-4	0	2	10	2.026	2.027	5	2.029	11	2.0290
-1	3	2	2	1.9869	1.9848	2	1.9885	2	1.9917
3	3	1	—	—	—	3	1.8942	2	1.897
5	1	0	3	1.8616	1.8621	1	1.8654	6	1.8715
4	2	1	3	1.8006	1.7998	—	—	2	1.812
1	5	0	10	1.7777	1.7770	10	1.7874	15	1.7904
0	4	2	7	1.6870	1.6890	—	—	2	1.697
-5	3	1	—	—	—	10	1.6480	17	1.6505
4	4	0	11	1.6390	1.6387				
-2	2	3	11	1.6319	1.6325	6	1.6346	12	1.6362
a(Å)				9.875(4)		9.894(5)		9.916	
b(Å)				9.044(4)		9.098(5)		9.107	
c(Å)				5.274(2)		5.279(3)		5.280	
$\beta(^{\circ})$				105.54(9)		105.26(9)		105.02	

*After Momoi (1964)

The lengths of the a and b axes are slightly shorter than those of johannsenites from the Madan mine, Bulgaria and Teragouchi, Japan (Momoi, 1964).

Chemical composition

Johannsenite from the Koryu mine occurs as very fine crystals less than 1 μm in length, as mentioned above. Thus, it was difficult to analyze the mineral by EPMA using a homogeneous crystal grain of johannsenite. Therefore, a fine-grained aggregate of johannsenite was used as a specimen for EPMA analysis to obtain its chemical composition and their analytical data are correspond to mean values of some fine johannsenite grains. In this case, the correction method by Bence and Albee (1968), and Hayashi and Sugaki (1984) was employed.

Analytical data for johannsenite from the Koryu mine are given in Table 2. The data of johannsenite from the Madan mine, Bulgaria are given for comparison. Johannsenite from both localiteis commonly contains small amounts of iron and magnesium. The atomic ratio of cations calculated based on six oxygens is also shown in Table 2. The atomic ratios of (Si + Al):(Mn + Fe + Mg + Ca + Al) for the Koryu specimen are 1.99–2.01:1.98–2.02, and lie close to the general formula of pyroxene. Johannsenite from the Madan mine has similar value: 1.96 to 2.01:1.96 to 2.00. The atomic ratio of

TABLE 2. Analytical data of johannsenite from the Koryu mine.

	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO ₂	50.3	48.6	50.3	49.9	49.2	49.1	49.9	50.1	49.3	49.6	48.3	47.8	49.5
TiO ₂	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Al ₂ O ₃	0.9	1.2	0.0	2.3	1.2	0.0	0.6	1.1	0.0	1.1	0.8	1.5	0.0
FeO	5.4	5.1	4.9	3.4	4.1	4.5	3.5	4.9	6.3	5.0	3.0	4.0	3.7
MnO	16.6	17.2	18.0	18.6	18.3	18.8	18.9	19.2	19.8	20.9	21.8	27.8	24.1
MgO	3.9	3.7	3.4	3.4	3.1	3.5	3.2	3.6	4.5	3.3	2.3	1.4	1.4
CaO	22.9	23.7	23.2	22.7	23.8	23.8	23.2	20.4	19.1	20.0	23.4	17.6	21.5
K ₂ O	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Na ₂ O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100.0	99.8	99.8	100.4	99.7	99.4	99.3	99.3	99.3	99.9	99.7	100.2	100.1
Si	2.00	1.95	2.01	1.97	1.97	1.99	2.00	2.01	2.00	1.99	1.97	1.96	2.01
Al	0.00	0.05	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.00
Al	0.04	0.01	0.00	0.08	0.03	0.00	0.03	0.05	0.00	0.04	0.00	0.04	0.00
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Fe	0.18	0.17	0.18	0.11	0.14	0.14	0.12	0.17	0.21	0.17	0.10	0.14	0.13
Mn	0.56	0.58	0.61	0.62	0.62	0.64	0.64	0.65	0.68	0.71	0.75	0.97	0.83
Mg	0.23	0.22	0.20	0.20	0.19	0.21	0.19	0.22	0.27	0.20	0.14	0.08	0.08
Ca	0.97	1.02	0.99	0.96	1.03	1.03	1.00	0.88	0.83	0.86	1.02	1.22	1.04
K	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

1–11: Koryu mine, 12–13: Madan mine, Bulgaria

Total oxygens = 6

FIG. 3. Chemical compositions of johannsenite plotted within the $\text{CaMnSi}_2\text{O}_6$ – $\text{CaMgSi}_2\text{O}_6$ – $\text{CaFeSi}_2\text{O}_6$ system in this study 1) Koryu mine; 2) Madan mine, Bulgaria and the literatures; 3) Schaller, 1938; 4) Momoi, 1964.

Ca to (Mn + Mg + Fe) ranges from 0.83–1.03 to 0.98–1.17 and 0.77–0.94 to 1.04–1.22 for the Koryu and Madan johannsenite, respectively. Johannsenite from the Koryu mine has chemical compositions from 57.7 to 75.6 mole% $\text{CaMnSi}_2\text{O}_6$, 14.0 to 23.9 mole% $\text{CaMgSi}_2\text{O}_6$ and 10.4 to 18.4 mole% $\text{CaFeSi}_2\text{O}_6$ as shown in Fig. 3. Those from Madan have compositions of 78 to 82, 7 to 10 and 10 to 12 mole% of these respective end members. Fig. 3 also shows compositional data of johannsenite from the Venetia in Italy, Puebla in Mexico and Oregon in USA (Schaller, 1938) and Tera-gouchi in Japan (Momoi, 1964).

Additional considerations

As mentioned above, johannsenite from the Koryu mine corresponds to a ferroan-magnesian species in the system $\text{CaMnSi}_2\text{O}_6$ – $\text{CaMgSi}_2\text{O}_6$ – $\text{CaFeSi}_2\text{O}_6$ as shown in Fig. 3. According to Abrecht (1980), there is gap between johannsenite and the diopside-hedenbergite solid-solution shown by dashed line in this figure. However,

compositions of johannsenite from the Koryu mine are plotted mainly in the region of the immiscible field of Abrecht (1980). The X-ray powder diffraction data for johannsenite from the Koryu mine indicate that it is a single phase and not a mixture of two phases of clinopyroxene as given in Table 1. Therefore the immiscible field between johannsenite and diopside-hedenbergite solid-solution of Fig. 3 suggested by Abrecht (1980) is not recognized.

According to Abrecht and Peters (1965) and Lamb *et al.* (1972) who studied phase relations between johannsenite and bustamite experimentally, johannsenite is stable below about 400°C but it inverts to bustamite above that temperature. The temperature of mineralization in the Koryu mine is estimated to have been 175° to 240°C from the compositions of electrum-sphalerite-pyrite assemblages (Sugaki *et al.*, 1984). These temperatures of the mineralization are within the stability field of johannsenite obtained by Abrecht and Peters (1975) and Lamb *et al.* (1972). These observations suggest that johannsenite is formed under hydrothermal conditions at low temperatures and pressures as seen in epithermal deposits such as the Koryu, Yatani, Yugashima and Kawazu mines in Japan.

Acknowledgment—The authors would like to express their thanks to Prof. A. C. Brown, University of Montreal, for critical reading of the manuscript. A part of expense for this study was defrayed by the Grant-in-Aid for Scientific Research from the Ministry of Education of Japan. The authors offer their sincere thanks to the Ministry of Education.

References

- ABRECHT, J. (1980) *Contr. Miner. Petrol.*, **74**, 253-260.
ABRECHT, J. & PETERS, T. (1975) *Contr. Miner. Petrol.*, **50**, 241-246.
ALLEN, V. T. & FAHEY, J. J. (1953) *Amer. Miner.*, **38**, 883-890.
BENCE, A. E. & ALBEE, A. L. (1968) *Journ. Geol.*, **76**, 382-403.
FRONDEL, C. (1965) *Amer. Miner.*, **50**, 780-782.
GSJ (Geological Survey of Japan) (1970) Introduction to Japanese minerals. Geological Survey of Japan.
HAYASHI, K. & SUGAKI, A. (1984) *Mining Geol.*, **34**, 151-162 (in Japanese).
HUTTON, C. O. (1956) *Amer. Miner.*, **41**, 581-591.
ITO, Y., MATSUMOTO, T. & YOSHIASA, A. (1982) *Miner. Journ.*, **11**, 84-92.
LAMB, C. L., LINDSLEY, D. H. & GROVER, J. E. (1972) *Geol. Soc. Amer. Abstr. Program*, **4**, 571-572.
MANKOV, S. & ANDEREVA, L. (1964) *Ann. l'Ecole superiure Mines Geol., Sofia Fasc. II Geol.*, **18**, 59-76.
MOMOI, H. (1964) *Mem. Fac. Sci. Kyushu Univ., Ser. D, Geology*, **15**, 65-72.
PADERA, K., MINCEVA-STEFANOVA, I. & KIROV, G. K. (1964) *Bull. Geol. Invest. Bulgaria Acad. Sci.*, **13**, 5-13.
SCHALLER, W. T. (1938) *Amer. Miner.*, **23**, 575-582.

- SCHIAVINATO, G. (1953) *Rend Soc. Miner. Tal.*, **9**, 1-11.
- SUGAKI, A., KITAKAZE, A. & ISOBE, K. (1984) *Journ. Japan. Assoc. Miner. Petrol. Econ. Geol.*, **78**, 123-140 (in Japanese).
- TANIGUCHI, H. (1969) *Mining Geol.*, **19**, 113-121 (in Japanese).
- TANIDA, K., NAMBU, M., KITAMURA, T., MASUTOMI, K., FUJIWARA, T. & TAKEMURA, M. (1977) *Chigakukenkyu*, **28**, 385-396.

Received May 29, 1985.