Vaesite from the Uchinotai deposits, Kosaka mine, Japan

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ABSTRACT

The first occurrence of vaesite in Japan is described from the Kuroko-type deposits of the Kosaka mine in Northeast Japan. Microprobe analysis showed its chemical composition to be very close to NiS_2 , though it contains small amounts of Fe, Cu, and Co. Sulfur fugacities at the time of deposition of the vaesite bearing ores were calculated to be $10^{-13.8}$, $10^{-11.0}$ — $10^{-11.7}$, and $10^{-8.7}$ — $10^{-9.9}$ atm. at 150°, 200°, and 250°C respectively on the basis of the observed mineral assemblage.

Vaesite, NiS_2 , was first described by Kerr (1945) from the Kasompi mine, Katanga, the Republic of Zaire. Though it has been reported from several other localities (e. g., Derriks and Vaes, 1955; Park, 1967; Ramdohr, 1969), detailed description of the mineral is very few. A new occurrence of the mineral from the Kuroko-type deposits of the Kosaka mine, Northeast Japan is here described.

Occurrence

The Uchinotai deposits are typical Kuroko-type, polymetallic sulfide-sulfate deposits occurring in Miocene acidic volcanic rocks (Horikoshi, 1969; Horikoshi and Sato, 1970). The deposits are composed of several unit ore bodies, and the ores in individual bodies are generally divided into the bedded galena-sphalerite-barite ore (black ore), the bedded pyrite-chalcopyrite ore (yellow ore) and the stockwork pyrite-chalcopyrite-quartz ore (siliceous ore). The bedded

ores overlie the stockwork ore and are concordant with the overlying sediments.

Vaesite has been found in microscopic amount in the black ore from the Uchinotai-nishi and the Otarube ore bodies. The mineral

Fig. 1. Photomicrographs of vaesite from the Uchinotai-nishi ore body (a) and the Otarube ore body (b). Reflected light, oil immersion. vs=vaesite, py=pyrite, cp=chalcopyrite, sp=sphalerite, tn=tennantite, ba=barite.

assemblages of the vaesite-bearing specimens are chalcopyrite-barite-galena-tennantite-vaesite-sphalerite in the Uchinotai-nishi ore body, and barite-sphalerite-galena-pyrite-chalcopyrite-vaesite-electrum in the Otarube ore body. At Uchinotai-nishi ore body, vaesite is in direct contact with chalcopyrite, barite, and tennantite, while in Otarube the direct neighbors are sphalerite, barite, and tennantite. The iron content of the sphalerite associated with vaesite is very low (less than 0.1 mole % FeS) and the electrum has a composition close to Au_6Ag_4 .

The vaesite occurs as minute anhedral to subhedral grains up to 200 microns in diameter (Fig. 1). Under the ore microscope, it is creamy grey, isotropic and slightly darker than chalcopyrite. No internal reflection is observed. Its polishing hardness is slightly lower than pyrite and distinctly higher than chalcopyrite.

Chemistry

The chemical compositions of six vaesite grains from the Uchinotai-nishi and the Otarube ore bodies are listed in Table 1. The

Table 1. Composition of vaesite from the Uchinotai-nishi ore body (1—3) and the Otarube ore body (4—6).

	1	2	3	4	5	6
Ni	44.7	44.1	44.4	45.4	43.9	44.7
Fe	1.2	1.3	0.9	0.9	0.8	1.7
Cu	0.6	0.7	0.6	1.0	0.8	1.0
Co	0.5	0.3	—	1.6	1.4	—
S	52.8	50.9	52.5	49.2	51.8	50.6
Total	99.8	97.3	98.4	98.1	98.8	98.0

1. $(\text{Ni}_{0.93}\text{Fe}_{0.02}\text{Cu}_{0.01}\text{Co}_{0.01})_{0.97}\text{S}_2$
2. $(\text{Ni}_{0.95}\text{Fe}_{0.03}\text{Cu}_{0.01}\text{Co}_{0.006})_{1.00}\text{S}_2$
3. $(\text{Ni}_{0.93}\text{Fe}_{0.02}\text{Cu}_{0.01})_{0.96}\text{S}_2$
4. $(\text{Ni}_{1.01}\text{Fe}_{0.02}\text{Cu}_{0.02}\text{Co}_{0.09})_{1.08}\text{S}_2$
5. $(\text{Ni}_{0.93}\text{Fe}_{0.02}\text{Cu}_{0.02}\text{Co}_{0.03})_{1.00}\text{S}_2$
6. $(\text{Ni}_{0.97}\text{Fe}_{0.04}\text{Cu}_{0.02})_{1.02}\text{S}_2$

Table 2. X-ray diffraction pattern of vaesite from the Uchinotai-nishi ore body.

Vaesite from the Uchinotai-nishi ore body, Kosaka mine (present study)			Vaesite from Kasompi mine, Katanga, Belgian Congo (A. S. T. M. card, 11-99)		
$d(\text{\AA})$	I		hkl	$d(\text{\AA})$	I
3.43	s	gn			
3.26	w	vs	111	3.27	20
3.03	s	cp			
2.95	s	gn (+tn)			
2.83	s	vs	200	2.83	100
2.53	m	vs	210	2.54	40
2.33	m	vs	211	2.32	40
2.10	s	gn			
2.00	m	vs	220	2.00	50
			221	1.892	5
1.856	m	cp			
1.784	m	gn			
1.707	s	vs	311	1.707	80
			222	1.634	20
1.591	w	cp			
1.568	w	vs	320	1.570	30
1.514	vw	vs	321	1.514	30
			410		
			322	1.375	10
			411	1.336	5
1.322	w	gn			
			331	1.304	20
			320	1.268	20
			421	1.234	20
1.208	w	vs(+gn, cp)	332	1.208	10
			422	1.158	30
			430	1.133	5
			431	1.113	5
1.092	w	vs	511		
			333	1.091	60
			520		
			432	1.053	20
			521	1.035	20
1.004	w	vs	440	1.003	40

vs=vaesite, gn=galena, cp=chalcopryite, tn=tennantite.

analyses were done by JXA-3 electron microprobe using metals for Ni and Co, and a chemically analysed chalcopyrite for Cu, Fe and S, as standards. The measured values were corrected for atomic number effect by Bishop-Springer's method and for absorption by Philibert's method using Heinrich's absorption coefficients.

The mineral contains small amounts of Fe, Cu, and Co, replacing Ni but is very close to a pure NiS_2 . Se was not detected.

X-ray diffraction data

The material from Uchinotai was removed from the polished surface under the microscope and studied by X-ray powder diffraction. The data obtained are shown in Table 2. Although considerable amounts of galena and chalcopyrite are present, the lines other than those of these two minerals agree well with the data for vaesite from the type locality.

Sulfur fugacities at the time of ore deposition

Estimation of sulfur fugacities at the time of ore deposition can be made on the basis of the observed mineral assemblage, if the associated minerals are assumed to have formed under equilibrium conditions.

Let us consider the following two sulfidation reactions;

The $\log f_{\text{S}_2}$ values for the reaction (1) can be calculated from the ΔG values determined as a function of temperature (Barton and Toulmin, 1964). The $\log f_{\text{S}_2}$ - T relation for the reaction (2) is also available (Barton and Skinner, 1967). From several lines of evidences,

the formation temperatures of the black ores in the Kuroko-type deposits are believed to be in the range of 150° to 250°C (Tokunaga *et al.*, 1970; Kajiwara, 1970, 1971; Sato, 1971). Thus, the ranges of sulfur fugacities possible for ores containing chalcopyrite and vaesite but lacking in bornite and polydymite, are estimated as $\approx 10^{-13.8}$, $10^{-11.0}$ — $10^{-11.7}$ and $10^{-8.7}$ — $10^{-9.9}$ atm. at 150°, 200° and 250°C, respectively. On the basis of the experimental work by Barton and Toulmin (1966), the very low iron content in the coexisting sphalerite appears to be consistent with the sulfur fugacities estimated above.

Concluding remarks

Most of the vaesites reported to date are inferred to have been formed from other Ni-bearing sulfides or arsenides through alteration or weathering processes (e.g., Ramdohr, 1969; Uytenbogaardt and Burke, 1971). The vaesite described here, however, is apparently of primary origin judging from its mode of occurrence.

Nickel content of the ores from Kuroko-type deposits is generally very low; the average for the Uchinotai-nishi ore body is 10–20 ppm. It seems likely that nickel was concentrated in the hydrothermal solution of the later stages and was precipitated as vaesite under relatively high sulfur fugacities.

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REFERENCES

- BARTON, P.B., Jr. & SKINNER, B.J. (1967) *Geochemistry of hydrothermal ore deposits*, H.L. Barnes, ed., 236. Holt, Rinehart and Winston, New York.
- BARTON, P.B., Jr. & TOULMIN, P., III (1964) *Econ. Geol.*, **59**, 747.
- BARTON, P.B., Jr. & TOULMIN, P., III (1966) *Econ. Geol.*, **61**, 815.
- DERRIKS, J.J. & VAES, J.F. (1955) *Proc. U.N. Intern. Conf. Peaceful Uses At. Energy, 1st, Geneva, 1955*, **6**, 94.

- HORIKOSHI, E. (1969) *Miner. Deposita*, 4, 321.
- HORIKOSHI, E. & SATO, T. (1970) *Volcanism and ore genesis*, T. TATSUMI, ed., 181. Univ. Tokyo Press, Tokyo.
- KAJIWARA, Y. (1970) *Volcanism and ore genesis*, T. TATSUMI, ed., 367. Univ. Tokyo Press, Tokyo.
- KAJIWARA, Y. (1971) *Geochem. Journ.*, 4, 157.
- KERR, P. F. (1945) *Amer. Miner.*, 30, 483.
- PARK, W. C. (1967) *Miner. Deposita*, 2, 372.
- RAMDOHR, P. (1969) *The ore minerals and their intergrowths*. Pergamon, Oxford.
- SATO, T. (1971) *Soc. Mining Geol. Japan Spec. Issue*, 2, 137.
- TOKUNAGA, M., MIYAZAWA, T., HONMA, H. & PARK, H. (1970) *Collected Abstracts of IMA-IGOD Meetings '70, Tokyo-Kyoto*, 246.
- UYTENBOGAARDT, W. & BURKE, E. A. J. (1971) *Tables for microscopic identification of ore minerals*. Elsevier, Amsterdam-London-New York.

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