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GODLEVSKITE (β-Ni_7S_6) FROM THE TEXMONT MINE, ONTARIO

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Abstract

Godlevskite (β-Ni_7S_6) has been identified from the Texmont mine, Ontario. Its powder pattern can be indexed on the basis of an orthorhombic cell, $a = 9.17$, $b = 11.27$, $c = 9.41$ Å, which compares closely with the cell reported by Kulagov *et al.* for godlevskite from the Noril'sk area. The pattern also closely resembles that reported (Kullerud & Yund 1962) for synthetic β-Ni_7S_6. For the Texmont material, the composition is 63.56 wt. % Ni, 3.65 wt. % Fe, 0.07 wt. % Co, 32.24 wt. % S (giving a metal: sulphur atomic ratio of 7 : 6.12); the reflectance (546 nm) varies from 52.1 to 39.8, and the Vickers microhardness is 464. The godlevskite is associated with pentlandite, millerite and heazlewoodite. Showing moderate pleochroism, its colour varies from being similar to slightly darker than that of the associated pentlandite. The anisotropism is stronger than that of heazlewoodite but less than that of millerite.

Introduction

The Texmont mine is a small (3.8×10^6 tons, 1.0% Ni) nickel-iron sulphide deposit associated with peridotite 20 miles south of Timmins, Ontario. The host rock belongs to a distinctive class of ultramafic lenses, common in Archean greenstone belts, that were emplaced in the early stages of formation of the belts and which, in some cases, are submarine extrusives (Naldrett 1972; Pike, Naldrett & Eckstrand 1972).

The sulphides, which consist largely of pentlandite and pyrite with minor amounts of heazlewoodite, violarite and chalcopyrite, occur disseminated in the peridotite in a narrow, steeply-dipping zone through the centre of the lens. The godlevskite described here has only been found in one sample of drill core from an unknown location in the mine. The sample is now part of the Royal Ontario Museum collection, catalogue numbers M31015 and M31016.

Previous Studies of Godlevskite

Until recently phases with the composition of godlevskite were known only from experimental studies. In their study of the Ni-S system Kullerud & Yund (1962) discussed early experimental work and presented their own findings that α-Ni_7S_6 is stable in the presence of a vapour below 573 ± 3°C. The compound shows a maximum range of solid solution at about 500°C, taking 0.35 ± 0.05 wt. percent Ni into solid solution. They

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found that when in equilibrium with Ni_3S_2, α-Ni_7S_6 inverts to the low temperature polymorph, β-Ni_7S_6, between 396 and 397.5°C, and when in equilibrium with NiS it inverts between 399 and 401°C. β-Ni_7S_6 shows very little variation in metal : sulphur ratio. Kullerud & Yund described it as resembling β-NiS (millerite) in its creamy yellow colour and anisotropism. They found that the *x*-ray pattern for β-Ni_7S_6 is similar to that reported by Lundqvist (1947) for his Ni_6S_5 phase.

In his discussion of the Fe-Ni-S system, Kullerud (1963) suggested that tie-lines between Ni_3S_2 and the monosulphide solid solution (Mss) might isolate Ni_7S_6 from iron-rich portions of the system and hence account for its rarity as a mineral. However, Craig, Naldrett & Kullerud (1967) found that at 400°C tie-lines exist between Ni_7S_6 and pentlandite rather than Ni_3S_2 and the Mss, re-opening the question of the occurrence of Ni_7S_6 in natural, iron-rich environments.

Kulagov, Evstigneeva & Yushko-Zakharova (1969) described a new nickel-rich mineral with an orthorhombic cell and a metal : sulphur ratio of 7 : 6.87 occurring in bornite-chalcopyrite veins in the Noril'sk and Talnakh deposits of northern Siberia. At Noril'sk the mineral occurred with bornite in selvages of a chalcopyrite vein in andesite while at Talnakh it occurred in disseminated bornite-chalcopyrite ore in sandstone and altered diabase near the contact of a large chalcopyrite ore body. They named the mineral godlevskite after M. N. Godlevskii, petrologist and geologist who has worked on the volcanic and intrusive rocks of the Noril'sk camp.

Description of the Texmont Material

X-ray data

A powder diffraction pattern was obtained for the Texmont godlevskite using a 114.6 mm diameter camera and unfiltered copper radiation. The data, corrected only for film shrinkage (Nuffield 1966), are compared in Table 1 with Kullerud & Yund's data for synthetic β-Ni_7S_8. The d(Å) spacings for a number of lines were generated using Kulagov *et al.'s* (1969) cell dimensions for their orthorhombic cell; these were matched with our spacings and our pattern indexed in this way as shown in the table. The six lines showing intensities of 3.0 or greater were then used to calculate the following cell dimensions for our material: $a = 9.17$, $b = 11.27$, $c = 9.41$Å which are similar to Kulagov *et al.'s* values of $a = 9.180$, $b = 11.262$, $c = 9.457$Å.

TABLE 1. COMPARISON BETWEEN X-RAY DATA FOR SYNTHETIC β-Ni_7S_6 AND TEXMONT GODLEVSKITE

Synthetic β-Ni_7S_6 (Kullerud & Yund 1965) *		Texmont Material		Possible (*hkl*)
I	*d*(Å)	*d*(Å)	*I*	
15	5.70	5.72	30	(111)
5	4.68	4.68	10	(002)
15	4.17	**		(102)
10	3.93	3.94	10	(112)
5	3.60			(028)
5	3.31			(221)
50	3.26	3.25	40	(131)
		3.01	10	(013) (300)
100	2.860	2.863	100	(113)
25	2.794	2.791	10	(132) (231)
20	2.736	2.748	10	(023)
15	2.600	2.615	10	(123)
5	2.525	2.533	10	(213)
5	2.405			(033)
5	2.392			(330)
15	2.347			(322)
30	2.330	2.330	03	(133)
5	2.236			
30	2.183	2.178	20	(303)
5	2.165			
10	2.131			
20	2.097	2.102	20	(332)
5	1.947			
20	1.905	1.905	20	(431)
30	1.835	1.830	10	(413) (500)
10	1.819			
65	1.806 }	1.800 ***	80	{ (501)
65	1.793 }		60	{ (440)
50	1.655	1.661	40	(433) (442)
20	1.630	1.627	10	(414) (522) (531)

* Determined with a diffractometer.

** Background from the glass fire used in our camera pattern obscured the possible presence of this line.

*** This line was somewhat diffuse on our film. On a second film taken with iron-filtered cobalt radiation two lines were distinguished in this position 1.804 ($I = 60$) and 1.792 ($I = 60$).

Chemical composition

The godlevskite from Texmont and the other sulphides, heazlewoodite, millerite and pentlandite, with which it co-exists were all analyzed using an EMX-ARL electron microprobe and processing the data with the computer program EMPADR VII (Rucklidge & Gasparrini 1969).

Our analyses, together with Kulagov *et al.*'s (1969) godlevskite analysis, are listed in Table 2. The atomic metal : sulphur ratios for all of our analyses agree closely with the ratios expected of these minerals but the Russian material has a ratio closer to that expected for NiS than Ni_7S_6. The Russian analysis is possibly in error (as Kulagov *et al.* admit) since their *x*-ray data matches that of Kullerud & Yund's (1962) synthetic material and also that of our sample closely, and the metal : sulphur ratios of these is well established as 7 : 6.

Microscopic description

Godlevskite occurs in close association with pentlandite, heazlewoodite and millerite, the four sulphides forming irregular blebs, 1-3 mm in diameter, within a sample of serpentinized peridotite. Pentlandite is the most abundant of the sulphides, comprising 60-80 percent of most sulphide blebs. The three nickel-rich sulphides are generally found at the centre of pentlandite masses. Godlevskite is the next most abundant sulphide occurring mostly as equant grains (about 0.2 mm diameter) that have sharp, unscalloped boundaries against pentlandite.

Much of the godlevskite is cut by fine veins and irregular, elongate bodies of heazlewoodite; some of it occurs in irregular intergrowths with millerite (see Fig. 1a for both these features). Apart from its presence in the intergrowths, millerite occurs as relatively massive bodies (100-200μm

TABLE 2. ELECTRON MICROPROBE ANALYSES OF GODLEVSKITE AND ASSOCIATED MINERALS

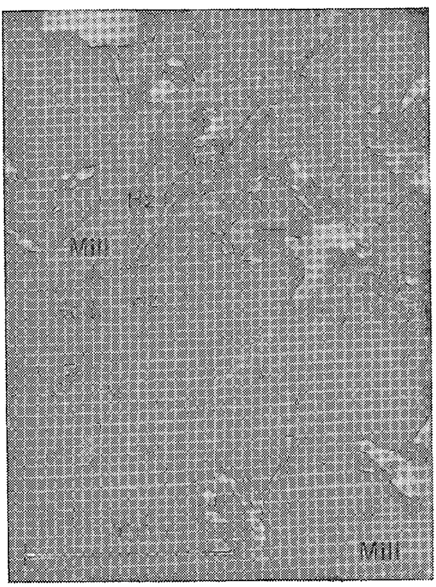
	Godlevskite *		Heazlewoodite	Millerite	Pentlandite
Wt.%	1	2			
Fe	3.65	3.0	0.20	0.75	22.49
Ni	63.56	61.5	72.92	63.52	43.48
Co	0.07	0.6	0.00	0.19	1.04
S	32.24	35.0	26.27	34.85	33.15
Total	99.52	100.10	99.39	99.31	100.16
Metal : sulphur	7 : 6.12	7 : 6.87	3 : 1.97	1 : 0.99	9 : 8.01

* Godleskite #1 is from Texmont and #2 is the Russian material.

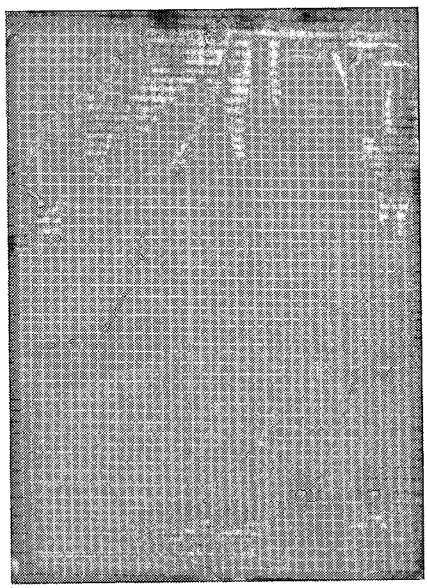
diam.) with sharp, unscalloped boundaries against godlevskite and pentlandite and also as small equant grains (Fig. 1b) associated with godlevskite.

The heazlewoodite veinlets are generally restricted to the godlevskite, although more rarely they cut millerite (Fig. 1a). They either terminate abruptly at contacts between godlevskite and pentlandite, alter in direction to follow these contacts, or extend as small tails, never more than 10μm long, into pentlandite. The veinlets contain numerous small (< 1μm wide) oriented lamellae of a strongly anisotropic mineral (Fig. 1a), that is probably millerite.

Godlevskite shows a fairly strong (similar in magnitude to pyrrhotite) reflection pleochroism changing from pale cream to pinkish cream. The pale cream colour is similar to that of the associated pentlandite (itself nickel-rich and slightly paler than the commoner, more iron-rich varieties of pentlandite) but when the godlevskite is oriented to have the pinkish



a



b

FIG. 1a. Heazlewoodite veinlets (containing small millerite lamellae) cutting godlevskite and millerite that is intergrown with godlevskite. Oil immersion. Partly crossed nicols.

FIG. 1b. Twinned godlevskite associated with pentlandite and millerite. Oil immersion. Partly crossed nicols.

cream colour it appears distinctly darker than the pentlandite. Godlevskite is darker in all orientations than the heazlewoodite, which is itself slightly pleochroic and looks either yellow or faintly bluish against the godlevskite. Millerite in the sample is slightly to distinctly yellower than all of the other sulphide minerals.

Godlevskite has a moderately strong anisotropism, more distinct than that of heazlewoodite but less than that of millerite. The anistropic colours vary from blue grey to neutral grey to slightly pinkish grey. No cleavage is visible and the mineral polishes to a smooth surface which contrasts with the blocky, fractured appearance of the surrounding pentlandite. A polysynthetic twinning (Fig. 1b) was observed in two grains but this is not a common feature of our sample.

Reflectance and microhardness

The reflectance was determined using a Vickers microscope, EEL digital microphotometer and Jena variable interference filter set to pass light of 546 nm. The determinations were made using a secondary silicon carbide standard (Reflectance$_{546}$ = 20.6) which had itself been calibrated against a primary standard. Numerous godlevskite grains were measured; the maximum reflectance was 52.1 and the minimum 39.8 (range for the Russian material was 56.4 to 37.7). The Vickers microhardness was determined with a Leitz Durimet microhardness tester at a force of 100 pond applied for 15 sec.; it was found to be 464. This is appreciably higher than the Russian value of 397.

Speculations on the Stability of Godlevskite

Although deductions from polished sections concerning the sequence of crystallization of ore minerals are fraught with pitfalls, our examination suggests that pentlandite, godlevskite and possibly some millerite existed stably together at one stage in the cooling of our material. The heazlewoodite veinlets (containing up to 25 percent of probable millerite lamellae) appear to have formed subsequently at the expense of godlevskite. As mentioned above, godlevskite is known to be stable at 400°C. The heazlewoodite veinlets in the natural material indicate that it may break down to heazlewoodite and millerite below this temperature. It may be significant that the godlevskite at Texmont is preserved in an ultramafic body that was possibly extrusive and therefore subjected to much more rapid cooling than an intrusion, thus preserving the godlevskite at an intermediate stage in its breakdown to heazlewoodite and millerite.

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