

On cooperite, braggite, and vysotskite¹

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Abstract

Detailed mineralogical analyses of cooperite, braggite, and vysotskite, together with phase equilibrium studies, reveal that, though there is no uncertainty regarding the identity of cooperite (PtS; $P4_2/mmc$), one may consider braggite (Pt,Pd)S and vysotskite PdS to be nickellean members of an isomorphous solid-solution series (Pd,Pt)S ($P4_2/m$). The results also suggest that this solid-solution series (braggite series) may be subdivided by restricting the name vysotskite to those members with less than about 10 mole percent PtS. Cooperite and braggite can both form at magmatic temperatures of 1000°C or above, but vysotskite is only formed at submagmatic temperatures, possibly by crystallization from a residual immiscible sulfide-rich melt or by solid-state reaction.

Introduction

Cooperite, braggite, and vysotskite are the only Pt-Pd sulfide minerals with ideal compositions in the system Pt-Pd-S. Cooperite is ideally PtS, braggite (Pd,Pt)S, and vysotskite PdS. All analyses, however, report the presence of significant amounts of Ni, so mineralogically they must be considered as being in the system Pt-Pd-Ni-S. We aim to clarify the nomenclature and to present new data on the compositions of the minerals. It is a pleasure to be able to do so in the Froudel-Hurlbut issue of *The American Mineralogist*, because these two distinguished mineralogists have clarified so many similarly confusing issues in the nomenclature of minerals.

Braggite and cooperite are both important platinum-group minerals (PG-minerals) and are known from many areas of the world; in the great Merensky Reef deposits of the Bushveld Igneous Complex in the Transvaal they are major ore minerals. Vysotskite has not so far been found in sufficient quantities to be considered an important ore mineral. First discovered in the Noril'sk deposits of the USSR and reported by Genkin and Zvyagintsev (1962), vysotskite

has since been reported, but not documented in detail, from the Stillwater Complex of Montana (Cabri and Laflamme, 1974) and the Lac des Isles deposit, Ontario (Cabri and Laflamme, 1976).

In this note we report new data on all three minerals from the Precambrian Stillwater Complex of Montana. Page *et al.* (1976) discussed the variations of PG-elements in the different mafic and ultramafic layers of the complex. In the layers identified by Page *et al.* as the Banded and Upper Zones we have identified, for the first time, the three minerals in the same deposit. The three minerals have not been found in contact so it is probable that the assemblage does not represent equilibrium, and its true significance can only be guessed at.

Previous mineralogical studies

Cooperite

Cooperite was discovered in samples from the Bushveld by Cooper (1928) and named by Wagner (1929) following a suggestion by a Mr. Wartenweiler in a published discussion following presentation of Cooper's paper. Bannister and Hey (1932) determined the mineral to be tetragonal with $a = 4.91$ and

Table 2. Electron microprobe analyses of coagelite-braggite-kyanite from different localities

Pt	Weight percent			S	Total	Formula					Mineral #	Sample	
	Pd	Ni				Pt	Pd	Ni	YM	S			
1.	81.5(73.0-84.8)	2.6(0.08-10.2)	0.74	14.6(13.9-15.8)	99.54	0.92	0.05	0.03	1.00	1.00		C	5
2.	71.8	4.0	7.3	17.3	100.4	0.69	0.07	0.23	0.99	1.01		C	5
3.	84.4	0.82	0.94	14.9	101.06	0.94	0.02	0.03	0.99	1.01		C	5
4.	69.5(66.0-71.4)	7.0(6.1-11.5)	6.0(5.5-6.5)	17.0(16.6-18.0)	99.5	0.68	0.12	0.19	0.99	1.01		B	5
5.	70.1(68.6-72.7)	6.9(6.2-8.2)	5.6(4.7-6.0)	16.5(16.2-16.6)	99.1	0.69	0.13	0.18	1.00	1.00		B	5
6.	67.0(66.0-68.6)	9.5(8.6-9.7)	5.6(4.3-6.3)	16.9(15.5-17.0)	99.0	0.65	0.17	0.18	1.00	1.00		B	5
7.	68.9(67.9-70.1)	8.1(7.5-8.1)	5.7(5.5-6.1)	16.5(16.0-16.6)	99.2	0.68	0.14	0.19	1.01	0.99		B	5
8.	3.7(0.19-8.4)	61.8(57.7-65.9)	10.2(9.0-10.8)	24.8(24.2-24.9)	100.5	0.02	0.75	0.23	1.00	1.00		V	5
9.	60.3	15.7	6.3	17.8	100.1	0.55	0.27	0.19	1.01	0.99		B	5
10.	48.0(46.6-49.2)	26.9(26.0-28.1)	5.0(4.5-6.0)	19.1(18.8-19.1)	99.0	0.42	0.43	0.14	0.99	1.01		B	5
11.	63.6	13.8	5.4	16.6	99.6	0.61	0.24	0.17	1.02	0.98		E	5
12.	52.3	19.5	5.1	17.6	100.5	0.52	0.32	0.16	1.02	0.98		B	5
13.	51.6(43.9-57.3)	22.6(19.2-26.5)	7.2(6.2-10.0)	18.9(17.7-20.3)	100.4	0.44	0.36	0.21	1.01	0.99		B	5
14.	47.5(42.1-51.5)	24.4(23.6-27.4)	9.0(8.8-9.5)	19.3(18.9-20.6)	100.2	0.40	0.37	0.25	1.02	0.98		B	5
15.	37.0(16.7-45.8)	37.6(31.9-52.6)	6.0(5.3-9.3)	20.3(18.5-22.4)	100.9	0.30	0.55	0.16	1.01	0.99		B	5
16.	37.0(24.4-50.4)	31.6(24.2-40.2)	10.4(5.9-14.0)	20.5(18.6-21.8)	99.5	0.29	0.46	0.27	1.02	0.98		B	5
17.	40.9	33.9	5.1	19.6	99.5	0.34	0.52	0.14	1.00	1.00		B	5
18.	40.3(36.1-42.6)	32.4(29.9-35.7)	7.1(6.3-9.0)	19.7(18.9-20.4)	99.5	0.33	0.49	0.19	1.01	0.99		B	5
19.	48.9(41.0-54.6)	24.9(22.0-28.9)	7.7(5.0-9.7)	19.0(18.1-20.1)	100.5	0.41	0.39	0.22	1.02	0.98		B	5
20.	67.4(66.0-69.8)	9.4(8.6-12.5)	5.7	16.9(16.9-17.6)	99.4	0.65	0.17	0.18	1.00	1.00		B	4
21.	67.9	8.8	5.7	16.8	99.2	0.66	0.16	0.18	1.00	1.00		B	4
22.	55.8	19.7	5.7	18.5	99.7	0.50	0.32	0.17	0.99	1.01		B	4
23.	68.1	8.8	5.6	16.7	98.9	0.67	0.15	0.18	1.00	1.00		B	4
24.	55.3(52.9-55.6)	21.4(19.9-22.3)	5.2(5.0-5.2)	18.5(18.2-18.8)	100.4	0.49	0.35	0.15	1.00	1.00		B	4
25.	49.9	25.3	5.2	19.2	100.6	0.43	0.41	0.15	0.99	1.01		B	4
26.	53.0	23.4	5.3	18.0	99.7	0.48	0.38	0.16	1.02	0.98		B	2
27.	59.9(57.4-60.8)	17.6(16.7-19.9)	5.2(4.9-5.5)	17.6(17.3-17.8)	100.2	0.55	0.38	0.16	1.01	0.99		B	2
28.	53.1	23.9	5.5	18.4	100.9	0.47	0.39	0.16	1.02	0.98		B	2
29.	51.7	24.5	5.6	18.4	100.2	0.48	0.39	0.16	1.01	0.99		B	2
30.	52.7	23.9	5.5	18.3	100.4	0.47	0.39	0.16	1.02	0.98		B	2

TABLE 2 - Continued

	pt	pd	Weight percent	Wt	S	Total	pt	pd	Formula	M	S	Mineral*	Sample**
31.	14.9(11.6-17.7)	54.4(53.0-58.0)	6.8(6.0-9.5)	23.1(22.8-23.4)	99.2	0.17	0.72	0.16	0.59	1.01	0.99	V?	1
32.	12.1(11.1-13.0)	57.4(56.7-58.6)	6.0	23.3(23.0-23.4)	98.8	0.09	0.75	0.14	0.58	1.02	0.98	V	1
33.	83.2	0.73	2.3	14.7	100.93	0.92	0.02	0.06	1.02	0.98	0.98	C	2
34.	80.7	3.4	1.1	15.6	106.8	0.87	0.07	0.04	0.98	1.02	1.02	C	2
35.	63.3(58.4-68.3)	14.6(9.8-19.5)	4.6	17.3(16.5-18.7)	100.3	0.59	0.25	0.14	0.98	1.02	1.02	B	6
36.	60.9	15.6	4.2	18.0	99.7	0.57	0.28	0.13	0.99	1.02	1.02	B	6
37.	63.0(59.2-66.8)	14.7(10.7-18.7)	4.6	18.2(17.7-18.7)	100.5	0.58	0.25	0.14	0.97	1.03	1.03	B	6
38.	12.6(9.1-14.4)	57.1(54.8-59.6)	6.6	23.0	99.3	0.09	0.75	0.16	1.00	1.00	1.00	V	7
39.	0.28	67.5	8.4	24.9	10.08	0.01	0.81	0.18	1.00	1.00	1.00	V	7
40.	8.2(7.5-9.1)	59.3(58.3-60.6)	8.9	23.9	160.3	0.06	0.74	0.20	1.00	1.00	1.00	V	7
41.	33.0(27.7-43.8)	39.6(31.5-41.9)	4.6(3.8-5.5)	20.8	98.0	0.27	0.59	0.12	0.98	1.02	1.02	B	7
42.	4.2(3.6-4.9)	58.6(57.5-59.7)	11.7(10.2-12.5)	24.9	99.4	0.03	0.71	0.26	1.00	1.00	1.00	V	7
43.	12.0(10.6-13.2)	58.9(58.0-61.0)	5.7	23.1	99.7	0.09	0.77	0.13	0.99	1.01	1.01	V	7
44.	3.4(2.5-4.6)	60.1(57.1-62.0)	12.1	25.3	100.9	0.02	0.72	0.26	1.00	1.00	1.00	V	7
45.	4.3	65.7	5.3	23.7	99.0	0.03	0.84	0.12	0.99	1.01	1.01	V	7
46.	5.0(1.6-9.6)	60.0(56.1-62.7)	9.3(7.5-10.4)	24.4	98.7	0.03	0.75	0.21	0.99	1.01	1.01	V	7
47.	54.3	26.2	2.8	18.6	102.5	0.49	0.43	0.08	1.00	1.00	1.00	B	7
48.	58 (56.2-59.9)	19.9(18.8-20.8)	3.2(2.9-3.6)	19.3	99.8	0.54	0.33	0.10	0.97	1.03	1.03	B	7
Anal.	49 to 53, taken	from Brynard et al (1976)											
Anal.	54 to 64, taken	from Schwelb et al (1976)											
54.	54.3(51.8-56.6)	22.7(20.5-24.2)	6.3	18.9	102.2	0.47	0.36	0.18	1.01	0.99	0.99	B	8
55.	58.9(57.4-61.0)	18.5(17.7-19.3)	6.1	17.9	101.4	0.53	0.31	0.18	1.02	0.99	0.99	B	8
56.	60.4(57.0-61.4)	17.9(16.5-19.4)	5.6	18.0	101.8	0.55	0.30	0.16	1.01	0.99	0.99	B	8
57.	61.4(50.4-62.9)	16.3(15.4-17.5)	6.0	17.9	101.6	0.56	0.27	0.18	1.01	0.99	0.99	B	8
58.	57.2(54.3-61.2)	19.3(17.1-21.1)	6.6	18.0	101.1	0.51	0.32	0.19	1.02	0.98	0.98	B	8
59.	52.6(43.5-55.6)	23.8(22.0-25.8)	6.7	19.0	102.1	0.45	0.37	0.19	1.01	0.99	0.99	B	8
70.	65.6(59.8-69.8)	14.2(11.5-18.7)	4.7	16.7	101.2	0.65	0.25	0.15	1.03	0.97	0.97	B	8
71.	55.0(53.4-56.9)	21.7(20.1-23.2)	6.2	18.2	101.1	0.49	0.35	0.18	1.02	0.98	0.98	B	8
72.	83.5	1.4	0.64	14.2	99.74***	0.96	0.03	0.02	1.01	0.99	0.99	C	9
73.	44.1	31.1	4.9	19.9	99.9***	0.37	0.48	0.13	0.98	1.02	1.02	B	9
74.	64.6	13.5	3.9	17.1	99.1***	0.63	0.24	0.12	0.99	1.01	1.01	B	9
75.	2.0	69.5	3.9	23.7	99.1***	0.01	0.83	0.09	0.99	1.01	1.01	V	10
76.		30.0(26.5-36.0)	4.7	19.6(19.1-20.5)	99.7	0.39	0.47	0.13	0.99	1.01	1.01	B	9