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JASKÓLSKIITE, A NEW Pb–Cu–Sb–Bi SULFOSALT FROM THE VENA DEPOSIT, SWEDEN

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ABSTRACT

Jaskólskiite is a new mineral species found in the Vena Cu–Co fahlband-type deposit, Bergslagen metallogenic province, central Sweden. It occurs in aggregates up to a few mm in diameter, intergrown with another Pb–Cu–Sb–Bi sulfosalt, native bismuth, galena, pyrrhotite and, rarely, antimony. The average of 16 electron-microprobe analyses is Pb 50.74, Cu 1.31, Sb 15.74, Bi 14.35, S 17.51, sum 99.65 wt.%. The balanced and normalized formula is $Pb_{2.22}Cu_{0.19}Sb_{1.17}Bi_{0.62}S_5$ or, ideally, $Pb_{2+x}Cu_x(Sb,Bi)_{2-x}S_5$, where Sb exceeds Bi and x is about 0.2. Jaskólskiite corresponds to synthetic $Pb_2Sb_2S_5$ of Wang (1973) and is a homologue of meneghinite. The mineral has an orthorhombic unit-cell with *a* 11.331(1), *b* 19.871(2), *c* 4.100(1) Å, $Z = 4$, space group *Pbnm*. The strongest seven lines in the X-ray powder pattern [*d* in Å(I)(*hkl*)] are: 3.710(100)(310), 3.595(50)(121), 3.333(60)(131), 2.970(80)(231), 2.761(60)(241), 2.751(50)(311), 2.050(50)(0.02). Jaskólskiite is lead-grey and has a metallic lustre and a dark grey streak. The calculated density is 6.50 g/cm³. In reflected light the mineral is grey with greenish to yellowish tints due to reflection pleochroism; there are no internal reflections. The reflectances in air are: 44.9, 37.2% (470 nm); 44.2, 36.3 (546 nm); 43.7, 36.1 (590nm); 41.9, 34.8 (650 nm). The Vickers microhardness VHN_{100} ranges between 165 and 179, corresponding to a Mohs hardness of 4. The name honors Professor Stanislaw Jaskólski (1896–1981).

Keywords: jaskólskiite, new mineral species, Pb–Cu–Sb–Bi sulfosalt, meneghinite homologous series, Bergslagen, Sweden.

SOMMAIRE

On trouve la jaskólskiite, nouvelle espèce minérale, dans le gîte de Cu–Co du type "fahlband" de Vena, dans la province métallogénique du Bergslagen en Suède centrale. Elle forme des agrégats de quelques mm de diamètre, en intercroissance avec un autre sulfosel de Pb–Cu–Sb–Bi, bismuth natif, galène, pyrrhotine et, rarement, antimoine. La microsonde électronique révèle, comme moyenne de 16 analyses, Pb 50.74, Cu 1.31, Sb 15.74, Bi 14.35, S 17.51, total 99.65% en poids, ce qui donne la formule électrostatiquement équilibrée et normalisée de $Pb_{2.22}Cu_{0.19}Sb_{1.17}Bi_{0.62}S_5$ ou, plus simplement, $Pb_{2+x}Cu_x(Sb,Bi)_{2-x}S_5$ $(Sb > Bi, x \simeq 0.2)$. La jaskólskiite, qui correspond au $Pb_2Sb_2S_5$ synthétique de Wang (1973), est un homologue de la méneghinite. C'est un minéral orthorhombique, *a* 11.331(1), *b* 19.871(2), *c* 4.100(1) Å, $Z = 4$, groupe spatial *Pbnm*. Les sept raies les plus intenses du cliché de diffraction X (méthode des poudres) [*d* en Å(I)(*hkl*)] sont: 3.710(100)(310), 3.595(50)(121), 3.333(60)(131), 2.970(80)(231), 2.761(60)(241), 2.751(50)(311), 2.050(50)(0.02). D'un gris de plomb, la jaskólskiite possède un éclat métallique et une rayure gris foncé. Sa densité calculée est de 6.50. En lumière réfléchie, ce minéral est gris à teintes verdâtres à jaunâtres dues au pléochroïsme de réflection. On n'observe pas de réflection interne. Dans l'air, les valeurs de la réflectance sont: 44.9, 37.2% (470 nm); 44.2, 36.3 (546 nm); 43.7, 36.1 (590 nm) et 41.9, 34.8 (650 nm). La microdureté Vickers (VHN_{100}) varie de 165 à 179, ce qui correspond à 4 dans l'échelle de Mohs. Le nom rappelle le professeur Stanislaw Jaskólski (1896-1981).

(Traduit par la Rédaction)

Mots-clés: jaskólskiite, nouvelle espèce minérale, sulfosel de Pb–Cu–Sb–Bi, série des homologues de la méneghinite, Bergslagen, Suède.

INTRODUCTION

Jaskólskiite was encountered during the study of sulfosalts from the abandoned Vena Cu–Co mine in southern Bergslagen, Sweden. The idealized formula, $Pb_{2+x}Cu_x(Sb,Bi)_{2-x}S_5$, and the X-ray-diffraction pattern suggest that the mineral corresponds to the synthetic orthorhombic phase $Pb_2Sb_2S_5$ of Wang (1973).

Jaskólskiite (JAS.KUL.SKI-AIT) is named in honor of Dr. Stanislaw Jaskólski (1896–1981), formerly Professor at the Akademia Górniczo–Hutnicza in Kraków and a pioneer in the development of ore microscopy in Poland. The mineral and name have been approved by the IMA Commission on New Minerals and Mineral Names. Type material is preserved in the collections of the Institute of Earth Sciences of the Free University in Amsterdam under number 150–J–2. The second occurrence of jaskólskiite is reported by Harris *et al.* (1984) from Canada and the third by Y. Moëlo (written comm.) from Portugal.

OCCURRENCE

The Vena ore field is a fahlband-type chalcopyrite–cobaltite deposit typical of the Åmmeberg–Tunaberg belt, which is located in the southern part of the Proterozoic metallogenic province of Bergslagen in central Sweden. The geology and the ore deposits of Bergslagen are

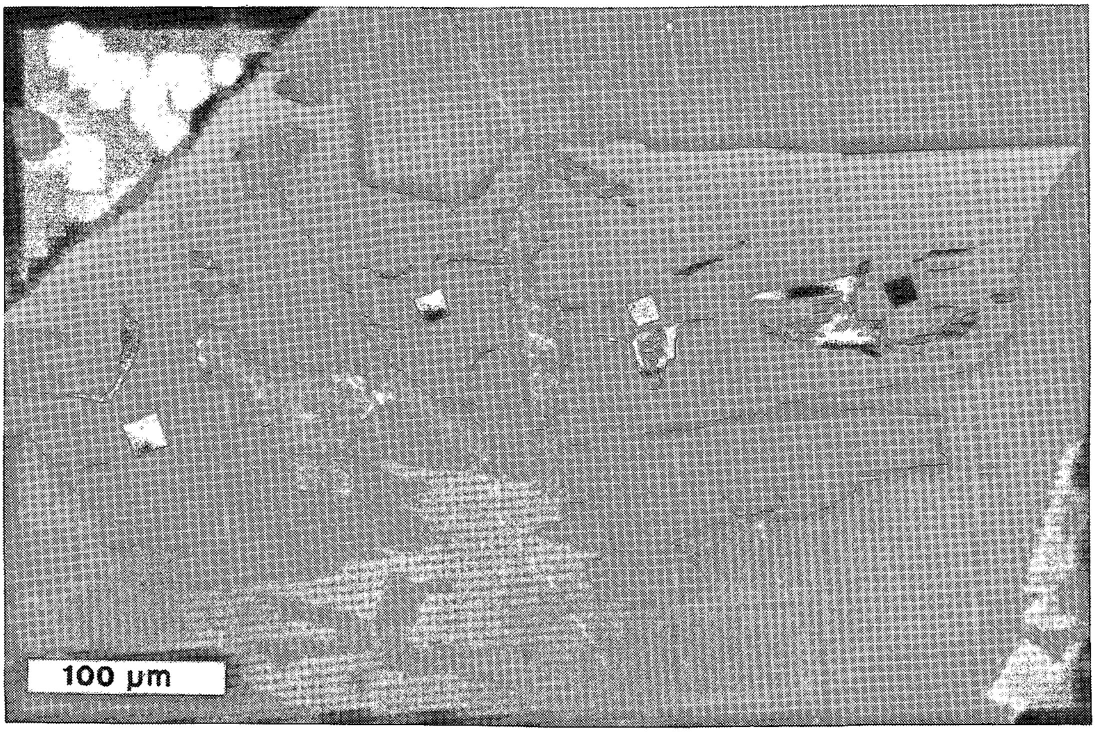

FIG. 1. Jaskólskiite grain (white) has been altered along cracks to secondary galena, pyrrhotite and bismuth. Jaskólskiite is surrounded by mineral "S". Oil immersion, nicols partly crossed.

described by Grip (1978). The Vena deposit is particularly well known in the mineralogical literature for the occurrence of kobellite (Sätterberg 1839; see Harris *et al.* 1968) and Sb-kobellite (Flink 1915). The specimens examined in this study contain aggregates up to a few centimetres in diameter of lead-grey sulfosalt intergrown with galena. Under the ore microscope two Pb–Cu–Sb–Bi sulfosalts were recognized: jaskólskiite and unnamed mineral "S". Mineral "S" is the major constituent, followed by pyrrhotite, chalcopyrite, arsenopyrite, galena, jaskólskiite, cobaltite, pyrite, sphalerite, bismuth, cubanite, freibergite, gudmundite, marcasite, antimony, costibite and mackinawite. No grains with a composition of kobellite were found. [*Note added in proof*: The name *izoklakeite* has been approved for mineral "S".]

TABLE 1. REFLECTANCE VALUES FOR JASKÓLSKIITE FROM VENA

Wavelength	R_1	R_2
470	37.2	44.9
546	36.3	44.2
590	36.1	43.7
650	34.8	41.9

WC-6 standard (Zeiss)

PHYSICAL AND OPTICAL PROPERTIES

Jaskólskiite occurs mainly as aggregates up to a few millimetres in diameter intergrown with mineral "S", galena, native bismuth and pyrrhotite (Fig. 1). In a few cases, small grains of native antimony were also found together with jaskólskiite.

Jaskólskiite has a lead-grey color and a metallic lustre. The streak is dark grey. In reflected light it is grey with greenish to yellowish tints due to reflection pleochroism. Anisotropism is strong without distinct colors. The reflectance measurements are listed in Table 1. The polishing hardness is higher than that of galena and mineral "S", but lower than that of pyrrhotite. Microindentation hardness VHN_{100}, based on ten indentations on several grains, gave 165–179, equivalent to a Mohs hardness of 4. The mineral reacts with HNO_3 (1:1) immediately, but no observable reaction occurs with HCl (1:1), KOH (40%) or $FeCl_3$ (20%).

Jaskólskiite could not be isolated in an amount sufficient for direct determination of density. Therefore, it was estimated by comparison with the density of other sulfosalts with a Pb/(Sb + Bi) ratio similar to that of jaskólskiite. Among these minerals there is a decrease of density corresponding to an increase in the Sb/(Sb + Bi) ratio (Fig. 2). The unnamed mineral species "S" from Vena ($Pb_{51}Sb_{20}Bi_{19}Cu_3AgFeS_{114}$) is probably identical to the Sb-kobellite investigated by Flink (1915). Its measured density of 6.535 g/cm^3 (Flink 1915) may be extrapolated to 6.60 g/cm^3 after a compensation for some impurities and assuming the above composition. The density *versus* composition diagram (Fig. 2), constructed for boulangerite and mineral "S", crosses the 0 point of the Sb/(Sb + Bi) ratio at 7.0 g/cm^3. This value fits well with the densities of lillianite $Pb_3Bi_2S_6$, neyite $Pb_7(Cu,Ag)_2Bi_6S_{17}$ and nuffieldite $Pb_2Cu(Pb,Bi)Bi_2S_7$. The estimated density of jaskólskiite, 6.47 g/cm^3, corresponds well with the calculated value of 6.50 g/cm^3.

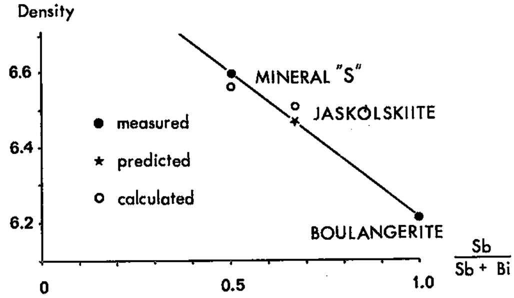

FIG. 2. Relationship between density and composition in some Pb-Sb-Bi-Cu sulfosalts. Density in g/cm^3.

Chemical Composition

Electron-microprobe analyses (Table 2) were performed with a Cambridge Instruments Microscan 9 using galena (for Pb), stibnite (Sb,S), metallic Bi and chalcopyrite (Cu) as standards. Apparent concentrations have been corrected with the Microscan 9 on-line ZAF program.

The average chemical composition determined is $Pb_{2.24}Cu_{0.19}Sb_{1.18}Bi_{0.63}S_5$; with assumed valences Pb^{2+}, Sb^{3+}, Bi^{3+} and Cu^+, the sum of positively charged cations is 10.1. If the amount of S is corrected to maintain charge balance, it becomes 5.05 and the formula can be normalized to $Pb_{2.22}Cu_{0.19}Sb_{1.17}Bi_{0.62}S_5$ or, ideally, $Pb_{2+x}Cu_x(Sb,Bi)_{2-x}S_5$, where Sb exceeds Bi and x is about 0.2. The number of formula units (Z) in the unit cell is 4, for an estimated density of 6.47 g/cm^3.

X-Ray-Diffraction Studies

The X-ray powder-diffraction data for jaskólskiite (Table 3B) were obtained on powder drilled out from grain 150-J-2 BB (Table 2) under the microscope and mixed with a rubber solution. A Straumanis-type 114-m-diameter Debye–Scherrer camera was used with Ni-filtered Cu radiation. These data are in good agreement with those obtained by Wang (1973) on synthetic $Pb_2Sb_2S_5$. The Guinier X-ray powder data in Table 3A were obtained with $CoK\alpha_1$ radiation on material contaminated with mineral "S". The lines of the admixed mineral "S" have been omitted from the table. Refined unit-cell parameters based on 21 powder lines gave a 11.331(1), b 19.871(2), c 4.100(1) Å. The crystal structure of jaskólskiite, using a single crystal from Vena, is currently being studied by Dr. E. Makovicky (Copenhagen) and coworkers. Immediately following are their selected results and ideas, communicated to the present author and published with their permission.

Weissenberg and rotation photographs indicate jaskólskiite to be orthorhombic, space group *Pbnm*. The alternative space-group permitted by extinctions, $Pbn2_1$, is excluded because of the identity of intensities of corresponding reflections $hk0$ and $hk2$. The crystal examined is primarily bounded by the faces of the forms {010} and {110} and, to a lesser degree, by {100}, {120} and {210}.

The crystal-structure determination shows that jaskólskiite belongs to the meneghinite homologous series. The structure of this series can be envisaged as formed by n-glide chemical twinning of slices (501) and ($\bar{5}01$) of an SnS-like archetype structure that contains Sb or Bi or both as well as Pb as cations. Tetrahedral voids on twin composition planes may be (partly) occupied by Cu atoms. The general formula of the series spans the end members $Me^{2+}{}_{2N-4}Me^{3+}{}_4S_{2N+2}$, with tetrahedral voids not filled, and the end members $Cu^+Me^{2+}{}_{2N-2}Me^{3+}{}_2S_{2N+2}$, with the tetrahedral voids fully occupied and with the heterovalent substitutions taking place in the SnS-like slabs.

According to the width of the slabs, meneghinite represents the fifth member of the series and jaskólskiite the fourth member; the third member still awaits discovery, although berthierite represents a closely related structure. The second member of the homologous series is represented by stibnite and the bismuthinite–aikinite series and the first members are the structures of the SbSI type (E. Makovicky, written comm. 1983).

TABLE 2. RESULTS OF ELECTRON-MICROPROBE ANALYSES OF JASKÓLSKIITE FROM VENA

	Weight %						Atomic proportions				
Grain code	Pb	Sb	Bi	Cu	S	Total	Pb	Sb	Bi	Cu	S
150J2 BB	51.64	15.91	14.16	1.37	17.54	100.62	2.28	1.19	0.62	0.20	5
150J2 H	49.67	16.23	14.49	1.11	17.40	98.93	2.20	1.23	0.64	0.16	5
150J2 KB	50.85	15.70	13.78	1.19	18.08	99.60	2.18	1.14	0.58	0.17	5
Mean of 16	50.74	15.74	14.35	1.31	17.52	99.65	2.24	1.18	0.63	0.19	5
St. dev.	0.64	0.23	0.35	0.11	0.31		0.03	0.02	0.02	0.09	

Normalized formula $Pb_{2.22}Sb_{1.17}Bi_{0.62}Cu_{0.19}S_5$

TABLE 3. X-RAY POWDER-DIFFRACTION DATA FOR JASKÓLSKIITE FROM VENA

A				B	
$I_{est.}$	$d_{obs.}$	$d_{calc.}$	hkl	$d_{obs.}$	$I_{est.}$
5	11.290	11.331	100		
5	9.920	9.936	020		
10	7.466	7.471	120		
20	5.719	5.718	130 x	5.73	20
10	5.452	5.449	210 x		
5	4.917	4.922	220	4.95	20
5	4.557	4.550	140		
30	4.308	4.306	230 x	4.30	30
10	3.865	3.855	101		
40	3.783	3.784	111		
40	3.752	3.750	150 x		
40	3.736	3.735	240 x	3.73	90
100	3.710	3.711	310 x		
50	3.595	3.594	121 x	3.60	50
60	3.333	3.332	131	3.34	50
30	3.312	3.312	060		
20	3.282	3.281	330		
30	3.252	3.254	250 x	3.25	30
40	3.180	3.179	160 x	3.17	50
30	3.159	3.162	041		
30	3.150	3.150	221 x		
20	3.043	3.046	141	3.04	10
5	3.000	3.007	340		
80	2.970	2.969	231 x	2.969	100
40	2.860	2.859	260 x	2.858	40
10	2.839	2.833	400		
15	2.805	2.804	410		
30	2.778	2.778	301 x		
60	2.761	2.761	241 x	2.759	90
50	2.751	2.751	311 x		
1	2.725	2.724	420		
5	2.676	2.675	321		
5	2.605	2.605	430		
1	2.574	2.574	061		
15	2.538	2.538	270 x	2.543	20
1	2.516	2.512	161		
5	2.346	2.345	261		
5	2.314	2.315	411		
5	2.307	2.307	450		
10	2.285	2.286	171 x		
40	2.269	2.269	370, 421	2.273	40
5	2.254	2.252	510		
30	2.198	2.198	431 x	2.199	30
30	2.152	2.153	460	2.154	10
30	2.124	2.124	081 x	2.122	40
10b	2.109	2.110	441		
50	2.051	2.050	002	2.053	40
5	2.006	2.007	022, 112		
		2.005	470		
15	1.9853	1.9854	371		
30	1.9686	1.9687	550 x	1.969	30
1	1.9573	1.9573	1.10.0		
1	1.9454	1.9450	521		
20	1.9063	1.9061	390	1.907	40
		1.9059	461		
10	1.8884	1.8886	600 x		
5	1.8708	1.8703	560		
10	1.8513	1.8516	381		
30b	1.7952	1.7942	312	1.792	40
10	1.7750	1.7747	551		
10	1.7580	1.7586	3.10.0		
15	1.7348	1.7343	252	1.726	40
5	1.7278	1.7284	391		
10	1.7096	1.7089	611		
5	1.6911	1.6903	621		
5	1.6674	1.6659	262	1.668	10
5	1.6140	1.6134	710		
5	1.5222	1.5228	282	1.523	10
		1.5215	1.12.1		
10	1.4873	1.4886	721		
15	1.4823	1.4820	2.12.1	1.484	20
10	1.4690	1.4682	731		
		1.4681	671		
20	1.4183	1.4169	3.13.0	1.417	20
10	1.4087	1.4080	751		
				1.329	20

Cell dimensions: *a* 11.331(1), *b* 19.871(2), *c* 4.100(1) Å.
A. Guinier camera, Co$K\alpha_1$ radiation, corundum used as internal standard, intensities estimated visually; lines attributed to admixed mineral "S" are omitted. x denotes lines used in unit-cell refinement. B. 114.6 mm Debye-Scherrer camera, Cu$K\alpha$ radiation, Ni filter.

Discussion

There are two minerals with stoichiometry close to $Pb_2Sb_2S_5$: veenite $Pb_2(Sb,As)_2S_5$ and sterryite $(Pb,AgCu)_2(Sb,As)_2S_5$ (Jambor *et al.* 1982), but both have X-ray powder patterns different from that of jaskólskiite. Bortnikov *et al.* (1981) and Moëlo *et al.* (1982) reported unnamed minerals with compositions corresponding to $Pb_2Sb_2S_5$, but these phases also have different X-ray powder patterns. This plurality of natural phases is confirmed by investigations in the PbS–Sb_2S_3 system, which have revealed several polymorphs of $Pb_2Sb_2S_5$ (Bortnikov *et al.* 1981). Jaskólskiite is related to the synthetic $Pb_2Sb_2S_5$ of Wang (1973), who reported the phase to be orthorhombic with *a* 19.80, *b* 11.40, *c* 4.04 Å, $Z = 4$, space group probably *Pnma* or $Pn2_1a$.

Recently Chang *et al.* (1980) synthesized several "*Y*-phases" with an X-ray powder pattern and a composition similar to those of jaskólskiite. Phase Y_2, $Pb_2Sb_{1.52}Bi_{0.48}S_5$, forms an extensive solid-solution with Y_1, Pb_2SbBiS_5. In terms of the (Bi,Sb) substitution, the jaskólskiite from Vena, with its Bi/(Bi+Sb) ratio of 0.35, may be regarded as a natural equivalent of phase Y_2 (ratio 0.24), whereas the Canadian occurrence, with a value of 0.41, is closer to Y_1 (ratio 0.50). Jaskólskiite from Portugal, $Pb_{2.18}Cu_{0.18}Sb_{1.47}Bi_{0.35}S_5$ (Y. Moëlo, written comm.), has a ratio of 0.19 and is close to Y_2, but plots outside the Y_1–Y_2 series. The reported lack of solid solution between Y_2 and $Pb_2Sb_2S_5$ in the experiments of Chang *et al.* (1980) is therefore somewhat surprising. Phases Y_1 and Y_2 may incorporate Fe, and in the system PbS–FeS–⅔Sb_2S_3–⅓Bi_2S_3 a single phase, Y_{Fe} $Pb_{1.875}Fe_{0.3125}Sb_{1.25}Bi_{0.625}S_5$, was found by Chang and coworkers.

Phases of the *Y* series are not stable below 415°C (Chang *et al.* 1980). Also, orthorhombic $Pb_2Sb_2S_5$ is only stable between 350 and 607°C (Wang 1973). These restricted stability limits strongly suggest that jaskólskiite is a metastable phase, or that the presence of Cu stabilizes its structure.

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