

JOLLIFFEITE AND UNNAMED CoAsSe: TWO NEW ARSENOSELENIDES FROM THE NORTH SHORE OF LAKE ATHABASCA, SASKATCHEWAN[†]

LOUIS J. CABRI AND J.H. GILLES LAFLAMME

Canada Centre for Mineral & Energy Technology, 555 Booth Street, Ottawa, Ontario K1A 0G1

ANDREW C. ROBERTS

Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

ALAN J. CRIDDLE

The Natural History Museum, Cromwell Road, London SW7 5BD, England

LARRY J. HULBERT

Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

ABSTRACT

Jolliffeite (ideally NiAsSe) and an unnamed mineral [(Co,Ni)AsSe], referred to as "unnamed CoAsSe", are new minerals found in samples from the Shirley Peninsula (Fish Hook Bay area), Lake Athabasca, Saskatchewan. The two new arsenoselenides occur as small discrete anhedral grains, closely associated with clausenthalite and unidentified Bi and Pb-Bi-Ag selenides in a pitchblende-rich fracture zone. Jolliffeite is white in plane-polarized reflected light, nearly isotropic, and the reflectance spectrum is flat (e.g., R_1 50.1% at 400 nm to 51.2% at 700 nm, in air). It is chemically and crystallographically the Se-analogue of gersdorffite-*Pa3*, with an a of 5.831(1) Å, and belongs to the pyrite subgroup of Bayliss (1986); $D(\text{calc}) = 7.10 \text{ g/cm}^3$ for $Z = 4$. The unnamed CoAsSe has similar optical properties to jolliffeite, except that it is slightly more anisotropic. The powder pattern could not be indexed; the three strongest lines [d in Å (h)] are: 2.592(100), 2.365(80), 1.746(60); the pattern differs from that of synthetic CoAsSe, quenched from 800°C and from 300°C. Neither pattern can be indexed on the orthorhombic cell of Nahigian *et al.* (1974). Jolliffeite honors the late A.W. "Fred" Jolliffe, for his contributions to the commercial exploration of this area of northern Saskatchewan.

Keywords: new mineral species, jolliffeite, NiAsSe, unnamed CoAsSe, gold (Ag, Pd, Cu, Hg), X-ray-diffraction data, electron-microprobe data, reflectance data, Lake Athabasca, Saskatchewan.

des échantillons prélevés sur la péninsule de Shirley (région de la baie de Fish Hook), au lac Athabasca, Saskatchewan. Ces deux arsénio-séleniures forment de petits grains xénomorphes, étroitement associés à clausenthalite et à des séleniures non identifiés de Bi et de Pb-Bi-Ag dans une zone fissurée dans un minerai de pitchblende. La jolliffeite est blanche en lumière réfléchie, et presque isotrope; son spectre de réflectance est plat (e.g., R_1 50.1% à 400 nm et 51.2% à 700 nm, dans l'air). Elle constitue l'analogue sélenifère de la gersdorffite-*Pa3*, avec a égal à 5.831(1) Å, et fait partie du sous-groupe de la pyrite tel que défini par Bayliss (1986); la densité calculée pour $Z = 4$ est de 7.10 g/cm³. La phase CoAsSe sans nom possède des propriétés optiques semblables à celles de la jolliffeite, mais elle est légèrement plus anisotrope. Son spectre de poudre n'a pas pu être indexé; les trois raies les plus intenses [d en Å (h)] sont 2.592(100), 2.365(80) et 1.746(60). Il diffère de celui de la phase CoAsSe synthétisé à 800° et à 300°C. Ni un ni l'autre de ces spectres concorde avec celui de Nahigian *et al.* (1974). La jolliffeite honore A.W. "Fred" Jolliffe pour ses contributions à l'exploration commerciale de cette région du nord de la Saskatchewan.

(Traduit par la Rédaction)

Mots-clés: nouvelles espèces minérales, jolliffeite, NiAsSe, CoAsSe sans nom, or (Ag, Pd, Cu, Hg), données de diffraction X, données de microsonde électronique, données de réflectance, lac Athabasca, Saskatchewan.

SOMMAIRE

Nous avons découvert deux nouvelles espèces minérales, la jolliffeite, de composition idéale NiAsSe, et une autre sans nom, de composition [(Co,Ni)AsSe], dans

INTRODUCTION

The mineralization in which the two new minerals were found occurs in what is considered to be a new geological environment for concentration of the platinum-group elements (Hulbert *et al.* 1989). These new minerals were discovered in drill core, hole FH-86-21, collared on Shirley Peninsula

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during the 1986 winter drilling program of Eldor Resources Ltd. The site occurs at latitude $59^{\circ}28'00''$ North and longitude $108^{\circ}24'00''$ West and lies within NTS 74 N/8. The Shirley Peninsula (Fish Hook Bay) area occurs along the north shore of Lake Athabasca, 18 km southeast of Uranium City, and is located in the Athabasca Mining District of northern Saskatchewan.

The Shirley Peninsula (Fish Hook Bay) area is underlain by rocks of the Murmac Bay Group, which are of Archean or Aphebian age. This group consists of a thick sequence of metasedimentary rocks, locally dominated by interbedded quartzites, dolomites, and minor mafic volcanic rocks. Ferruginous sedimentary units, as well as banded iron formation, outcrop on the Shirley Peninsula. Intrusive rocks consist of peridotite and gabbro bodies, the largest of which occurs in the Nicholson Bay area, 1.3 km to the west of the Shirley Peninsula. Structurally, the rocks lie along the east limb of the Goldfields Synclinorium, which plunges to the southwest. All lithologies in the area have been metamorphosed to the amphibolite facies. Further details of the geology have been described by Alcock (1915, 1917, 1936), Beck (1969), Jolliffe (1946), Robinson (1955), Tremblay (1968), and Tyrrell & Dowling (1896).

OCCURRENCE OF THE MINERALS

The new minerals are associated with pitchblende, which infills a fracture zone near a ferruginous dolomite - peridotite contact. A 1.6-m drill-hole intersection through the fracture zone was found to contain precious metal values of 12.17, 4.42 and 67.47 g/t for Pd, Pt, and Au, respectively. The new arsenoselenide minerals occur as very small discrete anhedral grains, the largest of which is $145 \times 240 \mu\text{m}$ in diameter. Jolliffeite (NiAsSe) and the unnamed CoAsSe are typically rimmed and closely associated with clausthalite and unidentified Bi and Pb-Bi-Ag selenides (Fig. 1). Other associated minerals found in the drill core are chalcopyrite, pyrite, hematite, arsenopyrite, bornite, calcite, dolomite, quartz, coffinite, pitchblende, native gold (Ag- or Pd-bearing), native silver, cobaltite or gersdorffite, tiemannite, löllingite, V-bearing mica (?), and mertieite II (?).

EXPERIMENTAL METHODS

The drill-core samples were mounted in araldite, polished on lead laps with diamond powders, and finished with $0.05 \mu\text{m}$ $\gamma\text{-Al}_2\text{O}_3$ on a cloth lap. Chemical analyses were obtained by wavelength-dispersion analyses (JEOL 733 electron microprobe) using the following standards and X-ray

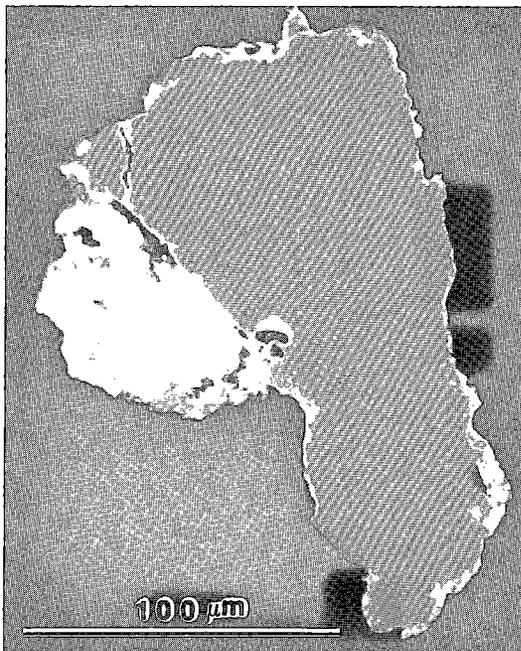


FIG. 1. SEM photomicrograph of jolliffeite (grain #18) with typical rim of clausthalite. The large bright area on the left consists of a fine-grained mixture of clausthalite and unidentified Pb-Bi-Ag selenides.

lines: pure metals ($\text{NiK}\alpha$, $\text{CoK}\alpha$, $\text{CuK}\alpha$, $\text{SbL}\alpha$), InAs ($\text{AsK}\alpha$), CuSe ($\text{SeK}\alpha$), and pyrite ($\text{SK}\alpha$).

Reflectance values were measured in air and in oil (Zeiss oil, $n_D = 1.515$, DIN 58.884, at 20°C) using a microscope-spectrophotometer (Zeiss MPM 03) with a WTiC standard (Zeiss, no. 314). The measurements were made using air and oil $16\times$ objectives ($\text{NA}_{\text{eff}} 0.2$) for jolliffeite, and air and oil $40\times$ objectives ($\text{NA}_{\text{eff}} 0.3$) for unnamed CoAsSe .

The X-ray powder-diffraction patterns were obtained with a 114.6-mm Gandolfi camera employing Fe-filtered $\text{CoK}\alpha$ radiation ($\lambda 1.9021 \text{ \AA}$) without internal standard. The powder patterns were corrected for film shrinkage. A single grain of jolliffeite and a composite grain of unnamed CoAsSe also were examined by precession single-crystal methods employing Zr-filtered Mo radiation.

PHYSICAL AND OPTICAL PROPERTIES

In plane-polarized reflected light, jolliffeite is white and, in the grains examined, lacks internal reflections. Neither bireflectance nor reflectance pleochroism were detectable by eye; between crossed polars, the mineral is very nearly isotropic.

TABLE 1. REFLECTANCE AND COLOR VALUES

λ nm	Jolliffeite (Grain 10)				Unnamed CoAsSe (Grain 1)			
	R_1	R_2	$^{im}R_1$	$^{im}R_2$	R_1	R_2	$^{im}R_1$	$^{im}R_2$
400	50.1	50.45	37.3	37.6	49.0	50.9	35.2	36.9
420	50.3	50.6	37.3	37.5	49.45	51.0	35.55	37.0
440	50.5	50.7	37.25	37.5	49.9	51.05	35.9	37.1
460	50.7	50.8	37.3	37.4	50.2	51.2	36.3	37.2
480	50.8	50.9	37.3	37.4	50.5	51.35	36.5	37.3
500	50.9	51.0	37.3	37.4	50.8	51.6	36.8	37.3
520	50.95	51.1	37.3	37.4	51.0	51.7	37.0	37.4
540	51.1	51.1	37.4	37.45	51.2	51.8	37.1	37.5
560	51.1	51.2	37.5	37.5	51.3	51.8	37.2	37.5
580	51.2	51.3	37.5	37.5	51.4	51.9	37.2	37.5
600	51.3	51.3	37.6	37.5	51.5	51.9	37.25	37.5
620	51.4	51.4	37.6	37.5	51.5	51.9	37.3	37.5
640	51.4	51.3	37.6	37.4	51.5	51.9	37.3	37.5
660	51.4	51.3	37.5	37.3	51.5	51.9	37.2	37.4
680	51.3	51.3	37.35	37.1	51.4	51.8	37.15	37.3
700	51.2	51.1	37.2	36.95	51.4	51.9	37.0	37.25
Color values (relative to Illuminant C)								
x	.311	.311	.311	.310	.312	.311	.313	.311
y	.318	.318	.317	.317	.319	.318	.320	.317
$Y\%$	51.1	51.2	37.5	37.5	51.2	51.8	37.1	37.5
λ_d	576	575	581	572	574	573	573	571
$P_c\%$	0.7	0.5	0.3	0.1	1.4	0.7	1.6	0.5

For the last reason, reflectance measurements were made at orientations corresponding to the photometric minima and maxima at 550 nm. The reflectance and computed color values (Table 1) and the flatness of the reflectance spectra (Fig. 2) conform with the visual impression of an essentially white mineral, lacking any hue. In particular, the excitation purity ($P_c\%$), which corresponds (in subjective terminology) to the saturation of a hue, is less than 1%, meaning that any perceived color will be dominated (99%) by the color characteristics of the light source. It is for this reason that no great reliance should be placed on the computed dominant wavelength (hue). Because the chromaticity coordinates for jolliffeite plot so close to those of the illuminant origin on the color diagram, a very small change in R ($\leq 0.5\%$) at either end of the spectrum will shift λ_d into the blue or purple sectors, *but* the mineral will still lack any perceptible color. This is also true for the unnamed CoAsSe (Table 1, Fig. 2) which, similarly, is white and lacks any perceptible bireflectance or reflectance pleochroism. However, between crossed polars, this mineral is slightly more anisotropic (grey rotation tints) than jolliffeite, and its anisotropy is subjectively enhanced by the presence of simple twinning. Quantitatively, the bireflectance (expressed here as the difference in $Y\%$ between R_1 and R_2) of the unnamed CoAsSe is 0.6%, whereas that of jolliffeite is 0.1% (*i.e.*, less

than the limits of confidence of reflectance measurement), and in keeping with its cubic nature.

The grains of jolliffeite and unnamed CoAsSe were found to be too small for the determination of the micro-indentation hardness. However, polishing hardness indicates that both minerals are harder than clausthalite, which has a VHN₁₀₀ range of 44–49 (Criddle & Stanley 1986). The small grain-size also did not permit the experimental determination of density.

CHEMICAL ANALYSES AND SYNTHESIS EXPERIMENTS

Jolliffeite and unnamed CoAsSe

Seven grains of jolliffeite were analyzed with an electron microprobe; the results are given in Table 2. The average empirical formula (based on a total of 3 atoms) is $(\text{Ni}_{0.81}\text{Co}_{0.19}\text{Cu}_{0.01}\text{Fe}_{<0.01})_{\Sigma 1.01}(\text{As}_{0.98}\text{Sb}_{<0.01}\text{S}_{0.98}(\text{Se}_{1.00}\text{S}_{0.01}))_{\Sigma 1.01}$. The majority of the grains analyzed show an inhomogeneous distribution of the major elements, very similar to that typical of Co- and Ni-sulfarsenides from Sudbury (Cabri & Laflamme 1976). The simplified formula is NiAsSe. Two grains of the unnamed CoAsSe also were analyzed with an electron microprobe (Table 3). They also show an inhomogeneous distribution of the major elements. An average empirical formula (based on a total of 3 atoms) is

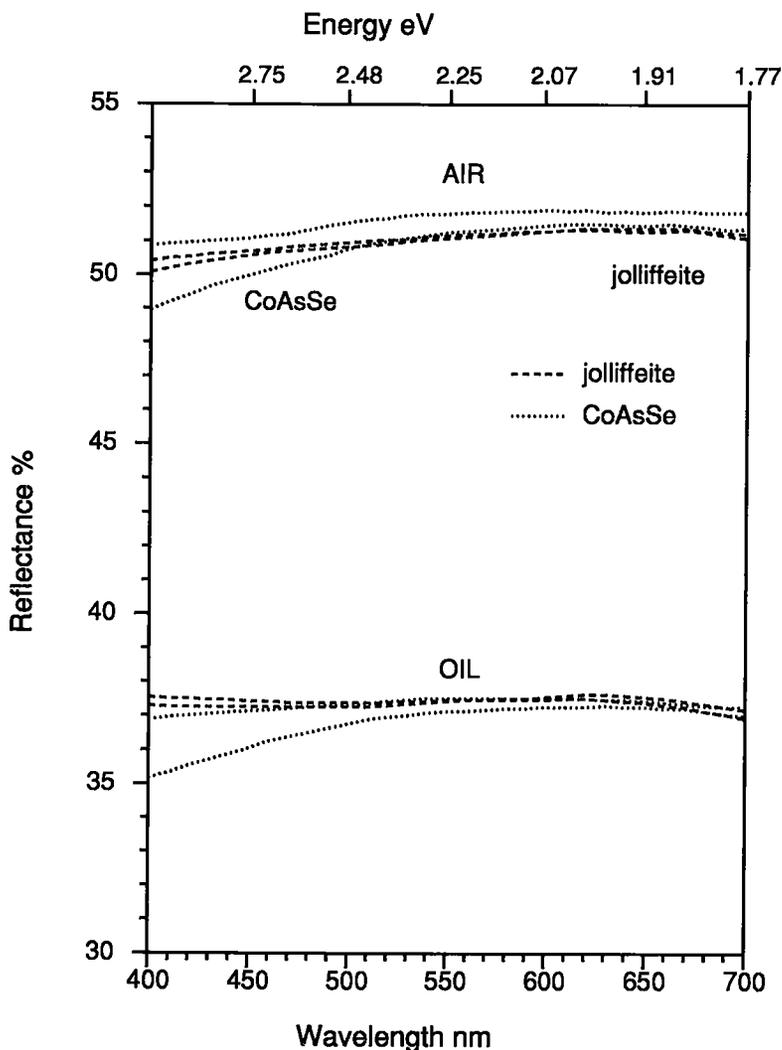


FIG. 2. Reflectance spectra between 400 and 700 nm of jolliffeite and unnamed CoAsSe, in air and in oil.

$(\text{Co}_{0.74}\text{Ni}_{0.27}\text{Fe}_{0.01})_{\Sigma 1.02}\text{As}_{0.99}(\text{Se}_{0.95}\text{S}_{0.04})_{\Sigma 0.99}$ or, more simply, CoAsSe. Bulk compositions of synthetic CoAsSe, annealed for 2 days at 800°C, after prior heating at 500°C, consist of a major phase ($\text{Co}_{1.02}\text{As}_{1.12}\text{Se}_{0.86}$) and a very minor phase (5%) with a composition close to SeAs.

Native gold

Results of electron-microprobe analyses of 10 grains of the associated native gold are presented in Table 4. The compositions are considered

unusual because the gold contains a wide range of minor elements (Ag, Pd, Cu, Hg) in variable quantities.

X-RAY STUDIES

Grain #7 of jolliffeite, dug out of a polished section, was mounted on a fiber and X-rayed in a Gandolfi camera. Subsequently the fragment was remounted for examination by precession single-crystal methods and oriented such that b^* is parallel to the dial axis. The levels collected were $hk0$, $hk1$,

TABLE 2. ELECTRON-MICROPROBE DATA FOR JOLLIFFEITE

Grain No.	Size (μm)	Weight per cent								Totals
		Ni	Co	Fe	Cu	As	Sb	Se	S	
1	50x50	18.4	8.9	0.14	0.08	33.9	n.d.	37.6	0.07	99.09
4	145x240	18.1	8.8	0.17	1.1	32.9	n.d.	38.5	0.10	99.67
5	80x80	15.0-22.4†	4.7-11.7		n.d.-2.0	31.5-34.4		37.6-39.8		98.74
7	100x120	22.2	4.9	0.14	n.d.	33.2	n.d.	38.3	n.d.	98.74
9	70x135	19.9-24.4	2.9-7.0			33.1-33.4		38.0-38.7		101.13
10	100x145	23.2	5.1	0.06	0.09	36.0	n.d.	36.6	0.08	101.13
18	75x175	19.8-25.8	2.7-8.6			35.1-36.8		36.0-37.8		100.91
		22.6	6.0	n.d.*	n.d.	36.9	n.d.	34.9	0.51	100.91
		18.9-26.5	2.1-9.6			33.9-46.0		21.5-39.2	n.d.-2.3	100.69
		25.3	2.8	n.d.	n.d.	34.3	0.09	38.2	n.d.	100.69
		18.2-27.0	0.82-10.2			31.9-35.5		37.1-40.7		99.38
		27.0	0.66	n.d.	0.07	34.2	0.15	37.3	n.d.	99.38

Atomic proportions											
	Ni	Co	Fe	Cu	Sum	As	Sb	Sum	Se	S	Sum
1	0.67	0.32	0.01	<0.01	1.00	0.97	-	0.97	1.02	<0.01	1.02
4	0.66	0.32	0.01	0.04	1.03	0.94	-	0.94	1.04	<0.01	1.04
5	0.82	0.18	0.01	-	1.01	0.95	-	0.95	1.05	-	1.05
7	0.83	0.18	<0.01	<0.01	1.01	1.01	-	1.01	0.97	0.01	0.98
9	0.81	0.21	-	-	1.02	1.03	-	1.03	0.92	0.03	0.95
10	0.91	0.10	-	-	1.01	0.97	<0.01	0.97	1.02	-	1.02
18	0.99	0.02	-	<0.01	1.01	0.98	<0.01	0.99	1.01	-	1.01

†compositional range; *n.d. = not detected, minimum detection limits for Fe, Cu, Sb and S are 0.03, 0.03, 0.05 and 0.05 wt.%, respectively.

TABLE 3. ELECTRON-MICROPROBE DATA FOR UNNAMED CoAsSe

Grain No.	Size (μm)	Weight per cent*				Se	S	Totals
		Co	Ni	Fe	As			
1	40x145	23.6	5.1	0.27	37.7	32.8	1.1	100.57
5	80x150	22.6-24.8	4.0-5.9	0.18	36.5-39.1	31.7-33.9	0.09	100.67
		17.8	10.3		33.2	39.1		
		15.6-20.0	8.2-12.3		32.3-34.1	38.0-40.2		

Atomic proportions								
	Co	Ni	Fe	Sum	As	Se	S	Sum
1	0.83	0.18	0.01	1.02	1.05	0.86	0.07	0.93
5	0.64	0.37	0.01	1.02	0.93	1.04	0.01	1.05

†compositional range; *Cu and Sb were not detected (minimum detection limits of 0.03 and 0.05 wt%, respectively).

TABLE 4. ELECTRON-MICROPROBE DATA FOR NATIVE GOLD

Anal. no.	Weight per cent*					Totals	Atomic proportions				
	Au	Ag	Pd	Cu	Hg		Au	Ag	Pd	Cu	Hg
1	86.1	8.9	3.1	1.3	0.12	99.52	0.77	0.14	0.05	0.04	<0.01
2	85.1-87.2	7.3-9.8	2.8-3.4	1.0-1.9	n.d.-0.21	99.49	0.79	0.19	<0.01	0.01	<0.01
3	86.8	11.7	0.09	0.46	0.44	99.48	0.79	0.19	-	0.01	0.01
4	87.0	11.3	n.d.	0.50	0.68	99.3	0.98	-	0.02	-	-
5	98.0	n.d.	1.3	n.d.	n.d.	99.3	0.98	-	0.02	-	-
6	97.0-98.8		0.73-1.6			98.90	0.79	0.19	-	0.01	0.01
7	85.9	11.5	n.d.	0.40	1.1	99.09	0.79	0.19	-	0.01	0.01
8	86.3	11.2	n.d.	0.39	1.2	99.14	0.71	0.24	<0.01	0.01	0.04
9	79.0	14.8	0.25	0.19	4.9	100.89	0.83	0.06	0.05	0.06	<0.01
10	91.9	3.8	2.9	2.0	0.29	101.18	0.73	0.21	-	0.01	0.05
11	90.9-93.2	2.4-5.1	2.4-3.4	1.8-2.2		99.51	0.71	0.24	<0.01	0.01	0.04
12	82.5	12.8	n.d.	0.28	5.6						
13	79.6	14.8	0.33	0.28	4.5						

*Sb was not detected (minimum detection limit of 0.05 wt%).

*Ok*l, *lk*l and 101^*Ab^* . Jolliffeite has cubic symmetry, with a measured unit-cell parameter a of 5.84 Å. Zero- and upper-level precession films reveal a $2mm$ symmetry and, coupled with the

systematic absence condition $hk0$ with $h \neq 2n$ (Ok l with $k \neq 2n$, $h0l$ with $l \neq 2n$), dictate that the space group is uniquely $Pa\bar{3}(205)$. A fully indexed powder-pattern is given in Table 5. Diffraction lines

TABLE 5. X-RAY POWDER DATA FOR JOLLIFFEITE

test	d _{meas.}	d _{calc.}	hkl
50	2.916	2.916	200
100	2.602	2.608	210
80	2.378	2.380	211
30	2.062	2.062	220
80	1.757	1.758	311
5	1.684	1.683	222
40	1.617	1.617	230
50	1.559	1.558	321
10	1.459	1.458	400

intensities estimated visually

solely ascribable to clausthalite have been deleted from the table. The unit-cell parameter a is 5.831(1) Å, refined on 9 unambiguously indexed lines between 2.916 and 1.459 Å; V is 198.3(1) Å³. All reflections were checked visually on precession single-crystal films.

Jolliffeite is chemically and crystallographically the Se-analogue of gersdorffite-*Pa3* (Bayliss 1986); a comparison of these two minerals is presented in Table 6. Assuming $Z = 4$ and the empirical formula, the calculated density is 7.10 g/cm³. The calculated density for end-member NiAsSe is 7.12 g/cm³. These values are substantially higher than those derived for gersdorffite-*Pa3* and are consistent with the complete substitution of Se (atomic weight 78.96) for S (atomic weight 32.064). They are also consistent with the measured density of 7.26(2) g/cm³ for synthetic CoAsSe-*Pnn2* (Nahigian *et al.* 1974), where Co (atomic weight 58.93) is slightly heavier than Ni (atomic weight 58.70).

Grain #5 of unnamed CoAsSe, carefully dug out

TABLE 7. X-RAY POWDER DATA FOR UNNAMED CoAsSe

test	d _{meas}
30	2.897
100	2.592
80	2.365
10	2.046
10	1.761
60	1.746
3	1.673
5	1.621
30	1.606
10	1.560
40	1.547
5	1.449
3	1.371

- intensities estimated visually
 - diffraction lines solely ascribable to clausthalite have been deleted

of a polished section as a single phase, was mounted and examined by precession single-crystal methods. Unfortunately, though a single phase chemically, the grain is cryptocrystalline and produced only diffraction rings on the precession films. Unindexed powder-diffraction data are presented in Table 7. The powder data for the unnamed CoAsSe could not be directly indexed by analogy with the pattern reported for cobaltite (PDF 18-431). X-ray powder-diffraction data for synthetic CoAsSe (quenched from 800°C and from 300°C) and given in Table 8 do not even remotely resemble those of the natural phase nor can they be indexed according

TABLE 6. COMPARISON OF GERSDORFFITE-*Pa3* AND JOLLIFFEITE

	Gersdorffite- <i>Pa3</i>	Jolliffeite
a Å	5.692	5.831(1)
V Å ³	184.41	198.3(1)
idealized formula	NiAsS	NiAsSe
D _{meas} (g/cm ³)	5.90	7.12 (idealized formula)
D _{calc} (g/cm ³)	5.97	7.10 (empirical formula)
Symmetry	cubic	cubic
Space Group	Pa3(205)	Pa3(205)
Z	4	4
Reference	PDF 12-705	this study

TABLE 8. X-RAY POWDER DATA FOR SYNTHETIC CoAsSe

Test	dÅmeas	Test	dÅmeas
20	3.907	30	2.142
30	3.174	90	1.984
10	3.059	10	1.955
70	2.993	20	1.891
3	2.890	20	1.864
100	2.694	20	1.846
80	2.620	40	1.788
30	2.544	30	1.729
30	2.350	30	1.686
5	2.189	25b	1.635

intensities estimated visually; b = broad line

to the orthorhombic cell reported by Nahigian *et al.* (1974).

DISCUSSION AND CONCLUSIONS

Little is known about phase relations in the synthetic system Ni-Co-As-Se, though it is apparent from the electron-microprobe data on these two new minerals that there is considerable substitution between Ni and Co. In addition, the analytical results indicate considerable substitution between As and Se, which may be related to true As-Se disorder at the atomic scale (as for As-S in gersdorffite-*Pa3*; Bayliss 1982). Jolliffeite is considered to be the Se analogue of gersdorffite-*Pa3*, which is the highest temperature polymorph, in the opinion of Bayliss (1982). More work is required on the phase relations and the crystallographic changes of NiAsSe with temperature. The name *jolliffeite* is proposed for the end-member NiAsSe with the *Pa3* structure, even though the end-member corresponding to this phase has not yet been found in nature. The type material is, therefore, a cobaltoan jolliffeite.

Synthetic CoAsSe was first reported by Hulliger (1962) as having the cubic structure of pyrite (*Pa3*); the details of synthesis were not discussed. Nahigian *et al.* (1974) synthesized CoAsSe *via* direct combination of the elements at ambient pressure and reported it to be orthorhombic with space group *Pnn2*. Henry *et al.* (1975) stated that this structure transforms partially to a pyrite-type cubic structure when treated at elevated temperatures and pressures, conceivably the structure reported by Hulliger (1962). Synthesis of the CoAsSe mineral was attempted using high-purity elements loaded in silica glass tubes, and subsequently evacuated and annealed for several months at 500°C in horizontal furnaces. Excess Se could be observed in the tube,

so the charge was placed at 600°C and the temperature raised slowly to 800°C over a two-day period. Some of the synthetic charges also were ground and annealed for periods of 9 days at 800°C and 17 days at 300°C. Our synthetic CoAsSe, however, does not correspond to either of these two structures, and the unnamed CoAsSe appears also to be different. It is also possible that (Co,Ni)AsSe is a phase distinct from the CoAsSe end-member.

The crystallographic relationship (if any) between unnamed CoAsSe and cobaltite, the nearest compositional analogue, remains unclear. There is, at present, no easy way to resolve these problems, or many of the other complexities among minerals in the natural system Ni-Co-As-Se. However, a possible way of doing this is suggested by a comparison of the reflectance spectra of jolliffeite and those of the compositional variants of gersdorffite (tabulated by Stanley in Criddle & Stanley 1986). Jolliffeite is sensibly isotropic, and the dispersion of its reflectance spectra corresponds only to those of gersdorffite-*Pa3* (otherwise known as gersdorffite II); the dispersion of the other structural variants is markedly different. There are also clear similarities in the dispersion of the reflectance of jolliffeite and of the unnamed CoAsSe. However, the latter is birefractant (anisotropic and twinned), hence, its space group cannot be *Pa3*, and its symmetry must be lower than cubic. In a qualitative sense, these subtleties, revealed by microscope-spectrophotometry, are invaluable in assessing the reliability of crystal-structure interpretations (*cf.* Bayliss 1986); yet, much more quantitative information is contained within two-media reflectance data than is generally used. For example, it is possible in principle to provide information for the synthetic compounds by using absorption spectra derived from these data (UV-visible-IR), together with knowledge of site occupancies from structure analysis. This, in turn, should provide a key to the interpretation of the minerals.

NAME AND PRESERVATION OF TYPE MATERIAL

The name honors Professor Emeritus A.W. "Fred" Jolliffe (1907-1988), Department of Geological Sciences, Queen's University, whose early geological mapping of the Beaverlodge area in northern Saskatchewan for the Geological Survey of Canada encouraged commercial exploration in the area. Prior to that, while he was employed by the Geological Survey of Canada, his mapping led directly to the discovery of a major gold mining camp. The city of Yellowknife, which has become the hub of the Western Arctic, was

founded at the site where Jolliffe's G.S.C. field party made the first major gold discovery in 1935. The mineral and the mineral name have been approved by the IMA Commission on New Minerals and Mineral Names in May 1989. Type materials of both minerals, consisting of a polished section and several fiber mounts, are deposited in the Systematic Reference Series of the National Mineral Collection, Geological Survey of Canada, Ottawa, under catalogue number NMC 65747. We hope that the second mineral, unnamed CoAsSe, will also be named, in due course, once unique X-ray-diffraction data are obtained.

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