Kurilite – Ag$_8$Te$_3$Se – a new mineral from the Prasolovskoe deposit, Kuril islands, Russian Federation

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ABSTRACT

Kurilite, with the simplified formula, Ag$_8$Te$_3$Se, is a new mineral from the Prasolovskoe epithermal Au-Ag deposit, Kunashir Island, Kuril arc, Russian Federation. It occurs as aggregates up to 2 mm in size, composed of brittle xenomorphic grains, up to several μm in size, in quartz, associated with tetrahedrite, hessite, sylvanite and petzite. Kurilite is opaque, grey, with a metallic lustre and a black streak. Under plane-polarized light, kurilite is white with no observed bireflectance, cleavage, or parting observed. Under crossed polars it appears isotropic without internal reflections. Reflectance values in air and in oil, are tabulated. It has a mean VHN (25 g load) of 99.9 kg/mm^2 which equates roughly to a Mohs hardness of 3. Electron microprobe analyses yield a mean composition of Ag 63.71, Au 0.29, Te 29.48, Se 5.04, S 0.07, total 98.71 wt.%. The empirical formula (based on 12 atoms) is (Ag$_{7.97}$Au$_{0.02}$)$_{\Sigma7.99}$Te$_{3.00}$(Se$_{0.86}$Te$_{0.12}$S$_{0.03}$)$_{\Sigma1.01}$. The calculated density is 7.799 g/cm^3 (based on the empirical formula and unit-cell parameters refined from single-crystal data). Kurilite is rhombohedral, $R3$ or $R\bar{3}$, a 15.80(1), c 19.57(6) Å, V 4231(12)Å^3, $c{:}a$ 1.2386, Z = 15. Its crystal structure remains unsolved. The seven strongest lines of the X-ray powder-diffraction pattern [d in Å(I)(hkl)] are: 3.727(20)(131), 2.996(50)(232), 2.510(30)(226,422), 2.201(100)(128,416,342), 2.152(20)(603), 2.079(30)(253), 2.046(20)(336,434). The mineral is named after the locality.

Introduction

Kurilite (ideally Ag$_8$Te$_3$Se) was discovered in 1988 by one of the authors (V.A.K.) at the Prasolovskoe epithermal Au-Ag deposit, Kunashir Island, Kuril arc, Russian Federation. It first entered the literature in 1989 (Kovalenker *et al.*, 1989) with the proposed formula (Ag,Au)$_2$(Te,Se,S), and a cubic cell and was

abstracted by Jambor and Grew (1992). It is in the ICDD PDF database as 00-45-1399 and is also present in several other databases. However, it was not submitted to the New Minerals Commission of the IMA at that time, although it was formally discredited (Burke, 2006) as being possibly synonymous with hessite or petzite. Additional mineralogical studies were undertaken, therefore, to clarify the chemical composition and crystal structure. In light of these new data, the mineral and its name were approved by the IMA Commission on New Minerals, Nomenclature and Classification, IMA No 2009-080. Kurilite is named for the locality, the Kuril Islands. Type material (part of the polished

section from which all the data were obtained) has been deposited at the Fersman Mineralogical Museum, Russian Academy of Sciences, Moscow, Russia, as 3717/1.

Occurrence and mineral assemblage

Kurilite occurs in the Prasolovskoe Au-Ag deposit (lat. 44°23′N, long.146°01′E), Kunashir Island, Kuril Islands, Russian Federation. The geology and mineralogy of the Prasolovskoe deposit have been described in detail (Kovalenker *et al*., 1989; Dunchenko, 1990; So *et al.*, 1995; Kovalenker and Plotinskaya, 2005; etc.). The deposit is located within a volcanic caldera of the same name which occupies the NW end of Kunashir Island. This island represents the southern end of the Kuril volcanic belt. This belt is located in the inner part of the Kuril island arc and is mostly composed of calc-alkaline volcanic rocks of Miocene to Quaternary age (So *et al.*, 1995). The Prasolovskoe caldera is filled with Miocene basaltic and rhyolitic tuffs which have been intruded by a middle-Miocene quartz diorite body and by late-Pliocene basalt to rhyolite dykes (So *et al.*, 1995). The mineralization occurs principally in veins or rarely in breccias surrounded by quartz-sericite or argillic alteration halos (So *et al.*, 1995). K-Ar dating of vein adularia points to a late-Pliocene age (1.94±0.10 Ma) (So *et al.*, 1995). Quartz-Au-Ag-bearing veins of major economic importance dip steeply NE and strike 500–600 m in length, and are 1–2 m thick with a vertical extension up to 270 m. Besides Au, Ag, Se and Te, the ores are also enriched in Cu, Pb, Zn, Sb, As, Mo, Bi and Sn (Dunchenko, 1990).

So *et al.* (1995) described the following stages of mineralization: Pyritic, Polymetallic and Gold-Silver. The Gold-Silver stage consists of cassi-terite, polysulphide, telluride and adularia ore types. So *et al.* (1995) classified the Prasolovskoe deposit as low-sulphidation type due to the presence of adularia in the veins. However, the occurrence of alunite, enargite and goldfieldite suggests a more intermediate sulphidation type.

Kurilite was found within the Au-Ag-Te-Se assemblage and is clearly of endogeneous hydrothermal origin. It usually forms aggregates, up to 2 mm in size, of micron-sized brittle xenomorphic grains within quartz, sometimes as overgrowths on tennantite-tetrahedrite-goldfiel-dite group minerals and rarely as intergrowths with native gold, hessite, sylvanite and petzite.

Optical and physical properties

Megascopically, kurilite is light grey to steel grey with a metallic lustre and a black streak. Under plane-polarized light it is white and resembles galena. Under crossed nicols, kurilite appears isotropic without internal reflections and does not show any cleavage or parting. The average Vickers hardness number (VHN) for a 25 g load hardness is 99.9 kg/mm^2 (range 77.2–114, 10 indentations), and the indentations are perfect to slightly fractured. This mean VHN corresponds to a Mohs hardness of ~3. The density could not be measured because of the small grain size. On the basis of the empirical formula and unit-cell parameters derived from single-crystal data, the calculated density is 7.799 g/cm^3.

The reflectance values were measured relative to a WTiC standard with a Zeiss MPM8

TABLE 1. Reflectance data for kurilite.

Wavelength (nm)	Air	Oil	Wavelength (nm)	Air	Oil
400	42.3	26.6	560	42.0	25.5
420	42.6	26.9	580	41.6	25.0
440	43.0	27.0	589 (COM)	41.4	24.8
460	43.0	27.0	600	41.3	24.6
470 (COM)	43.0	27.0	620	40.8	24.2
480	43.0	26.9	640	40.6	23.9
500	42.8	26.6	650 (COM)	40.4	23.6
520	42.6	26.4	660	40.2	23.4
540	42.4	26.0	680	39.8	22.9
546 (COM)	42.3	25.9	700	39.2	22.4

microspectrophotometer (NHM, London), in air and oil (refractive index 1.515), and the results are presented in Table 1 and Fig. 1. The reflectance values are close to those of petzite (37.8−45.0%) and hessite (39−43.6%) in air. However, kurilite has convex reflectance curves that are similar to cervelleite (Ag$_4$TeS) or aguilarite (Ag$_4$SeS) (Fig. 1).

Chemical composition

Electron-microprobe analyses were carried out with a Cameca SX-50 microprobe, equipped with four wavelength spectrometers (NHM, London), under the following conditions: beam diameter 1−2 μm, accelerating voltage 20 kV, sample current 20 nA, exposure time 20 s (analysts C.T. Williams and J. Spratt). Standards employed were: synthetic compounds ZnS for S, HgTe for Te, PbSe for Se, BiTe for Bi, PbS for Pb and pure metals for Cu, Fe, Ag, Au and Sb. Analytical lines: Kα for S, Cu and Fe; Lα for Te, Ag, Sb, Cu and Se; Mα for Bi, Pb and Au. The peak overlap correction was 0.72% for Te/Sb.

The results of seven analyses are presented in Table 2. Kurilite is relatively homogeneous with Ag contents of 64.46−63.01 wt.%, Te 29.78−29.13 wt.%, Se 5.33−4.50 wt.%, and contains traces of Au (0.46−0.13 wt.%) and S (0.09−0.05 wt.%). Bi, Cu, Fe, Sb and Pb are below

detection limits. It should be noted that previous studies (Kovalenker *et al.*, 1989) showed significant Au (up to 3.58 wt.%) and S (up to 3.93 wt.%) as well as a much wider range of Te and Se contents (24.64−31.80 and 4.02−9.14 wt.%, respectively), all of which suggested a formula of (Ag,Au)$_2$(Te,Se,S). However, these data could also have been the result of contamination of neighbouring petzite, sylvanite or some other telluride. Grains analyzed in the present study showed no intergrowths with any other ore minerals and demonstrate very limited Te *vs*. Se substitution. The empirical formula, calculated for 12 atoms, is (Ag$_{7.97}$Au$_{0.02}$)$_{\Sigma7.99}$Te$_{3.00}$ (Se$_{0.86}$Te$_{0.12}$S$_{0.03}$)$_{\Sigma1.01}$, and the idealized formula, Ag$_8$Te$_3$Se, requires: Ag 65.14, Te 28.90, Se 5.96, total 100.00 wt.%.

X-ray crystallography

Several previous X-ray powder-diffraction studies (Kovalenker *et al.*, 1989 and several unpublished data) resulted in diffraction patterns that were successfully indexed on a cubic cell with a = 11.27 Å. Space groups *Pm*3*n* or *P*43*n* were permissible based on systematic absences.

Single-crystal X-ray studies were carried out using a Bruker 4-circle diffractometer and data were well observed out to 45º2θ, but the intensity fell off quickly beyond this point. A primitive
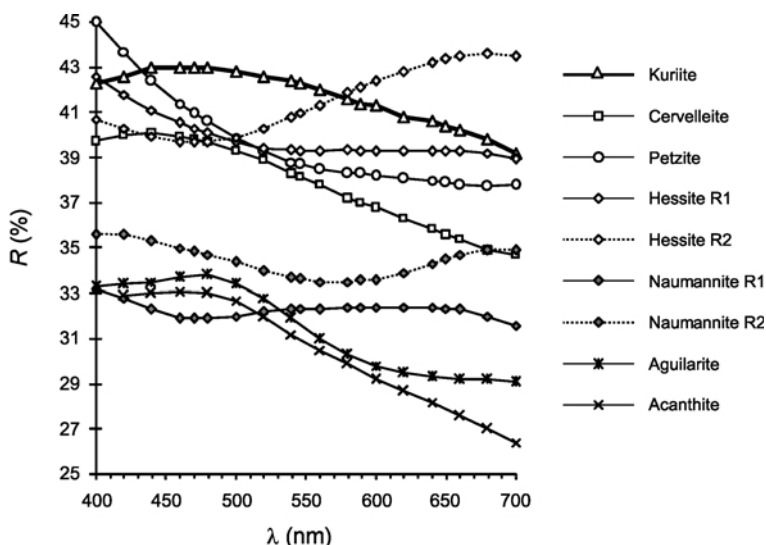

FIG. 1. Reflectance curves for kurilite and related minerals. The data for the related minerals are from QDF3 (Criddle and Stanley, 1993)

TABLE 2. Electron-microprobe data for kurilite.

Sample no.	Ag	Au	Te	Se	S	Total
Wt.%						
1	63.70	0.33	29.30	5.33	0.09	98.77
2	63.01	0.18	29.53	5.25	0.09	98.19
3	64.46	0.46	29.78	4.50	0.05	99.36
4	63.28	0.27	29.65	5.06	0.09	98.42
5	63.27	0.24	29.62	4.87	0.06	98.31
6	63.87	0.46	29.39	5.27	0.05	99.14
7	64.37	0.13	29.13	5.02	0.05	98.79
Formula units						
1	7.94	0.02	3.09	0.91	0.04	12
2	7.91	0.01	3.14	0.90	0.04	12
3	8.04	0.03	3.14	0.77	0.02	12
4	7.93	0.02	3.15	0.87	0.04	12
5	7.96	0.02	3.16	0.84	0.03	12
6	7.95	0.03	3.10	0.90	0.02	12
7	8.03	0.01	3.08	0.86	0.02	12

pseudocubic unit cell ($a \approx 11$ Å) was observed, but angles for the cell deviated significantly (>0.5º) from orthogonal. The cell transformed readily up to a metrically rhombohedral cell and further investigation of reflection intensities shows the data are consistent with trigonal symmetry ($\bar{3}$ Laue class). Attempts at determining the crystal structure were not successful; a final R = 16% was obtained assuming $R\bar{3}$ space group, but while a portion of the structure appeared reasonably well ordered, the other portion exhibited significant disorder, with the site-occupancy factors for many of the sites being <25% of their predicted values. Kurilite is trigonal and has a space group $R3$ or $R\bar{3}$.

X-ray powder diffraction data were obtained by means of a 114.6 mm Debye-Scherrer powder camera using Cu radiation, Ni filter (λ Cu-$K\alpha$ = 1.54178 Å) without internal standard (Table 3). Intensities were estimated visually. No corrections for shrinkage were applied. The diffraction pattern was indexed on a 15.80(1), c 19.57(6) Å, V 4231(12) Å^3, $c:a$ 1.2386, Z = 15, based on powder data derived from collapsing 3D single-crystal data into a powder diffraction trace and cell refinement of 13 lines between 3.727 and 1.861 Å. Indexing is somewhat tentative on a number of reflections due to the plethora of hkl's possible for the large rhombohedral cell.

Relation to other species

Kurilite belongs to Hey class 3.2 (sulphides *etc.* of Ag). In the Nickel-Strunz Classification, kurilite fits in the 2BA group (metal:chalcogene>1:1) together with acanthite (Ag_2S), aguilarite (Ag_4SeS), naumannite (Ag_2Se), cervelleite (Ag_4TeS), and hessite (Ag_2Te). In the Dana classification, it belongs to the 2.4.2 group (sulphides − including selenides and tellurides $A_mB_nX_p$, with $(m+n):p$ = 2:1). Kurilite is chemically similar to hessite, cervelleite, and aguilarite, and optically, with petzite and cervelleite. Despite the fact that the kurilite structure remains unsolved it is clearly not isostructural with any related minerals and appears to be the only trigonal mineral in the group. It is important to note that other natural ternary phases in silver−chalcogen systems (e.g. cervelleite and aguilarite), in contrast to kurilite, have equal quantities of chalcogens in formulae.

Little has been published on experimental investigations of the Ag-Se-Te system (Bontschewa-Mladenowa *et al.*, 1972; Aramov *et al.*, 1977). In spite of this, Aramov *et al.* (1977) and Mikolaichuk *et al.* (1977), in the pseudo-binary system AgSe−AgTe, reported a solid-solution at temperatures above 800ºC. At 150ºC, the system contains two solid solutions − 0 to 40 and 85 to 100 mole % AgTe. Below 150ºC, solid

TABLE 3. X-ray powder diffraction data for kurilite.

$I_{est.}$	$d_{(meas.)}$ (Å)	$D_{(calc.)}$ (Å)	hkl	$I_{est.}$	$d_{(meas.)}$ (Å)	$d_{(calc.)}$ (Å)	hkl
10	6.546	6.523	003	3	2.239	2.243	505
*20	3.727	3.726	131			2.235	431
*10	3.541	3.538	312			2.211	128
10	3.392	3.397	205	100	2.201	2.202	416
		3.379	223			2.192	342
5	3.220	3.229	042	*20	2.152	2.153	603
*50	2.996	2.989	232	*30	2.079	2.077	253
*5	2.803	2.804	404	20	2.046	2.049	336
*10	2.714	2.715	143			2.044	434
*10	2.644	2.642	324	*5	1.977	1.975	440
*5	2.567	2.564	241	3	1.887	1.889	621
30	2.510	2.515	226			1.882	02$\overline{10}$
		2.500	422	*5	1.861	1.863	2$\overline{6}$2
10	2.447	2.449	235	3	1.843	1.846	517
		2.438	511			1.819	526
* 5	2.386	2.388	054	20	1.817	1.815	704
* 5	2.277	2.280	600			1.815	354

114.6 mm Debye-Scherrer powder camera using Cu radiation with Ni filter (λ Cu-$K\alpha_1$ = 1.54178 Å). The intensities were estimated visually. Not corrected for shrinkage and no internal standard.
* lines used for unit-cell refinement. Indexed on a 15.80(1), c 19.57(6) Å.
The strongest lines are marked in bold.

solution exists in the interval 0−50 mole % AgTe, *i.e.* Ag$_2$Se to Ag$_4$TeSe and 0−8 mole % AgSe (Aramov *et al.*, 1977). High-temperature solid solution was reported to be cubic (Mikolaichuk *et al.*, 1977) and, within the interval 70−100 mole % Ag$_2$Te, hardness was estimated to be as much as 110−115 kg/mm^2 (Bontschewa-Mladenowa *et al.*, 1972), which is close to that for kurilite.

References

Aramov, N., Odin, I. and Boncheva-Mladenova, Z. (1977) Study of the silver selenide−silver telluride system. *Thermochimica Acta*, **20(1)**, 107-113.

Bontschewa-Mladenowa, Z., Karbanov, S.T., Martschewa, N. (1972) Metallographische Untersuchungen über das System Ag$_2$Te$_x$Se$_{1-x}$. *Monatshefte fur Chemie*, **103**, 1158-1162.

Burke, E.A.J. (2006) A mass discreditation of GQN minerals. *Canadian Mineralogist*, **44**, 1557−1560.

Criddle, A.J. and Stanley, C.J. (editors) (1993) *The Quantitative Data File for Ore Minerals* (3rd edition). Chapman and Hall, London, UK.

Dunchenko, V.Y. (1990) Gold-silver mineralization of the Great Kuril Ridge. *Yuzhno-Sakhalinsk Far Eastern Division of USSR Academy of Science, Institute of Marine Geology and Geophysics, Annual Report*, 63 pp. [in Russian].

Jambor, J.L. and Grew, E.S. (1992) New Mineral Names. *American Mineralogist*, **77**, 207−213.

Kovalenker, V.A., Nekrasov, I.Ya., Sandomirskaya, S.M., Nekrasova, A.N., Malov, V.S., Danchenko, V.Ya. and Dmitryeva, M.T. (1989) Sulfide-selenide-telluride mineralization of epithermal manifestations of Kurile-Kamchatka volcanic belt. *Mineralogicheskii Zhurnal*, **11(6)**, 3−18 [in

Russian].

Kovalenker, V.A. and Plotinskaya, O.Yu. (2005) Te and Se mineralogy of Ozernovskoe and Prasolovskoe epithermal gold deposits (Kuril − Kamchatka volcanic belt). *Geochmistry, Mineralogy and Petrology*, **43**, 118−124.

Mikolaichuk, A.G., Romanishin, B.M., Timchishin, M.V. (1977) X-Ray Investigation of the Ag$_2$Te$_X$Se$_{1-X}$ system, *Izvestia Akademii Nauk SSSR, Neorganicheskie Materialy*, **13(11)**, 2112−2113 [in Russian].

So, C.-S., Dunchenko, V.Ya., Yun, S.-T., Park, M-E., Choi, S-G, and Shelton, K.L. (1995) Te- and Se-bearing epithermal Au-Ag mineralization, Prasolovskoe, Kunashir Island, Kuril Island Arc. *Economic Geology*, **90**, 105−117.