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Gillulyite, $Tl_2(As,Sb)_8S_{13}$, a new thallium arsenic sulfosalt from the Mercur gold deposit, Utah

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ABSTRACT

Gillulyite, ideally $Tl_2(As,Sb)_8S_{13}$, is one of several Tl minerals that are found at the Mercur gold deposit, Tooele County, Utah. The mineral is found as cleavable masses up to 2 cm in diameter and, rarely, as crystals 1 mm in length. It occurs within vuggy masses of barite, in barite veins, in calcite veins, and in the silty carbonaceous limestone host rock. Associated minerals are barite, calcite, orpiment, realgar, lorandite, raguinite, and pyrite.

Gillulyite has a deep red color and a brick red streak. It is translucent, but it tarnishes rapidly to a near-metallic luster. The calculated density is 4.14(1) g/cm³ and the measured density is 4.02(2) g/cm³. The difference may be due to orpiment inclusions within the sample. Mohs hardness is 2.0–2.5 and mean VHN_{15} is 108. In reflected plane polarized light in air, gillulyite is light gray in color, very similar to orpiment, but marked by deep red internal reflections. The mineral has distinct anisotropy. With crossed polars the mineral is bright red because of the abundant internal reflections. Reflectivity values, measured in air, range from a minimum of 27.79% to a maximum of 31.85%.

X-ray diffraction studies show that gillulyite is monoclinic with refined unit-cell parameters $a = 9.584(3)$ Å, $b = 5.679(2)$ Å, $c = 21.501(6)$ Å, $\beta = 100.07(2)°$, and $V = 1152(1)$ Å³. The space group is either $P2/n$ or Pn. The eight strongest lines in the X-ray powder pattern [d in Å (I) (hkl)] are: 4.14(60) (105), 3.87(60) (014), 3.63(90) (210, 105), 3.077(100) (30$\bar{3}$), 2.814(100) (021), 2.718(60) (120), 2.613(55) (206), 2.502(70) (20$\bar{8}$), 2.393(60) (40$\bar{2}$), 1.766(70) (0,0,12). Electron microprobe analyses for five grains of gillulyite give an averaged empirical formula based on 13 S atoms of $Tl_2As_{7.5}Sb_{0.3}S_{13}$. The mineral is named after the late James C. Gilluly of the U.S. Geological Survey.

INTRODUCTION

Gillulyite, $Tl_2(As,Sb)_8S_{13}$ is a thallium arsenic sulfosalt with minor Sb. The mineral was discovered at the Mercur gold deposit in the southern Oquirrh Mountains, Tooele County, Utah, approximately 56 km southwest of Salt Lake City. The Mercur deposit is a sediment-hosted, disseminated gold deposit that is characterized by micrometer-sized native gold and a Tl-As-Hg-Sb geochemical signature. Gillulyite is found in organic-rich, unoxidized carbonates in association with sulfides and sulfosalts such as pyrite, orpiment, realgar, lorandite, and raguinite. The general geology of the southern Oquirrh Mountains and related mine geology is described by Gilluly (1932). Previous work pertaining to the geological, mineralogical, and geochemical relations of the Mercur gold deposit includes that of Jewell and Parry (1987, 1988), Kornze (1987), and Tafuri (1987).

Specimens used in microprobe study have been deposited in the National Museum of Natural History, Smithsonian Institution, along with other specimens from the type locality. Two matrix specimens and numerous small grains have been deposited in the Royal Ontario Museum and in the Harvard Mineralogical Museum.

The mineral is named in honor of the late James C. Gilluly, author of the U.S. Geological Survey Professional Paper 173, *Geology and Ore Deposits of the Fairfield*

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and Stockton Quadrangles, Utah. This paper presents the fundamental geology of the Mercur gold deposit and of the surrounding area and forms the basis for much of the ongoing work in the region. The mineral description and name were approved by the International Mineralogical Association Commission on New Minerals and Mineral Names.

OCCURRENCE

Type gillulyite was collected from the upper beds of the Mercur mine series about 25 m below the contact with the Long Trail Member on the 6780 level of the Lulu cut of the South Mercur pit at mine coordinates N20900, E20280. Realgar, orpiment, lorandite, and pyrite were abundant, particularly in the upper part of the upper beds where As-, Sb-, and Tl-bearing fluids appear to have been somewhat restricted in upward movement by C-rich shales of the Long Trail Member. The contact between the Long Trail Member and the Mercur mine series above the discovery locality was particularly enriched in sulfides.

The discovery location is relatively undeformed and unoxidized. Mineralization was restricted to a few meters from fractures, and this resulted in lower ore tonnages than found elsewhere in the mineralized graben. The specific area where the gillulyite occurred contained subeconomic Au mineralization (less than 0.857 g per ton), with the nearest body of ore grade rock being located more than 30 m away. However, recent microprobe analyses of samples from the gillulyite area have revealed relatively high values of Au in association with the sulfides and sulfosalts (Wilson and Wilson, 1991).

Gillulyite occurs primarily as cleavable masses in vuggy, coarsely crystalline, euhedral barite. It also occurs in massive barite veins, calcite veins, and in the carbonaceous silty limestone host rock. Lorandite, orpiment, and realgar occur in the same manner. Orpiment is the sulfide that is associated most often with gillulyite. Usually gillulyite appears to have been deposited contemporaneously with the orpiment, exhibiting sharp boundaries between adjacent grains. Rarely, orpiment has been observed as small blebs within gillulyite, and gillulyite as isolated blades in orpiment. Lorandite occurs as botryoidal crusts in the vugs within the barite masses but has not been observed in direct contact with gillulyite. Samples from nearby areas contain abundant lorandite but no gillulyite.

CHEMICAL COMPOSITION

Nine different grains containing no microscopically visible impurities were examined using a fully automated Cameca SX50 electron microprobe operated at 15 kV and 10 nA. These relatively low values of operating conditions allowed avoidance of the visible damage to crystal surfaces of orpiment and gillulyite that was noted at 30 kV and 20 nA.

Several different standards were used for Tl, As, and S, but the best results were obtained with an analytical routine using natural lorandite for Tl, As, and S, and antimony telluride for Sb. This resulted in the following average analytical values and their ranges: Tl 28.4(2)% (28.0–28.8%), As 39.3(5)% (38.4–39.8%), Sb 2.2(4)% (1.7–3.1%), S 28.7(2)% (28.4–29.0%), and a total wt% of 98.8(3)% (98.3–99.3%). The results indicate that only Tl, As, Sb, and S are present in significant amounts. Other elements (Fe, Cu, Ag, Au, Hg, Bi, Zn, and Pb) were sought, but were not present in other than trace amounts (<0.2 wt%). Our data for 20 analyses of five gillulyite grains give an empirical formula of $Tl_2As_{7.5}Sb_{0.3}S_{13}$ based on 13 S anions. The idealized formula is $Tl_2(As,Sb)_8S_{13}$, which has been confirmed by preliminary crystal structure analysis.

CRYSTALLOGRAPHIC RELATIONS

Gillulyite is monoclinic, space group $P2/n$ or Pn, with $a = 9.584(3)$ Å, $b = 5.679(2)$ Å, and $c = 21.501(6)$ Å, $\beta = 100.07(2)°$, and $V = 1152(1)$ Å^3. Cell parameters were determined and refined with a Rigaku AFC5S 4-circle goniometer (graphite-monochromated Mo$K\alpha$ radiation) using diffraction angles from 25 automatically centered reflections in the 2θ range of 36–47°. A suite of precession photographs confirmed the 4-circle cell parameters and allowed determination of the space group. An analysis of the crystal structure is in progress and will be published separately.

Indexed X-ray diffraction powder data (Table 1) were acquired primarily using a Siemens D-500 APD using Ni-filtered Cu$K\alpha$ radiation, a θ-2θ step scan with step width 0.05° 2θ, step time 20 s, and a range of 3–100°. Supplementary data for a few peaks and most intensity data were obtained with a Phillips PW 1840 X-ray diffractometer using a significantly larger sample. Values of 2θ were corrected by use of an external standard made up of a mixture of Si (NBS SRM 640b) and synthetic fluorphlogopite mica (NBS SRM 675). The pattern was indexed using cell parameters obtained from the single crystal study.

PHYSICAL PROPERTIES

Gillulyite is translucent and has a deep red to maroon color; it tarnishes quite rapidly to darker red or blue. It resembles deep red realgar, but the colors are usually distinguishable when the two are directly compared. The gillulyite streak is a bright brick red, as compared to the more orange-red streak of realgar. On exposure to air, realgar tends to rapidly weather to an orange powder whereas gillulyite does not. The color of gillulyite is also similar to those of cinnabar, lorandite, and christite, phases which are likely to occur with it and with which it may be confused. X-ray diffraction data are necessary to readily distinguish it from these minerals, although most lorandite at this location is a darker maroon color and often botryoidal and opaque. The luster of gillulyite is vitreous but may appear metallic in some tarnished specimens. Hardness is estimated at 2–2.5 on Mohs scale on the basis of scratch tests using gypsum, orpiment, and realgar. Hardness, as determined using a Vickers diamond indenter, ranged from VHN 87 to VHN 132 for

TABLE 1. X-ray powder diffraction data for gillulyite

d_{obs}	d_{calc}	I	hkl
6.18	6.19	10	$10\bar{3}$
5.48	5.49	15	011
5.30	5.29	30	004
5.01	5.00	20	012
4.87	4.87	15	110
4.72	4.72	15	200
4.42	4.42	10	013
4.14	4.14	60	$10\bar{5}$
4.04	4.05	5	202
3.87	3.87	60	014
3.75	3.75	15	$11\bar{4}$
3.63	3.63	90	210
	3.63		105
3.51	3.50	10	211
3.43	3.43	30	114
3.39	3.39	5	015
3.35	3.35	25	$11\bar{5}$
3.30	3.30	25	212
3.25	3.25	35	204
3.20	3.20	10	$21\bar{4}$
3.077	3.080	100	$30\bar{3}$
2.837	2.840	45	020
2.814	2.814	100	021
2.766	2.767	10	$30\bar{5}$
2.739	2.741	5	116
	2.743		022
2.718	2.719	60	120
2.613	2.615	55	206
2.502	2.502	70	$20\bar{8}$
2.441	2.442	40	$22\bar{1}$
2.393	2.393	60	$40\bar{2}$
2.360	2.359	30	400
	2.358		025
2.339	2.337	40	305
2.238	2.239	25	223
	2.241		118
2.206	2.205	40	$41\bar{2}$
	2.208		$12\bar{6}$
2.029	2.027	10	404
	2.032		225
1.984	1.984	30	0,1,10
1.937	1.937	30	$40\bar{8}$
1.894	1.893	35	030
	1.896		317
1.849	1.848	40	$50\bar{5}$
	1.850		128
	1.851		501
1.817	1.816	40	2,0,10
1.766	1.764	70	0,0,12
1.758	1.757	30	$51\bar{5}$
1.668	1.668	25	036
1.619	1.620	30	229
1.595	1.597	45	$60\bar{2}$
1.477	1.478	5	$43\bar{3}$
1.414	1.413	5	0,2,13
	1.413		3,2,10
	1.417		041

five determinations with a mean value of 108 kg/mm². Load was 25 g applied for 15 s.

There are two formula units per unit cell resulting in a calculated density of 4.14(1) g/cm³ for an ideal formula of $Tl_2As_{7.74}Sb_{0.26}S_{13}$. Measured density is 4.02(2) g/cm³ for an apparently pure 25 mg grain as determined by immersion using an analytical balance. The measured number may be low because of the technique or because of intergrown orpiment which has been observed microscopically in some grains.

TABLE 2. Reflectance values for gillulyite in air

Wavelength (nm)	Minimum (%)	Maximum (%)
400	28.20	31.02
440	28.27	31.00
480	27.94	31.11
546	28.53	31.85
589	27.79	30.94
640	28.44	31.57
700	28.08	31.65

Note: The reflectance values were obtained on a semiautomated Leitz system utilizing no. 447 SiC standard from Leitz.

A few small specimens were recovered in which the mineral occurs as slender prismatic crystals not exceeding 2 mm in length, and usually much smaller. The relatively simple monoclinic crystals exhibit forms {110}, {010}, and {011}. No twinning was observed.

Gillulyite has one perfect cleavage {001} that is obvious on every specimen examined. The presence of elongated pits on polished surfaces of a few specimens suggests two other poorly developed cleavages.

OPTICAL PROPERTIES

In air, by reflected light, polished sections of gillulyite have a light gray color and are distinctly anisotropic with no observable bireflectance. Pits and scratches reveal deep red internal reflections which may not be obvious on well-polished surfaces. The mineral polishes very well along cleavage surfaces, although it scratches readily. When polished along surfaces not parallel to the perfect cleavage, elongated cleavage pits may develop. Gillulyite is slightly lighter in color and has slightly greater relief than orpiment, but optically is most easily distinguished from orpiment by the red internal reflections. With crossed polars, gillulyite is bright red as a result of the abundant internal reflections. In oil, the bireflectance varies from weak to moderate and exhibits colors of pale rose to dusky rose. Colors and observations of bireflectance in oil are strongly influenced by the pervasive internal reflections.

Reflectance values, measured in air (Table 2), range from 27.79% to 31.85% and are quite similar to the values reported for lorandite (31.4–32.6%, 530 nm; Uytenbogaardt and Burke, 1985, p. 44). This matches our observations of both minerals as seen in polished sections.

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