

PENROSEITE AND TRUDELLITE: TWO NEW MINERALS

BY SAMUEL G. GORDON.

On the Third Academy Mineralogical Expedition: Bolivia and Chile, 1925, the writer visited the well-known localities Colquechaca and Cerro Pintados. Amongst the material obtained at these places were two minerals which proved to be new:

Penroseite: $2\text{PbSe}_2 \cdot 3\text{CuSe} \cdot 5(\text{Ni}, \text{Co})\text{Se}_2$, or
 $\text{PbSe} \cdot \text{Cu}_2\text{Se} \cdot 3(\text{Ni}, \text{Co})\text{Se}_2$, orthorhombic, and
Trudellite: $\text{Al}_2(\text{SO}_4)_3 \cdot 4\text{AlCl}_3 \cdot 4\text{Al}(\text{OH})_3 \cdot 30\text{H}_2\text{O}$, trigonal.

These are described below. It is hoped to publish an account of the trip and a description of the other specimens at a future date.

PENROSEITE

Penroseite was obtained in a small collection of minerals which the writer purchased from a local merchant at Colquechaca, Bolivia. This collection had been made by a miner named Castellana, whose widow had sold it to the merchant. As far as could be learned, Castellana had worked in various mines in the vicinity of Colquechaca. His collection consisted largely of specimens of "ruby silver" (pyrargyrite), native silver, argyrodite, argentite, and vivianite, all of which are typical minerals from mines in the vicinity of Colquechaca.

In the collection was a single mass of a metallic mineral, which weighed about one kilogram. It was slightly rounded and covered with a thin, brownish film of limonite. In slight cavities in the surface the limonite was black and stalactitic. Locally, the surface of the mass showed bluish-green stains of a nickel or copper mineral, and druses of brown, very minute, rhombohedral crystals which resemble siderite. It would seem that the mass had not been found in situ, but probably represented a bit of "float."

When the mass was broken up, it was found to consist almost entirely of a lead-gray, radiating, columnar mineral. A few small cavities, the largest of which was about 3 cm. in length, were lined with brown rhombohedral crystals up to 3 mm. in size of goethite pseudomorphous after siderite. Some veins of limonite extended into the mass. A few small crystals of cerussite were also noted in some of the cavities.

Physical Properties.—The physical properties of penroseite are: color lead-gray; streak black; opaque; luster metallic; hardness 3; brittle; specific gravity 6.93.

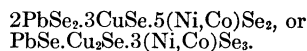
Crystallography.—Penroseite is massive, with a radiating, columnar, or sometimes granular, structure. There are four cleavages: *c* (001) perfect, but curved; *a* (100), and *b* (010), perfect; and *m* (110) distinct. The basal cleavage is curved, giving the mineral a concentric, botryoidal appearance, when viewed on such surfaces.

Measurement of cleavage fragments showed the three principal cleavages to be at 90° with respect to each other¹; the mineral is therefore orthorhombic. The prismatic cleavage gave too indistinct a series of reflections to obtain any trustworthy angles.

Mineralography.—When clean cleavage fragments of the specimen were examined in polished section under vertical illumination, they were seen to consist of three minerals: 95 to 96 % of penroseite, 2 to 3% of a white selenide, and 2% of goethite or limonite. The white selenide and the goethite or limonite appear as very thin veins through the penroseite. The white selenide is present in amount about equal to the silver selenide indicated in the analysis; and is believed to represent a silver selenide; with the reagents, however, it behaves similarly to clausthalite, and may be that mineral. The results of the mineralographic examination are given in Table I.

Chemical Composition.—Five grams of carefully selected cleavage fragments, free from visible impurities, were given to Dr. J. E. Whitfield for analysis after a mineralographic examination for purity. The results are shown in Table II. No sulfur, antimony, tin, thallium, or germanium were found in the mineral.

Penroseite is remarkable for its high content of selenium, as it contains about twice as much of this element as any heretofore described selenide. In order to satisfactorily account for the selenium, maximum valencies must be assigned to the metals. In Table III, the derivation of the following two formulas is indicated:



The molecules PbSe_2 and CuSe assigned to the first formula do not occur in the known selenides, although the molecule NiSe_2 is

¹ The basal cleavage was not sufficiently curved to prevent measuring the angles in tiny fragments.

analogous to the mineral melonite, NiTe_2 . Moreover, a small amount of selenium is not accounted for. This may be explained by supposing that the minute limonite veins carry some elemental selenium or selenium oxide, representing an alteration of the penroseite.

TABLE I: MINERALOGRAPHY OF PENROSEITE

| Mineral | Penroseite | Unknown Mineral | Limonite |
|------------------|---|---|-------------------------------|
| Color | Cream | White | Gray |
| Estimated Volume | 95 to 96% | 2 to 3% | 2% |
| HNO_3 | Effervesces. Rapidly etches to rough gray surface. Fumes tarnish brown. | Turns brick red. | Negative. |
| HCl | Negative. | Turns pale gray. Rubs to paler tint. | Slowly etches to darker gray? |
| KCN | Tarnishes brownish. Rubs to paler color. | Negative. | Negative. |
| FeCl_3 | Negative. | Turns pale gray with some iridescence. Rubs to a paler color. | Negative. |
| HgCl_2 | Negative. | Negative. | Negative. |
| Hardness | Medium. | Low. | Low. |

The second formula represents the molecules as PbSe , and Cu_2Se to conform with those occurring in the known natural selenides. A slight deficiency of selenium is shown in the analysis of the mineral with that required by this formula.

The silver is present in amount equal to the quantity of the white mineral occurring in thin veins in penroseite, and it is believed to be present as a silver selenide.

While a cobaltiferous variety of clausthalite has been given the name tilkerodite, this is the first nickel selenide to be reported.

Pyrognostics.—Penroseite is easily fusible, coloring the flame a beautiful azure blue. It gives off reddish-brown smoke, with an occasional white wisp at the border of the smoke column. The characteristic disagreeable "horse radish" odor of Se is instantly experienced. These details are even observable in a candle flame.

Before the blowpipe, the mineral decrepitates. In the closed

tube penroseite decomposes, and a coating of selenium is deposited on the wall of the tube; lower down the coat is black, and is seen to consist of globules of selenium; higher up, the coat consists of translucent, acicular, red crystals.

The mineral dissolves readily in HNO_3 with effervescence. The solution upon the addition of NH_4OH in excess turns a methyl blue (Cu and Ni). Dimethyl glyoxime yields a scarlet precipitate (Ni).

TABLE II: ANALYSIS OF PENROSEITE
BY DR. J. EDWARD WHITFIELD

| | I | II | III |
|-------------------------|--------|--------|-------|
| Se | 59.80 | 60.23 | .7604 |
| Ag | 2.04 | 2.05 | .0190 |
| Pb | 17.13 | 17.25 | .0833 |
| Cu | 7.84 | 7.90 | .1243 |
| Ni | 11.14 | 11.22 | .1912 |
| Co | 1.34 | 1.35 | .0229 |
| Fe_2O_3 | 1.08 | | .2141 |
| | 100.37 | 100.00 | |

I: Analysis by Dr. J. Edward Whitfield.

II: Analysis recalculated omitting Fe_2O_3 .

III: Formula ratios.

TABLE III. DERIVATION OF FORMULA OF PENROSEITE

| Molecular Ratios | $2\text{PbSe}_2.3\text{CuSe}.5(\text{Ni}, \text{Co})\text{Se}_2$ | $\text{PbSe}.\text{Cu}_2\text{Se}.\text{Ni}, \text{Co})\text{Se}_3$ |
|------------------|--|---|
| Se .7604 | | |
| Pb .0833 | $\text{PbSe}_2 .0833 = .0416 \times 2$ | $\text{PbSe} .0833 = .0208 \times 4$ (1) |
| Cu .1243 | $\text{CuSe} .1243 = .0414 \times 3$ | $\text{Cu}_2\text{Se} .0621 = .0207 \times 3$ (1) |
| (Ni, Co) .2141 | $\text{NiSe}_2 .2141 = .0428 \times 5$ | $\text{NiSe}_3 .2141 = .0214 \times 10$ (3) |

Locality—Colquechaca is situated in Bolivia, about 150 kilometers southeast of Oruro. A railroad extends in this direction as far as Catavi, from which point Colquechaca is about a day and a half to two days' trip by mule. The mines are situated in the Cerro Hermosa, an intrusive mass of rhyolite. The ore occurred locally in fissure veins in the rhyolite; and the district owes its celebrity to the many rich pockets of ruby silver (pyrargyrite) formerly found. Very little mining activity is evident at present.

Reasons were given in the introduction for believing that the penroseite was not found in situ, but was a bit of "float" from some

unworked prospect, or undiscovered vein. Some doubt therefore exists regarding the exact locality. As the rest of the collection, of which the penroseite was a part, consisted of characteristic specimens from the mines at Colquechaca, it seems certain that the mineral came also from the vicinity. It may be remarked that no selenium or nickel minerals have heretofore been reported from Bolivia.

About 1000 miles farther south in the Andes, at Cacheuta near Mendoza, Argentina, many selenides were formerly found; none however, contained nickel, and it seems incredible that this specimen could have come from that remote district.

Name.—It is a pleasure to name this new mineral in honor of Dr. Richard A. F. Penrose, Jr.

TRUDELLITE

About 80 kilometers southeast of Iquique, in the Province of Tarapacá, Chile, is Pintados, the well-known locality for pickeringite and tamarugite. Pintados may be reached by railway from Iquique, or Antofagasta. It is a cluster of buildings, lying near the eastern foot of the Coastal Hills, which at this point were formerly known as the Cerro Pintados. It is also at the western edge of the Tamarugal Pampa, in which, to the northeast, is the oasis of Pica. In the distance across the Pampa Tamarugal are the Western Cordillera of the Andes.

On the hillside, just above the floor of the pampa, are two groups of trenches and pits, respectively one and two kilometers northwest of Pintados station. The larger working, two kilometers northwest of Pintados, is the locality for the fine fibrous masses of tamarugite and pickeringite seen in many older collections.

The smaller group of pits and trenches, one kilometer northwest of Pintados, are little more than prospect diggings. The principal minerals there are gypsum, anhydrite, pickeringite, and the new mineral trudellite.

The Coastal Ranges in general consist of Cretaceous limestones and other sediments, lying unconformably upon crystalline schists, gneisses, gabbros, etc. The underlying rocks are obscured by a talus breccia, covered with gravel. At the trudellite locality, the excavations exposed a compact, fine-grained, buff-colored rock, which on optical examination proved to be largely composed of anhydrite and gypsum. This rock probably represents an altered

limestone. The gypsum, pickeringite, and trudellite occur as veins cementing the overlying talus breccia, just beneath the wind-blown gravel layer. This breccia consists at the pits, of a mottled-red and gray rock, now largely composed of sulfates. It was not possible to determine the original rock from the examination of crushed fragments. Trudellite frequently contains tiny red fragments of this altered rock, and the mineral was probably the result of its alteration.

Nearby, another pit exposed a pyritic vein in a conglomeratic rock, indicating that the decomposition of pyritic veins may have contributed to the origin of the sulfates. The pampa up to the foot of the hills, shows evidence of former working for nitrate.

Perhaps the most abundant mineral at the trudellite locality is gypsum; it occurs in fibrous masses, with the fibers perpendicular to the walls of the veins. Sometimes the gypsum fibers are curved. Some powdery anhydrite is found with the gypsum. The pickeringite occurs in compact, yellow masses, with an extremely fine, short fibrous structure. The fibrous appearance is indicated by a silky sheen when the specimen is held in the proper direction. The pickeringite is evidently the result of alteration of another sulfate, perhaps trudellite.

At the pits two kilometers northwest of Pintados, the pickeringite occurs as white, silky, long, fibrous masses, which are sometimes rose pink when freshly broken. The associated tamarugite occurs in coarse fibrous masses, which are colorless or white, and show a pronounced prismatic cleavage.

Physical Properties.—The color of trudellite is amber yellow (Ridgway). The luster is vitreous. The hardness is about 2.5. The specific gravity was determined by dropping freshly broken fragments into mixtures of benzol and bromoform, and found to be 1.93.

Optical Properties.—Optically, trudellite is uniaxial negative. The indices of refraction were determined by the immersion method. Some difficulty was encountered owing to the deliquescent character of the mineral. This was overcome by dropping fragments in the index oils and crushing them under the cover glass. The indices of refraction obtained for Hg yellow light are:

$$\epsilon = 1.495, \omega = 1.560; \omega - \epsilon = .065; \text{all } \pm .005$$

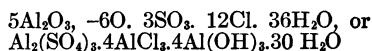
Crystallography.—Trudellite occurs in compact masses, with an indistinct rhombohedral cleavage; the mineral is therefore trigonal. This was at first determined from the optical properties. Fragments under oblique illumination showed only a single quadrant of a uniaxial figure; it was therefore suspected that the mineral was lying on a cleavage at some angle to the vertical axis. Such a cleavage is rare in the hexagonal and tetragonal systems, but common in the trigonal system. Careful inspection of cleavage surfaces substantiated the conclusion that the cleavage was rhombohedral. Under the microscope occasional fragments were found that had a rhombohedral outline, and showed symmetrical extinction. The cleavage, however, was too indistinct to obtain any goniometric measurements.

Chemical Composition.—An analysis, given in Table IV, was made of trudellite by Dr. Earl V. Shannon, who also kindly furnished the following details. Owing to the very deliquescent character of the mineral, the analysis was attended with difficulty.

The sample was crushed and quickly ground in an agate mortar and sealed in a vial. All portions analyzed were weighed out at the same time, and most of the constituents were determined on a single sample of 2.5 grams, which was weighed out and boiled in water.

Another portion of 0.5 gram was weighed in a small porcelain crucible, and placed in a drying oven for 4 hours, with hourly weighings, with the following losses: first hour 17.66%, second hour 5.70% third hour 7.44%, fourth hour 3.40%. The sample was then placed in a dessicator over CaCl_2 to stand overnight, whereupon it regained 1% in weight. Again heated for an hour at 112° it lost 2.10%. The total loss in 5 hours was thus 35.30%, of which it was later determined that 13.30% was chlorine. The sample was then transferred to a Penfield water tube and 14.60% additional water was obtained. A total direct water determination by the Penfield method gave 36.60%. A portion of 0.5 gram allowed to stand in an open porcelain crucible for 24 hours lost 4.10%. Another 0.5 gram portion, allowed to stand 72 hours over H_2SO_4 of a dilution equivalent to a water vapor pressure of 19 mm. of mercury, took up 129.44% of its own weight of water, went into solution and hydrolyzed. A portion of 0.5 gram allowed to stand 72 hours in a dessicator over CaCl_2 lost 4.46% H_2O .

If the soda, magnesia and lime be ignored, as probably present as impurities, the ratios yield the following formula:



Optical examination of the sample analysed showed it to be apparently composed of a single mineral.

ANALYSIS OF TRUDELITE

BY DR. EARL V. SHANNON

| | I | II | | III | IV |
|--------------------------------|--------|-------|-------|-----------|--------|
| SiO ₂ | 0.57 | | | | |
| Al ₂ O ₃ | 25.67 | .251 | .257 | .051 × 5 | 29.54 |
| Fe ₂ O ₃ | 1.00 | .006 | | | |
| CaO | 1.56 | .028 | .067 | | |
| MgO | 0.66 | .014 | | | |
| Na ₂ O | 1.58 | .025 | | | |
| SO ₃ | 13.60 | .170 | .170 | .057 × 3 | 13.86 |
| Cl | 24.42 | .689 | .689 | .057 × 12 | 24.60 |
| H ₂ O | 36.60 | 2.032 | 2.032 | .057 × 36 | 37.54 |
| | 105.66 | | | | 105.54 |
| Less 0 = Cl ₂ | 5.49 | | | | 5.54 |
| | 100.17 | | | | 100.00 |

- I. Analysis of truedellite by Dr. Earl V. Shannon.
 II. }
 III. } Formula ratios.
 IV. Theoretical composition.

Pyrognostics.—The mineral is very deliquescent. It has a sweet, astringent taste. On dissolving in water, some of the alumina is precipitated. It thus behaves similarly to some of the soluble complex calcium sulfates, in which Ca sulfate is thrown down. However, it can be distinguished from these by the insolubility of the precipitate. AgNO₃ yields a characteristic precipitate (Cl); as does BaCl₂ (SO₄).

Before the blowpipe the mineral is infusible. After strongly heating and moistening with Co(NO₃)₂, and heating again, the characteristic blue color indicating Al is obtained. In the closed tube, truedellite yields much acid water.

Name.—The writer takes pleasure in naming this mineral truedellite, after Mr. Harry W. Truedell, well-known Philadelphia amateur mineralogist, and member of this Academy.