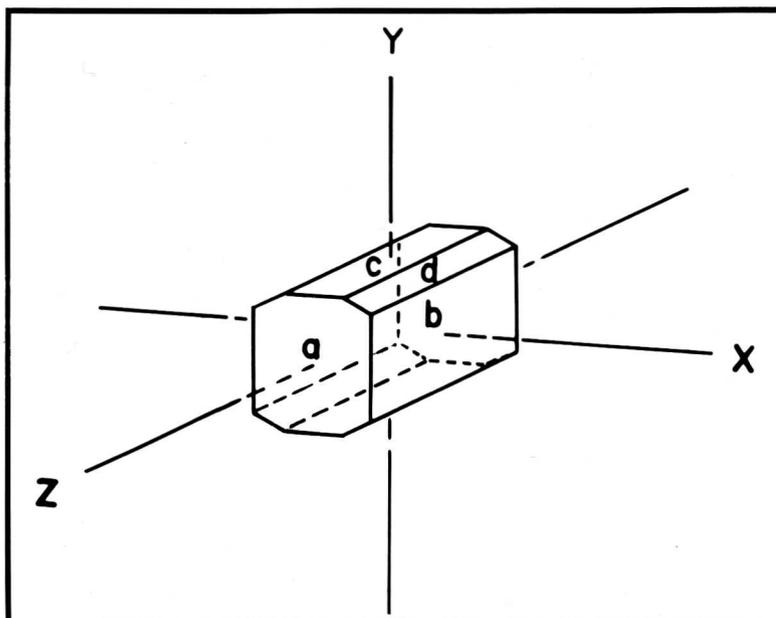


# GRAEMITE

## A New Bisbee Mineral

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### ABSTRACT

Graemite has been found in one specimen collected in 1959 by Richard Graeme for whom it is named. The specimen came from the Cole shaft at Bisbee, Arizona.

The specimen contains several large teineite crystals embedded in malachite and cuprite. The largest of these are pseudomorphosed by dense aggregates of platy graemite crystals.

The specific gravity is  $4.13 \pm 0.09$ ,  $H = 3-3.5$ . The color is near jade green, RHS-125A. Brittle with good cleavage on {010} and distinct parting on {100}. Optically (+) with  $2V \text{ calc} = 48-1/2^\circ$ ,  $n_\alpha = 1.920$ ,  $n_\beta = 1.960$ ,  $n_\gamma = 2.20$ ; dispersion low. Pleochroic with  $Y > Z = X$  and  $Z$  and  $Y$  blue green,  $X$  yellowish green;  $X = b$ ,  $Y = c$ ,  $Z = a$ .

Strongest lines are 6.395 (10), 3.434 (8), 12.803 (5), 2.558 (5), 2.873 (4), 2.343 (4), 5.640 (3), 2.801 (3);  $a = 6.805 \text{ \AA}$ ,  $b = 25.613$ ,  $c = 5.780$ . Probable space group  $Pcmm$ . With  $Z = 10$ ,  $D_{\text{calc}} = 4.24 \text{ g/cm}^3$ .

Chemical analysis showed  $\text{CuO} = 31.0\%$ , 31.9, 30.0;  $\text{TeO}_2 = 60.8\%$ , 61.4, 61.4 by AA and colorimetry respectively. Water by the Penfield method gave 7.0%, 9.5. This leads to  $\text{Cu}_{9.77}(\text{TeO}_3)_{9.62} \cdot 11.42 \text{ H}_2\text{O}$  or  $\text{CuTeO}_3 \cdot \text{H}_2\text{O}$ .

### INTRODUCTION

Although Bisbee is a mining camp well known for its beautifully crystallized oxide ores of copper it has produced surprisingly few new species during its life. Probably the main reason for this is the simplicity of its hypogene ores in terms of the elements present and mineralogy.

Nevertheless, some of the new species found there have been remarkably abundant or well crystallized in the type specimen. Paramelaconite is a good example and spangolite probably is as well.

The new species graemite carries on this tradition for, although only one specimen is currently known, it is quite spectacular for a new species. The piece was retrieved from an ore car in 1959 by Richard Graeme and recently loaned to us for identification. The specimen came from the 1200 level of the Cole shaft, probably from the 202 stope, the only active oxide stope in the upper Cole at that time.

The type specimen measures about  $2-1/2 \times 2-1/2 \times 2$  inches and is a loose spongy aggregate of cuprite crystals embedded in a dense matted matrix of tiny malachite needles. Embedded in the malachite are several large electric blue teineite prisms. These measure at least 8 mm long and have corroded, pitted surfaces. Cuprite and an occasional graemite crystal are attached to the surfaces. Two very large teineite crystals occur and are totally replaced by graemite. One was at least 20 mm long, the other is 8 mm in cross section, but both are broken.

Graemite replaces these as divergent platy, bladed crystals arranged in random fashion. In the stoutest teineite relic they show a radial divergence but on the surfaces of both pseudomorphs they tend to lie with their long axes [100] near parallel to the prism axis of the teineite. The specimen contains an estimated 500 mg of graemite.

During this study a second locality for graemite was found. The samples were provided by John Forrester and were collected at a small prospect in the Dome Rock Mountains, Yuma County, Arizona. These samples consist of massive "chalcocite" in a quartz-tourmaline gangue. Small corroded blebs of bornite and traces of weissite were found embedded in the chalcocite. Fractures are filled with brochantite and malachite and may be lined with crystalline goethite, and gold. By carefully breaking the chalcocite so that it fractured in fresh material rather than along brochantite-filmed surfaces, small cavities were found that housed goethite, gypsum, teineite, and graemite. As at Bisbee, graemite appears to replace teineite, and the latter mineral is invariably corroded.

The species description is based solely upon the Bisbee specimen.

#### PHYSICAL PROPERTIES

Graemite is a lovely blue green color, near jade green, Royal Horticultural Society RHS-125A, with a similar but pale streak. In general appearance graemite could be confounded with chalcophyllite, malachite or aurichalcite. The Mohs hardness is 3–3.5, and the mineral is brittle with a good cleavage on {010} and pronounced parting on {100}. No fluorescence was observed in short or long wavelength U. V. The specific gravity was determined on the Berman balance as  $4.13 \pm 0.09$  from five trials using a 6 mg sample in toluene at 24.5° C.

#### CHEMISTRY

Emission spectrographic analysis showed major Te and Cu with a trace of Ag. Microchemical tests confirmed this and a test specific for tellurite gave a strong reaction; testing for tellurate gave negative results. Tests for halogens and sulfate were likewise negative.

Table I shows the results of the chemical analyses. The mineral was dissolved and run in 1:1 HNO<sub>3</sub> by atomic absorption for Cu. Tellurium was determined colorimetrically in 3 normal HBr. We also report an analysis of the teineite; identical methods were used. Water was determined (and observed) by the Penfield method. During heating graemite decrepitated, turning a sickly green and then fused easily to a grey blebby slag. We consider the value of 9.5% H<sub>2</sub>O to be erroneously high since a tiny fragment was ejected from the tube during decrepitation.

The analyses lead to the empirical cell contents Cu<sub>9.77</sub> (TeO<sub>3</sub>)<sub>9.62</sub> · 11.42 H<sub>2</sub>O or CuTeO<sub>3</sub>·H<sub>2</sub>O. The teineite analysis confirms the formula CuTeO<sub>3</sub>·2H<sub>2</sub>O.

Graemite is easily soluble in cold reagents including 40% KOH, 10% HCl, and 1:1 NH<sub>3</sub> but is insoluble in water.

#### MORPHOLOGY AND OPTICS

On the outer surface of the teineite relics, graemite may occur as euhedra of fairly good quality capable of giving reflections on the goniometer. Such a crystal is pictured in Figure 1. The only forms found are *a* {100} *b* {010} *c* {001} and *d* {021}. Although *b* tends to be slightly distorted into a mosaic of near-parallel rectangular domains, *a*, *c*, and *d*

give bright crisp reflections. In the interior of the teineite relics the habit changes from that figured to notably extended on [100] and flattened on {010}. Crystals up to 8 mm long were noted. No evidence was seen, either morphological or optical, that graemite is not orthorhombic *2mm*.

In transmitted light graemite is modestly pleochroic with Y and Z blue green and X yellowish green with Y > Z = X. The optic orientation is shown in Figure 1 and of course extinction is parallel in all orientations since the principal crystallographic directions are pinacoidal.

The 2V (+) is 48-1/2° (calc.) and the indices of refraction are  $n_\alpha = 1.920$ ,  $n_\beta = 1.960$  (both  $\pm 0.003$ ), and  $n_\gamma = 2.20 \pm 0.005$ . The latter index was determined in S-Se melts; all indices are for the NaD line. Dispersion of the optic axes was not observed.

#### X-RAY DATA

The X-ray powder pattern of graemite is typical of a layered mineral with a few strong lines and numerous weak or diffuse ones. An indexed pattern is presented in Table II.

Rotation on all three axes and Weissenberg level photographs were accomplished using CuK<sub>α</sub> radiation. These patterns were characterized by strong sets of 0k1 reflections and remarkably weak reflections in the h01 region. Results of this study lead to the proposed space group *Pcmm* but this is not a certainty because of the failure to record many h01 reflections, even after long exposures.

Cell edges were refined from powder data and are as follows:  $a = 6.805 \text{ \AA} \pm 0.006$ ,  $b = 25.613 \pm 0.015$ ,  $c = 5.780 \pm 0.006$ . The calculated density is thus 4.24 g/cm<sup>3</sup> which compares favorably with the measured specific gravity, 4.13; Z = 10.

#### CONCLUSIONS

Graemite apparently replaces teineite as a consequence of partial dehydration of the latter mineral. The source of the tellurium is uncertain, of course, and this element is probably very rare at Bisbee. However rickardite has been noted in trace amounts in the ores (Galbraith & Brennan, 1970).

A number of new Cu-tellurites have been found in the prolific Moctezuma district; some have been described, some descriptions are forthcoming. A suite of unknown tellurites has also been found in Arabia (F. Cesbron, pers. comm., 1973). Diffraction data for these various species fail to show any resemblance to graemite. So far as we are aware this compound has not been known artificially.

It is not unlikely that additional graemite specimens may be found in material collected from the environs of the 202 stope, known for its connellite crystals. Old Bisbee specimens purporting to be connellite should be carefully reexamined. Some may prove to be teineite, originally misidentified on the basis of the striking similarity in color to connellite. The presence of teineite would of course enhance the possibility of coexisting graemite, its natural dehydration product.

**TABLE I  
CHEMICAL ANALYSES**

	GRAEMITE							TEINEITE		
	1	2	3	4	5	6	7	8	9	10
CuO	31.0	31.9	30.0			31.0	.390	30.93	27.4	28.91
TeO <sub>2</sub>	60.8	61.4	61.4			61.2	.383	62.06	56.2	58.00
H <sub>2</sub> O				7.0	9.5	8.2	.455	7.01	16.7	13.09
						100.4		100.00	100.3	100.00

- 1, 2, 3 CuO on 0.620, 0.625, 0.455 mg respectively;  
TeO<sub>2</sub> on 0.620, 0.637, 0.477 mg: analyses by  
M. Duggan, Phelps Dodge Corporation.
- 4 On 0.2535 mg; Penfield method.
- 5 On 0.5064 mg; Penfield method.
- 6 Average of columns 1 - 5.
- 7 Ratios
- 8 Theory for CuTeO<sub>3</sub>·H<sub>2</sub>O.
- 9 By Penfield method; H<sub>2</sub>O on 0.209 mg; Teineite:  
Cu and Te on 0.315 mg, M. Duggan, analyst.
- 10 Theory for teineite.

**Table II  
Indexed powder data for graemite;  
CrK $\alpha$  radiation, 114.6 mm Straumanis camera**

I	d	d	hkl	I	d	d	hkl
est.	meas.	calc.		est.	meas.	calc.	
5	12.803	12.806	020	1	2.658	2.661	260
10	6.395	6.403	040			2.660	102
3	5.640	5.638	011	5	2.558	2.561	0.10.0
2	5.274	5.268	021			2.553	091
1	4.789	4.786	031	1	2.517	2.517	052
1	4.273	4.269	060	½	2.492	2.492	270
8	3.434	3.434	061	½	2.423	2.417	261
1	3.375	3.373	210	4	2.343	2.342	0.10.1
2	3.196	3.202	080	1	2.268	2.268	072
1	3.160	3.161	230	1	2.160	2.162	281
2	3.092	3.092	071			2.160	0.11.1
½	3.009	3.005	240	1	2.133	2.133	232
1	2.920	2.913	211			2.134	0.12.0
4	2.873	2.872	012	1	2.029	2.028	092
3	2.801	2.801	081	1	2.003	2.002	0.12.1
3	2.773	2.773	231			2.005	341
3	2.735	2.737	032			2.003	360

plus 20 lines to 1.23 Å, none with I<sub>est</sub> >2.

**ACKNOWLEDGEMENTS, ETC.**

We are grateful to Miss Marjorie Duggan for the excellent analytical work. Phelps Dodge geologist Richard Graeme, longtime collector and student of Bisbee minerals, provided us with the specimen which he had carefully preserved for 15 years. The species is named in his honor.

The type specimen will be housed in the University of Arizona collection. The mineral and name have been submitted to the committee on new minerals and names, IMA. GALBRAITH, F. W. and D. J. BRENNAN (1970) *Minerals of Arizona*. Ariz. Bur. Mines Bull. 181. Univ. of Ariz. Tucson