

TWO NEW TELLURITES OF IRON: MACKAYITE AND BLAKEITE. WITH NEW DATA ON EMMONSITE AND "DURDENITE"

CLIFFORD FRONDEL AND FREDERICK H. POUGH,

Harvard University and The American
Museum of Natural History.*

ABSTRACT

Two new tellurites of iron, mackayite and blakeite, are described, and a third new tellurite is noted. Durdenite of Dana and Wells (1890) from Honduras is shown to be identical with emmonsite of Hillebrand (1885, 1904) from Cripple Creek, Colorado. The name emmonsite is retained for the species. Two new localities for emmonsite, at Silver City, New Mexico, and Goldfield, Nevada, are described. A resumé of the descriptions of mackayite and blakeite follows.

Mackayite is a hydrated ferric tellurite of uncertain formula, perhaps $\text{Fe}_2(\text{TeO}_3)_3 \cdot x\text{H}_2\text{O}$. Tetragonal. Space group probably $I/4acd$. Cell dimensions: $a_0 = 11.70 \pm 0.02$, $c_0 = 14.95 \pm 0.02$; $a_0:c_0 = 1:1.278$ (x -ray); $1:1.259$ (morphology). Crystals prismatic [001] with $a\{010\}$, $m\{110\}$, $g\{012\}$ and $f\{112\}$; rarely pyramidal $\{112\}$. No cleavage. $H = 4\frac{1}{2}$. $G = 4.86$. Fracture subconchoidal. Luster vitreous. Color peridot- to olive-green and blackish-green. Streak light green. Optically, uniaxial positive (+), with $\omega = 2.19 \pm 0.02$, $\epsilon = 2.21 \pm 0.02$. Faintly pleochroic, with ω yellowish-green, ϵ green. Found sparingly at Goldfield, Nevada, as a secondary product in vugs and seams in silicified rhyolite and dacite, associated with emmonsite, tellurite, alunite, barite, quartz, and the new mineral blakeite. Named for John W. Mackay (1831-1902), a mine operator on the Comstock Lode and benefactor of the Mackay School of Mines.

Blakeite occurs in minute amounts as microcrystalline crusts of a deep reddish-brown color. Contains Fe and Te as the only major constituents but the formula is unknown. Nearly or quite isotropic, with $n = 2.16 \pm 0.02$. Named after William P. Blake (1826-1910), a pioneer geologist and mineralogist of the American southwest.

Emmonsite and mackayite on heating to 750°C. fuse and lose water and the residue gives the x -ray powder pattern of artificial anhydrous $\text{Fe}_2(\text{TeO}_3)_3$. Blakeite gives in addition faint lines apparently belonging to admixed FeTeO_4 . X -ray powder diffraction data are given for mackayite, blakeite, emmonsite, artificial $\text{Fe}_2(\text{TeO}_3)_3$, and for a new, unnamed, tellurite of iron from Honduras.

INTRODUCTION

The writers recently have had opportunity to examine a large suite of material from Goldfield, Nevada, comprising masses and drusy crusts of emmonsite associated with several seemingly new compounds of iron and tellurium. The material was collected by Mr. C. D. Woodhouse of Santa Barbara, California, to whom the writers are indebted for a loan of specimens. Information regarding the details of the occurrence and some additional specimens were supplied by Mr. Hatfield Goudy of Jamestown, California.

* Contribution from the Department of Mineralogy and Petrography, Harvard University, No. 267. Prepared in collaboration with the Department of Geology and Mineralogy, The American Museum of Natural History.

Hitherto, four compounds of iron and tellurium have been reported as occurring in nature. These are durdenite of Dana and Wells (1890), emmonsite of Hillebrand (1885), a speculative substance, ferrotellurite, described by Genth (1877), and an ill-defined, unnamed, material from Cripple Creek, Colorado, analyzed by Knight (1894). The characterization of these minerals is not as complete as might be desired, especially where the description of possibly new minerals of similar composition is concerned. Type specimens of durdenite and emmonsite were obtained for the purpose of verifying the physical and other characters and for getting the *x*-ray powder diffraction patterns. Specimens of the minerals described by Genth and by Knight were not available. A summary of the present knowledge of the four substances mentioned follows.

EMMONSITE

Two localities for emmonsite have been described, but there is no certainty that the material from the two are identical. The mineral was originally reported by Hillebrand in 1885 from a locality near Tombstone, Arizona. The substance, for which scant physical and crystallographic data are available, occurred very sparingly as yellowish-green scales and patches in a hard brownish gangue composed of an intimate mixture of cerussite, quartz, and a brown oxygenated compound of iron and tellurium that was not further described. Optically, the material is stated by Cross, cited in Hillebrand, to be:

TABLE 1. ANALYSES OF EMMONSITE

	1.	2.	3.	4.	5.	6.	7.	8.
Fe ₂ O ₃	[20.02]	[20.10]	[21.30]	[20.30]	22.67	22.81	22.79	25.41
Fe	14.00	14.06	14.90	14.20				
TeO ₂	[74.80]	[74.01]	[73.90]	[74.00]	70.83	71.80	70.20	62.34
SeO ₂								2.12
Te	59.77	59.15	59.05	59.14				
H ₂ O+ } H ₂ O- }	3.28				4.68	4.82	0.21	10.13
P ₂ O ₅					0.34			
Al ₂ O ₃						0.58	0.54	
ZnO				1.94				
CaO				0.56				
Total	[98.10]	[94.11]	[95.20]	[96.80]	98.52	100.01	93.74	100.00

Analyses 1, 2, 3 and 4 by Hillebrand (1885) were made on material from Tombstone, Arizona. Oxide per cent calculated from determination of element. Analyses 5, 6 and 7 by Hillebrand (1904) were made on material from Cripple Creek, Colorado. Analysis 8 by Wells (cited by Dana and Wells (1890)) on "durdenite" = emmonsite is from Honduras. Recalculated to 100 after deduction of 23.89 per cent insoluble material.

"System probably monoclinic. The good cleavage plane may represent the clinopinacoid, for while extinction in it never seems to take place exactly parallel to the longer axis of the fragments, all those which allow of tests perpendicular to the cleavage plane do extinguish parallel to its trace. Plates parallel to the cleavage generally show that two directions of less perfect cleavage exist, which are nearly at right angles to each other. Extinction 8° to 12° from one of these directions. Refraction strong. Pleochroism very slight. Position of optical axes not determinable."

Three partial analyses were made upon material admixed with 3-5 per cent quartz and a small per cent of the brown mineral mentioned. A fourth analysis was made on 150 mg. of material containing quartz, gypsum (?) and calamine but none of the brown mineral. These analyses are cited in columns 1-4 of Table 1. Qualitative chemical tests indicated that the mineral was essentially a ferric tellurite and not a ferrous tellurate. In a later note, Hillebrand (1890) gave a new determination of the water (4.2 per cent) and re-determined the ratio of $\text{Fe}_2\text{O}_3:\text{TeO}_2$ as 1:3.75. One gathers from Hillebrand's remarks that all of his material from this locality was used up in the chemical work.

In 1904, Hillebrand described an iron tellurite from the W. P. H. mine at Cripple Creek, Colorado, which was provisionally regarded as emmonsite. The mineral occurred in green mammillary forms associated with tellurite and partly oxidized calaverite. Lindgren and Ransome (1906) state that this, or a similar mineral, is probably generally present in oxidized ores at Cripple Creek. The mineral melts at a low heat to a red-brown liquid as does the original emmonsite. The optical properties are described by Schaller, cited in Hillebrand (1904), as follows:

"There are two cleavages, one parallel to $b(010)$ and another parallel to a form in the orthozone. Axial plane parallel to $b(010)$. Bx_a perpendicular to a cleavage face in the orthozone. The extinction on the clinopinacoid is inclined 25° to 30° to the vertical axis. $2E$ is approximately 40° . Double refraction medium, and the mineral is non-pleochroic."

Additional optical properties determined on the original specimen are given by Larsen (1921, 1934), as follows:

Optically negative (-). $2V=20^{\circ}\pm$, Dispersion $r>v$, strong. X is nearly \perp to a cleavage. $X=1.95\pm 0.02$, $Y=b=2.09\pm 0.02$, $Z=2.10\pm 0.02$.

Hillebrand made three partial analyses on portions of from 150 to 200 mg. each of the material from Cripple Creek. These analyses, after deducting 22.44 per cent of gangue, are as given in columns 5-7. The mean of the four analyses of the material from Tombstone corresponds to the ratio $\text{Fe}_2\text{O}_3:\text{TeO}_2:\text{H}_2\text{O}=1:3.63:1.42$, and the mean of the three analyses of the material from Cripple Creek corresponds to the ratio $\text{Fe}_2\text{O}_3:\text{TeO}_2:\text{H}_2\text{O}=1:3.12:1.85$. Little weight can be placed on these ratios considering the small size of the analyzed samples and the known presence of impurities. Analysis 8 on durdenite, a mineral now shown to be identical with

emmonsite, gives the ratio $\text{Fe}_2\text{O}_3:(\text{Te,Se})\text{O}_2:\text{H}_2\text{O}=1:2.59:3.54$. The formula $\text{Fe}_2(\text{TeO}_3)_3 \cdot 2\text{H}_2\text{O}$ probably best represents the composition of emmonsite.

The original analyzed specimen (U.S.N.M. 86846) of the so-called emmonsite from Cripple Creek was made available for examination through the courtesy of Mr. E. P. Henderson of the U. S. National Museum. The *x*-ray powder diffraction pattern differs entirely from those of artificial $\text{Fe}_2(\text{TeO}_3)_3$, mackayite, and blakeite, but is identical with that of durdenite. The spacing data are given in Table 3 and the pattern is shown in Fig. 5. On heating, the material lost water and fused. The residue gave the *x*-ray pattern of artificial anhydrous $\text{Fe}_2(\text{TeO}_3)_3$. In view of the uncertainty as to the true nature of the original emmonsite from Tombstone and the improbability that more complete data on this material will be forthcoming, since there appear to be no specimens extant, it seems advisable to attribute the properties of the material from Cripple Creek to the species. The available data suggest that the two materials were identical.

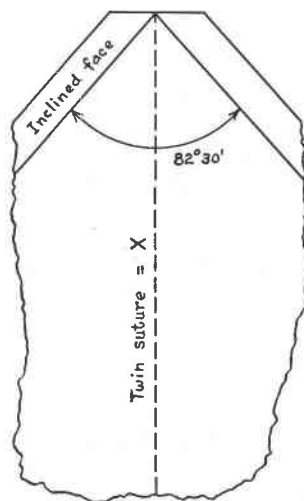


FIG. 1. Microscopic twinned crystal of emmonsite.

Two new occurrences of emmonsite were found in the course of the present study. Emmonsite occurs rather abundantly in oxidized material at Goldfield, Nevada, associated with tellurite and two new minerals, mackayite and blakeite, described beyond. The mineral appears variously, as fibrous crusts with a botryoidal surface, as drusy crusts of mi-

nute indistinct crystals, in dense and compact microcrystalline masses which grade into the matrix and, rarely, as radial groups of rough, serrated, acicular crystals. The matrix is brecciated, ferruginous and silicified rhyolite and dacite. The color of the mineral is bright green, inclining towards pale green and yellowish-green in some of the dense masses. Optically, this material had $X=1.962\pm 0.004$ =light green, $Z=2.12\pm 0.02$ =darker green, and otherwise corresponded to the emmonsite from Cripple Creek. A sketch of a microscopic twin crystal is shown in Fig. 1; X is parallel to the twin suture.

The minute crystals of the druses and radial aggregates are in part outwardly stained or altered to a brownish tint of color. This occurrence appears to have been known for some time, inasmuch as specimens labelled emmonsite from Goldfield, Nevada, were purchased by the Harvard Mineralogical Museum from a dealer in 1930. Ransome (1909) stated that greenish-yellow and canary-yellow selenian ferric tellurites occur as fibrous, lichen-like rosettes in oxidized ore at several localities in the Goldfield district.

Emmonsite also occurs near Silver City, New Mexico, as green botryoidal crusts in crevices in quartz- and pyrite-rich vein material. The mineral has been derived by the alteration of native tellurium, with which it is usually associated. The specific gravity was determined on the microbalance as 4.52.

“DURDENITE”

Durdenite was originally described by Dana and Wells in 1890, who observed greenish-yellow small, mammillary masses associated with selenian tellurium on specimens from the El Plomo mine in the Ojojoma district, Tegucigalpa, Honduras. The analysis by Wells is cited in column 8 of Table 1. The optical constants of a mineral from the type locality ascribed to durdenite were later published by Larsen (1917, 1921). A second occurrence of this mineral in Calaveras County, California, was then established by Larsen by optical measurements. Larsen's optical data follow:

Material from Honduras is optically negative (-) with $2V_{Na}=22^\circ\pm 1^\circ$ and strong dispersion $r>v$. X is perpendicular to a face or cleavage and two other perfect cleavages, possibly faces, occur normal to this one with an angle of 72° between them. Y bisects the acute angles between the cleavages. Strongly pleochroic, with absorption $Z>Y>X$. $X=1.702$, nearly colorless; $Y=1.955$, pale greenish-yellow; $Z=1.965$, pale sulfur yellow (indices ± 0.005). Probably orthorhombic.

Material from California is optically negative (-) with $2V_{Na}=24^\circ\pm 2^\circ$ and has very strong dispersion $r>v$. The grains tend to lie on a cleavage normal to X. $X=1.710\pm 0.005$, $Y=1.94\pm 0.01$, $Z=1.95\pm 0.01$.

Durdenite also was said by Lindgren and Ransome (1906) to occur at Cripple Creek, Colorado, but details of the occurrence are lacking.

A specimen of durdenite from the type locality in Honduras which answered to the original description in every particular was obtained for study from the collection of the American Museum of Natural History (Spec. no. 16832). Two different minerals were present on the specimen. One was a greenish-yellow botryoidal substance which corresponds to the mineral described by Dana and Wells and is their durdenite. The x -ray powder diffraction pattern of this mineral corresponds exactly with that of Hillebrand's emmonsite from Cripple Creek. The following optical data were obtained. Biaxial negative, with small $2V$; $X = 1.962 \pm 0.002$, Z slightly greater than 2.09; strong dispersion with $r > v$. Weakly pleochroic in green with absorption $Z > X$. These data correspond to those given by Larsen (1921) for type emmonsite from Cripple Creek and verified independently by the writers on material from this locality. The chemical analyses of the minerals from the two localities are very similar, and differ principally in the amount of water reported. This discrepancy can carry little weight in view of the nature of the analyses. In light of these facts the identity of durdenite with emmonsite must be accepted. The question of priority of name is vexing, but it appears desirable to retain the name emmonsite for the species.

The second of the two minerals on the Honduras specimens was observed by Dana and Wells and was tentatively identified by them as tellurite. The optical properties of this mineral as determined here correspond exactly with those given by Larsen (1921) for "durdenite" and cited above. Larsen mistook the mineral for the durdenite, which it overlays. The mineral forms tiny, thin, orthorhombic plates with a honey-brown color and an adamantine luster. A spectrographic analysis, kindly made by Dr. Rockwell Kent, Jr., on a Baird two meter grating instrument, revealed the presence of only Fe and Te in significant amounts, with traces of Cu, Ag, Mg, Ca, V, Al, Si and Sb. Selenium may be present, however, in appreciable amounts. The x -ray powder pattern and the optical constants of the mineral are entirely different from those of the other iron tellurites and there is no question but that the mineral is a new and distinct species. It is intended to give a formal description of this mineral at a future time. The x -ray spacing data are listed in Table 3 and the pattern is shown in Fig. 5.

FERROTELLURITE

The name ferrotellurite was given by Genth in 1877 to microscopic tufts of a straw- to lemon-yellow mineral found with tellurite and native tellurium at the Keystone mine, Magnolia district, Boulder Co., Colo-

rado. Qualitative tests showed the presence of iron and tellurous oxide, and the mineral was suggested to be ferrous tellurate, FeTeO_4 . Later, Genth stated in a private communication to E. S. Dana (1892) that it was not impossible that the substance was tellurite colored yellow by a salt of iron. This substance hardly seems worthy of further record in view of the complete lack of definitive characters.

UN-NAMED TELLURITE OF IRON OF KNIGHT

This substance, from Cripple Creek, Colorado, was analyzed by Knight in 1894. The description states only that the substance formed light brown amorphous masses with a dull luster and a bright yellow streak. The hardness is given as between 3 and 4. The material occurred intimately admixed with calaverite. The composition of the HCl-soluble portion of a bulk sample of the mixture, amounting to about 25 per cent of the total, is given in column 1, below. A second, similar analysis of another specimen is given in column 2. The water represents the ignition loss between 100° and 160° .

	Fe_2O_3	TeO_2	H_2O	Total
1.	30.27	68.05	1.68	100.00
2.	35.44	62.79	1.77	100.00

The average of these analyses is not far from the ratio $2\text{Fe}_2\text{O}_3 \cdot 4\text{TeO}_2 \cdot 1\text{H}_2\text{O}$, but this is due to chance as likely as not. If the Te determination is high, as would seem probable, the substance might be a hydrated ferric tellurite. In any case, this substance, like ferrotellurite, lacks definitive characters and hardly could again be recognized with certainty from the existing description.

MACKAYITE

The new mineral described here under the name mackayite was found in specimens from two deposits in Goldfield, Nevada. The better crystals came from a small shaft between the Jumbo and Clermont mines, known as the McGinnity shaft. The tellurites came from the 90 foot level, which is now inaccessible. Crusts of smaller crystals occur on specimens from the Sheets-Ish lease of the Mohawk mine. Mackayite occurs in small, well developed crystals in vugs and seams in silicified rhyolite and dacite, much of which has been converted to a silicified fault breccia. It is associated with abundant crusts and masses of emmonsite, white powdery masses of tellurite, crystals of alunite, quartz and barite, limonite and a few reddish-brown crusts of a second new mineral, blakeite, described beyond. Mackayite is extremely rare and none of the specimens seen were very rich; most of them showed but a few isolated crystals.

At the instance of Mr. C. D. Woodhouse, the writers propose the name mackayite for the species after John W. Mackay (1831–1902), a mining operator who in a few years amassed a great fortune on the Comstock Lode, Nevada. The name is intended to recognize Mackay's financial endowment of the School of Mines of the University of Nevada.

X-Ray Crystallography

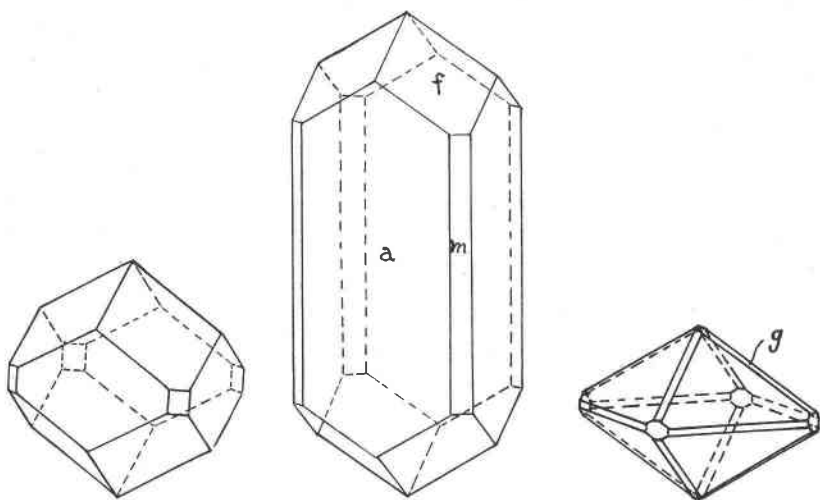
The *x*-ray powder pattern of mackayite is entirely distinct from the patterns of the other known iron tellurites. The spacing data are given in Table 3 and the pattern is represented in Fig. 5. A Weissenberg *x*-ray study was made of a crystal fragment similar in habit to Fig. 2. Rotation 0- and *n*-layer photographs were taken about [001] and rotation and 0-layer photographs about [100] and [110]. The symmetry of the films is entirely in accordance with tetragonal centrosymmetry, $4/mmm$. The cell dimensions as calculated from high order axial reflections on the 0-layer photographs are:

$$a_0 = 11.70 \pm 0.02, c_0 = 14.95 \pm 0.02; a_0 : c_0 = 1 : 1.278.$$

The space group probably is $I/4acd$, which would uniquely fix the point-symmetry as ditetragonal-dipyramidal.

Morphology

Mackayite crystals are well developed and are consistent with ditetragonal-dipyramidal symmetry. No general forms are present. The habit is simple, and varies somewhat in different crystals. Usually all crystals on a single specimen have the same habit. The commonest crystals are those of Fig. 2. Elongated prismatic crystals like those of Fig. 3 were observed on but one specimen. The crusts of exceedingly minute crystals, such as those of the Sheets-Ish lease, seem invariably to be like those of Fig. 4. The form $g \{012\}$ always is exceedingly narrow, giving no definite signal but rather just a brilliant reflection when observed on the goniometer. On most crystals $a \{100\}$ was a broad face, showing some vertical striation, and tending to give a multiple signal in the zone [001]; $m \{110\}$ is narrow, and gives better signals. f was the only face that could be measured on the terminations and it was often not smooth enough to give satisfactory reflections, especially in crystals of any size. In general, because of the character of the reflections, the data from the goniometric measurements is probably less accurate than those given by the *x*-ray measurements. An angle table is given in Table 2. The crystals reached a maximum of 1 mm. in length but most were far smaller.



FIGS. 2, 3 and 4.

TABLE 2. ANGLE TABLE FOR MACKAYITE
 Tetragonal; ditetragonal dipyramidal— $4/m\ 2/m\ 2/m$ (?)
 $a:c=1:1.259$; $p_0:r_0=1.259:1$

Form	ϕ	ρ	Λ	\bar{M}
<i>a</i> 010	0°00'	90°00'	90°00'	45°00'
<i>m</i> 110	45 00	90 00	45 00	90 00
<i>g</i> 012	0 00	32	90 00	68
<i>f</i> 112	45 00	41 41	61 57	90 00

Chemistry

A pure sample of about 150 mg. total weight was separated from about a half kilogram of gangue by a process of magnetic and heavy liquid separation followed by hand picking. Unfortunately a projected analysis cannot be undertaken at the present time due to the diversion of the analyst and laboratory facilities to other work. Qualitative chemical tests revealed the presence of Fe, Te and H₂O as major constituents. A spectrographic examination indicated that only Fe and Te were present in significant amounts. On heating, mackayite fuses, loses water, and the residue gives the x-ray powder pattern of artificial anhydrous Fe₂(TeO₃)₃. Mackayite is similar to emmonsite in this respect. Mackayite is believed to be a hydrated ferric tellurite, either polymorphous with emmonsite, or, more probably, having the same Fe to Te ratio as that species but differing in the content of water of crystallization.

Physical Properties

Mackayite is not cleavable. The fracture is subconchoidal. Brittle. The mineral distinctly scratches fluorite but does not scratch apatite so that the hardness may be given as $4\frac{1}{2}$. The specific gravity was determined on the microbalance as 4.86. This value may be somewhat in error inasmuch as the determination was made on a very small sample of the coarse powder by means of a supplementary wire basket. The luster is vitreous. The color of the mineral varies from light peridot-green to olive- and brownish-green. Some of the larger crystals are greenish-black in color. The streak is light green. Transparent. In crushed grains under the microscope mackayite is greenish-yellow to yellowish-green in color. Optically, the substance is uniaxial positive (+). The indices of refraction were determined in sulfur-selenium melts as $\omega=2.19$, $\epsilon=2.21$ (both ± 0.02). The mineral is very faintly pleochroic with ϵ yellow-green and ω green.

BLAKEITE

The new mineral here described under the name blakeite occurs very sparingly as microcrystalline crusts of a rich brown or deep reddish-brown color. The crusts rest upon unaltered emmonsite crystals. Neither the specific gravity nor the hardness could be determined. The powder easily abrades gypsum and the specific gravity is greater than 3.1. The material is rather harsh to the touch and readily breaks down to a coarse powder. The streak is yellowish-brown while the luster of the aggregate is dull. Under the microscope blakeite appears as brown to golden-yellow and yellowish-brown transparent grains that often present a semblance of cubic outline. No evidence of admixture was seen. The material is either nearly or quite isotropic; some grains are very faintly birefringent, but it is not certain if this is a property of the mineral or is an anomalous feature. The index of refraction, measured in sulfur-selenium melts, is 2.16 ± 0.02 .

A spectrographic examination revealed the presence only of Te and Fe. In comparison to emmonsite and mackayite the mineral contains less Te and more Fe. The x-ray powder diffraction pattern differs entirely from those of the other Fe-Te minerals. The spacing data are given in Table 3 and the pattern is represented in Fig. 5. On heating, blakeite does not fuse or change color. The heated material gives a new x-ray pattern, that represents a mixture of anhydrous ferric tellurite with a substance that appears to be ferric tellurate. A pure sample of approximately 60 milligrams weight was prepared and it is hoped that an analysis can be made at some future date. The mineral is provisionally classed as an anhydrous ferric tellurite, but it is possible that the Te is present in two valences. It is of interest to note that earthy brown

oxygenated compounds of iron and tellurium were reported by Hillebrand (1885) from Tombstone, Arizona, and by Knight (1894) from Cripple Creek, Colorado.

The name blakeite is given in honor of William P. Blake (1826–1910), a pioneer geologist and mineralogist of the American southwest.¹ Blake was the first person to recognize the occurrence of tellurium minerals in California.

PARAGENESIS OF MACKAYITE AND BLAKEITE

Mackayite and blakeite formed in the oxidized zone of the McGinnity and Sheets-Ish ledges. Mr. Hatfield Goudy says* that a crosscut intersecting the same ledge at 120 feet shows only native tellurium and pyrite. There can be little question but that all of the ferric tellurites formed as a result of the alteration of those primary minerals. One specimen showed native tellurium solidly embedded in quartz, while in the fissures were crystals of mackayite and emmonsite.

The sequence of mineralization would appear to be about as follows. The rock, a rhyolite or dacite porphyry, was brecciated and silicified. The quartz phenocrysts of the original rock are still present apparently unaffected in a fine-grained siliceous ground mass. At the same time, small amounts of tellurium and pyrite together with scattered crystals of barite and alunite were deposited. Barite seems to have been a little earlier than the alunite. The solutions which brought about this alteration presumably were ascending hypogene. All of the subsequent alteration, on the other hand, is clearly the result of descending supergene solutions. The age relationship between emmonsite and mackayite is very confusing and it seems likely that formation was almost simultaneous, with one or the other forming dependent upon local conditions. Specimens were seen in which mackayite crystals had commenced to alter to emmonsite on the surface, and on the other hand, small radiating rosettes of emmonsite were seen to be slightly corroded while mackayite in the same specimen was quite fresh. Presumably some change in the character of the solutions could function to make one or another of the two minerals stable at the same time in different portions of the vein. Though the emmonsite was corroded and the mackayite fresh in one specimen, in another specimen small spheres of emmonsite were perched on a type 1 mackayite crystal. Blakeite is clearly later than either of the two; in the best specimen it formed a thick rather loose layer over some of the best unaltered emmonsite crystals which were seen. Thin limonite films were also seen to coat the tellurites, but other limonite stained sur-

¹ An appreciation of Blake's life and work is given in the *Bull. Geol. Soc. Am.*, **22**, 36–47 (1911).

* Personal communication.

faces were flecked with mackayite and emmonsite, so this substance can be considered a mineral of all stages of the oxidation.

ARTIFICIAL FERRIC TELLURITE AND FERRIC TELLURATE

Ferric tellurite was prepared by the standard method of adding a weakly acid solution of ferric chloride to a solution of sodium tellurite in the theoretical proportions. The voluminous brown precipitate was allowed to stand in contact with the faintly acid mother liquid for 48 hours. The precipitate, after filtration and washing, dried out to a hard hydrous gel that did not give an x -ray diffraction pattern. The material gave a rather diffuse pattern with a heavy background after heating to 510°C. The pattern became quite clear and sharp when the material was heated at 750°. The substance did not fuse. The residue obtained by fusing emmonsite and mackayite gives the x -ray pattern of this substance. The spacing data are given in Table 3 and the pattern is shown in Fig. 5. Under the microscope the artificial material appeared homogeneous, and was composed of a fine-grained yellowish-brown to yellow and greenish-yellow substance with strong birefringence and very high indices. An attempt was made to prepare ferrous tellurite by starting with ferrous sulfate and sodium tellurite but the product oxidized very rapidly to ferric tellurite.

Efforts to prepare ferric tellurate were not entirely successful. The substance was precipitated by the reaction of ferric chloride and sodium tellurate in water solution in the required proportions. The air-dried gel did not give an x -ray pattern, and material heated at 450° gave only a very faint pattern that was badly fogged. A sample heated at 750° when examined under the microscope was found to consist of a mixture of two substances: a yellowish-green material with strong birefringence that appeared to be identical with ferric tellurite, and a material forming flat hexagonal plates of a deep reddish-brown color. The latter substance may be ferric tellurate. An x -ray photograph of the mixture showed almost all of the lines of ferric tellurite together with a number of additional lines. The stronger ones of these extra lines were present in the pattern of the residue obtained by heating blakeite to 750°. The presence of ferric tellurite in the heated sample of artificial ferric tellurate probably is due to the reduction of the tellurate at high temperatures. Lenher and Wolesensky (1913) have shown that the alkali tellurites oxidize to tellurates when heated to about 450° but that the alkali tellurates are reduced to tellurites when heated above 450° to red heat. Only half of the Te in the alkali ditellurites appears to oxidize on heating.

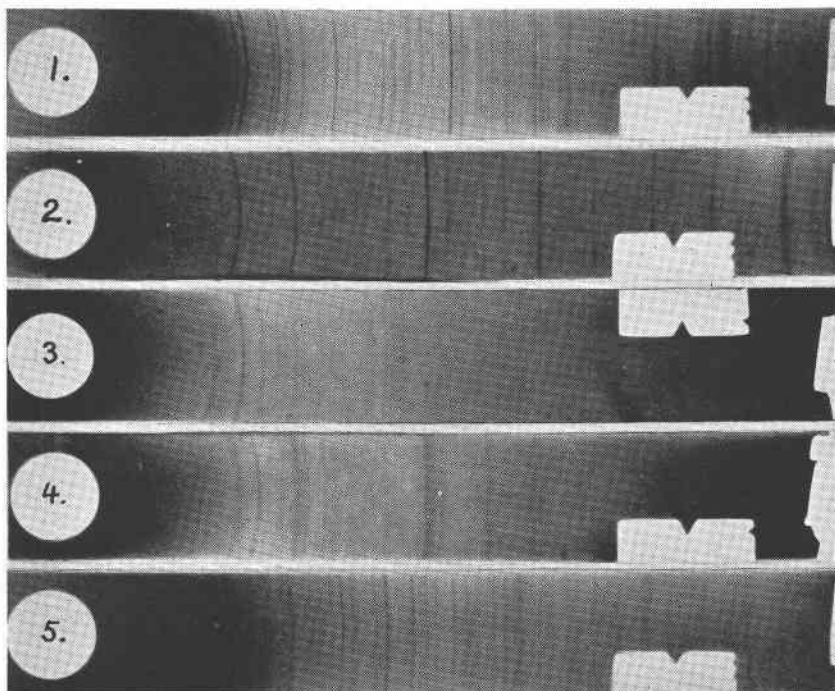


FIG. 5. X-ray powder photographs of iron tellurites. Fe radiation, unfiltered.

1. Mackayite. Goldfield, Nevada.
2. Artificial $\text{Fe}_2(\text{TeO}_3)_3$.
3. Emmonsite. Goldfield, Nevada. Identical patterns are given by "durdenite" from Honduras and emmonsite from Cripple Creek.
4. Blakeite. Goldfield, Nevada.
5. New, undescribed iron tellurite from Honduras.

TABLE 3. X-RAY SPACING DATA FOR IRON TELLURITES. FE RADIATION. SPACINGS BELOW 1.47 ARE NOT LISTED.

Emmonsite		Mackayite		Blakeite		Artificial Fe ₂ (TeO ₃) ₃		New Fe-Te Mineral (Hondura)	
<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>	<i>d</i>	<i>I</i>
5.80	7	6.18	1	5.44	5	4.56	1	7.83	2
4.05	6	5.57	1	4.20	5	4.12	3	7.31	2
3.68	8	5.46	1	3.71	1	3.61	1	7.13	5
3.62	6	5.07	1	3.51	1	3.27	9	6.32	1
3.56	6	4.94	7	3.33	7	2.79	2	5.74	9
3.47	1	4.08	1	3.00	10	2.72	1	3.92	3
3.39	3	3.93	1	2.88	1	2.66	1	3.75	1
3.29	4	3.74	6	2.79	1	2.54	8	3.70	2
3.13	10	3.64	2	2.69	3	2.32	3	3.57	6
3.06	2	3.50	3	2.54	9	2.29	1	3.40	2
2.97	1	3.31	8	2.45	4	2.23	3	3.34	10
2.90	2	3.16	10	2.29	5	2.06	2	3.23	7
2.86	9	3.08	1	2.26	1	2.02	2	3.05	4
2.76	1	2.99	1	2.22	2	1.88	3	2.98	4
2.69	8	2.93	5	2.19	2	1.87	1	2.94	1
2.62	2	2.89	5	1.93	1	1.85	1	2.86	4
2.51	9	2.77	6	1.91	5	1.80	1	2.79	4
2.48	3	2.71	7	1.87	1	1.71	10	2.75	1
2.43	1	2.61	4	1.82	1	1.63	4	2.64	2
2.38	1	2.58	2	1.75	2	1.61	1	2.57	1
2.29	7	2.50	1	1.72	8	1.54	1	2.54	5
2.25	3	2.47	6	1.69	3	1.52	4	2.40	1
2.21	6	2.44	1	1.66	3	1.49	1	2.37	2
2.17	1	2.38	1	1.57	1	1.46	4	2.35	2
2.13	1	2.29	1	1.56	2	1.39	1	2.31	2
2.05	4	2.21	7	1.50	6	1.37	6	2.28	2
2.01	1	2.11	2	1.45	2	1.27	3	2.21	2
1.98	4	2.06	5	1.39	1	1.22	1	2.12	7
1.95	7	2.03	1	1.37	1	1.18	5	2.06	3
1.93	1	1.91	5	1.29	1	1.15	1	2.03	3
1.88	4	1.86	3	1.15	1	1.11	5	1.99	1-
1.85	6	1.85	4			1.08	3	1.97	1-
1.83	1	1.81	2			1.07	1	1.93	4
1.81	1	1.79	2			1.05	7	1.87	8
1.80	8	1.78	4					1.85	1
1.75	2	1.73	4					1.76	1
1.73	2	1.70	2					1.75	6
1.71	1	1.69	4					1.72	1
1.69	1	1.66	1					1.70	3
1.68	1	1.64	1					1.66	3
1.66	2	1.61	9					1.63	1
1.64	2	1.60	3					1.59	5
1.63	1	1.58	5					1.55	3
1.58	2	1.56	1					1.54	1-
1.57	2	1.53	1					1.52	3
1.55	1	1.52	4					1.49	2
1.54	1	1.50	1					1.47	3
1.52	1	1.49	4						
1.47	2	1.47	1						

REFERENCES

- DANA, E. S., AND WELLS, H. L., *Am. Jour. Sci.*, **40**, 78 (1890).
DANA, E. S., *System of Mineralogy*, New York, 6th ed., 980 (1892).
GENTH, F. A., *Proc. Am. Phil. Soc.*, **17**, 119, for 1877 (1878).
HILLEBRAND, W. F., *Proc. Colorado Sci. Soc.*, **2**, 20 (1886).
HILLEBRAND, W. F., *Am. Jour. Sci.*, **40**, 81 (1890).
HILLEBRAND, W. F., *Am. Jour. Sci.*, **18**, 433 (1904); also in *U. S. Geol. Surv., Bull.* **262**, 56 (1905).
KNIGHT, F. C., *Proc. Colorado Sci. Soc.*, **5**, 66 (1894-1896).
LARSEN, E. S., *Am. Mineral.* **2**, 45 (1917).
LARSEN, E. S., *U. S. Geol. Surv., Bull.* **679** (1921).
LARSEN, E. S., AND BERMAN, H., *U. S. Geol. Surv., Bull.* **848** (1934).
LENHER, V., AND WOLESENSKY, E., *Jour. Am. Chem. Soc.*, **35**, 718 (1913).
LINDGREN, W., AND RANSOME, F. L., *U. S. Geol. Surv., Prof. Pap.* **54**, 118 (1906).
RANSOME, F. L., *U. S. Geol. Surv., Prof. Pap.* **66**, 133 (1909).