REDEFINITION OF TELLUROBISMUTHITE AND VANDIESTITE.

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ABSTRACT. Tellurobismuthite, long considered to be a variety of tetradymite, is a distinct species. Composition Bi$_2$Te$_3$. Rhomboedral, with $a_n=10.51$ and $a=24^\circ27'$. Cell contents in the rhomboedral unit = Bi$_2$Te$_3$. The chemical and physical proportions are described and eleven localities, five of which are new, are cited.

The supposed species vandiestite is shown by X-ray study and a new chemical analysis to be a mixture of tellurobismuthite and hessite.

TELLUROBISMUTHITE.

The known analyses of the natural bismuth tellurides aside from those relating to gruenlingite, joseite, and wehlrite fall into two groups: (1) analyses that contain four to five per cent S and which are close to the formula Bi$_2$Te$_5$S (tetradymite, type) and (2) analyses that contain <0.7 per cent S and which are close to the formula Bi$_2$Te$_2$. The significance of this difference in composition has long been uncertain. Tetradymite was viewed by Rose (1849) as a solid solution of Bi, Te, and S, and Genth (1885) represented Bi$_2$Te$_3$, Bi$_2$Te$_2$S, and metallic Bi by the formula Bi$_2$(Te,Se,S,Bi)$_3$. Dana (1892) similarly classed the material of the composition Bi$_2$Te$_3$ as a compositional variant of tetradymite proper, and this usage has been followed in recent descriptions by Short and Henderson (1926) and others. On the other hand, Wherry (1920), Doelter (1926), Balch (1863), and others have considered Bi$_2$Te$_3$ and Bi$_2$Te$_2$S to be distinct species, on the assumption that the rôle of S is unique and not in the nature of an isomorphous substitution, and the opinion that Bi$_2$Te$_2$S is a definite compound was early held by Berzelius (1831). However, definite proof of the major contentions, that the two substances are members of an isomorphous series or were distinct compounds, has been lacking.

X-ray study by Lange (1939) has now shown that Bi$_2$Te$_3$ and Bi$_2$Te$_2$S co-exist in regions of the artificial system Bi-Te-S, and that the transition Bi$_2$Te$_3$-Bi$_2$Te$_2$S therefore must be discontinuous. An earlier study of this system by Amadori (1915, 1918) led to the recognition of Bi$_2$Te$_3$,Bi$_2$S$_3$, and Bi$_4$Te$_3$S$_3$, but no indication was found of Bi$_2$Te$_2$S or Bi$_4$TeS$_3$; the observed phases crystallized out in the pure state.

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or in eutectic mixtures, and no evidence of solid solution between Te and S was observed. The freezing point, electrical conductivity, and magnetic susceptibility curves of the system Bi-Te also show sharp singularities corresponding to Bi₂Te₃. Further, it may be noted that a complete compositional variation in point of S content of the natural materials is lacking, and that the two minerals sometimes occur together in microscopic intergrowth. In view of these facts, the natural material of the composition Bi₂Te₃ must be considered to be a species distinct from tetradymite. The name tellurobismuthite, originally suggested by Wherry (1920), is adopted for this mineral. A description of tellurobismuthite, based on the examination of a large suite of natural material known from chemical analysis or X-ray study to be Bi₂Te₃, follows.

CRYSTALLOGraphy.

Found only as foliated masses or irregular plates flattened \{0001\}. Artificial Bi₂Te₃ is rhombohedral, with the space group \textit{R} \textit{3m}, \textit{R}3 \textit{2} or \textit{R}3. Cell dimensions (Lange): \(a_o = 4.37\), \(c_o = 30.42\) (hexagonal coördinates); \(a_{rh} = 10.45\), \(a = 24^\circ 8'\). Cell contents in the rhombohedral unit = Bi₂Te₃. X-ray powder patterns of analyzed natural Bi₂Te₃ from Hachita, New Mexico, and from Whitehorn and Mt. Sierra Blanca, Colorado, were identical, aside from very slight differences in cell dimensions, with the pattern of artificial Bi₂Te₃. The cell dimensions \(a_o = 4.38\) and \(c_o = 30.6\), \(a_{rh} = 10.51\) and \(a = 24^\circ 2'\), were obtained for the material from Whitehorn. Slightly different cell dimensions among material from other localities were apparent by direct comparison of the films. In faint films a pseudo cell with \(c_o\) one-third the true value may be obtained.¹ The tellurobismuthite patterns as a group are readily distinguished from those of tetradymite (Fig. 1, for Cu radiation), although there is a marked general similarity between the patterns of the two minerals.

Tetradyomite also is rhombohedral, with the space group \textit{R} \textit{3m}, \textit{R}3 \textit{2} or \textit{R}3, and with cell dimensions \(a_o = 4.32\), \(c_o = 30.01\) very close to those of tellurobismuthite. Structurally, both tellurobismuthite (Lange, 1939) and tetradyomite (Harker,

¹ A cell with \(c_o\) thirded \(a_o = 4.24, c_o = 11.10\); Co radiation; material from Mt. Sierra Blanca, Colorado) was earlier reported by the writer in an abstract—Amer. Min. 25, 208, 1940.
1934) are composed of layers of Bi and Te or of Bi₂Te₄ and S atoms stacked parallel [0001] essentially in the fashion of cubic close-packing. In tellurobismuthite layers of Te atoms take the place of the layers of S atoms in tetradyrmite. The perfect basal cleavage, rhombohedral symmetry, and intermetallic properties of gruenlingite (Bi₄Te₃S₈), joseite (Bi₃Te₈S), and wehrlite (Bi₃Te₂?) suggest that these minerals also are variations on the general structural scheme of tetradyrmite.

**Physical Properties.**

Cleavage {0001} perfect. May exhibit a distinct parting inclined at about 62° to {0001}; only one direction was observed, but presumably three equivalent directions are present. The ρ angle of this parting is close to the ρ angle, 63°30½', of {1011} of tetradyrmite in the orientation and unit of Haidinger (1831). Laminae flexible, but not elastic. Hardness 1½ to 2. Specific gravity 7.82. The calculated specific gravity of the artificial material is 7.87, and of the natural material (a₀ = 4.38, c₀ = 30.6; Whitehorn, Colorado) is 7.79. Melting point 573° C. (artificial material (Mönckemeyer, 1905)). Luster metallic, splendent on fresh cleavages and tarnishing dull or iridescent. Color and streak pale lead gray. Soils paper. Thermoelectrically negative (material from Dahlonega, Georgia (Schrauf and Dana, 1894)). Sometimes exhibits a triangular set of striations at 60° on cleavage surfaces, apparently due to gliding accompanying mechanical deformation. The inclined parting mentioned above may be of this origin. Also translation gliding with T {0001}.

Etch reactions on polished surfaces for the known bismuth tellurides are summarized in Table 1. The writer is indebted to Mr. Esper S. Larsen, 3rd, of Harvard University, for contributing this data. The identity of all of the specimens was verified by X-ray powder photographs. The joseite used was the type material of Damour, and the X-ray data for this species and for gruenlingite is identical with that given by Garrido and Feo (1938). It may be remarked that the etch

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2 Average of the value 7.816 (pycnometer) obtained by Hillebrand (1908) on material from Whitehorn, Colorado, and verified (7.81, microbalance) by the writer, and the value 7.83 obtained here on material from Mt. Sierra Blanca, Colorado (anal. 3, Table II). The range of all reported values is 7.65 ± 0.16.
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Table 1.
Etch Reactions for Tellurobismuthite, Tetradyomite, Grueningite, and Joseite.

<table>
<thead>
<tr>
<th></th>
<th>Tellurobismuthite</th>
<th>Tetradyomite</th>
<th>Grueningite</th>
<th>Joseite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>White</td>
<td>White</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Hardness</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Polarized Light</td>
<td>Weakly anisotropic in gray, yellow gray</td>
<td>Weakly anisotropic in gray, yellow gray</td>
<td>Weakly anisotropic in gray, yellow gray</td>
<td>Weakly anisotropic in gray, yellow gray</td>
</tr>
<tr>
<td>HNO$_3$</td>
<td>Efferv. Tarnish brown to black, Fumes tarnish</td>
<td>Efferv. Tarnish black, Fumes tarnish</td>
<td>Efferv. Tarnish black, Fumes tarnish</td>
<td>Efferv. Tarnish black, Fumes tarnish</td>
</tr>
<tr>
<td>HCl</td>
<td>Faint tarnish, gray or brown; very slow</td>
<td>Almost negative</td>
<td>Almost negative</td>
<td>Very slow tarnish, gray</td>
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<tr>
<td>KCN</td>
<td>Negative</td>
<td>Negative</td>
<td>Almost negative, faint brown tarnish</td>
<td>Negative</td>
</tr>
<tr>
<td>FeCl$_3$</td>
<td>Rapid tarnish, gray or iridescent; sometimes slow</td>
<td>Rapid tarnish, gray to iridescent</td>
<td>Rapid tarnish, gray</td>
<td>Rapid tarnish, gray</td>
</tr>
<tr>
<td>KOH</td>
<td>Almost negative, tarnish gray to iridescent</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>HgCl$_2$</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Weak tarnish, brown to iridescent</td>
</tr>
</tbody>
</table>

tests given by Wahlstrom (1937), Short (1934), and Davy-Farnham (1920) for tetradyomite are not in agreement, and differ somewhat from the data here given. The tests cited by Murdoch (1916) are at complete variance with the other work and probably refer to bismuthian galena. The data given for tellurobismuthite (described as tetradyomite) by Short and Henderson (1926) also differ slightly from that given here. It is seen from the present data that no certain separation between the four bismuth tellurides can be made in polished section. The minerals are best identified by their X-ray powder patterns. The specific gravities are diagnostic, but accu-
rate results are difficult to obtain because of the plasticity and ready cleavage of the material.

Microscopic intergrowths of tetradymite with other bismuth tellurides have been reported by Shonon (1931), Dunham (1935), and Schneiderhöhn-Ramdohr (1931). A foliated tin-white telluride from Boliden, Sweden, was found by X-ray examination in the course of the present study to be a mixture of tetradymite and tellurobismuthite. An oriented microscopic intergrowth of gruenlingite and native bismuth has also been reported (Garrido, 1933; Garrido and Feo, 1938), and was originally described as a distinct species under the name orucite, Bi₈TeS₄.

COMPOSITION.

An intermetallic compound, Bi₂Te₅. Small amounts of Se (up to 0.20 weight per cent) in substitution for Te have been reported. The small amounts of S sometimes found are probably due to admixture of tetradymite or sulphides. The older analyses have been tabulated by Doelter (1926), to which may be added the analyses of Short and Henderson (1926), Henderson (1937), and Yagi (1936).

OCURRENCE.

The following localities, five of which are new, have been substantiated by chemical analysis or by X-ray examination. The distinction between tellurobismuthite and tetradymite still remains to be made for many of the occurrences of the bismuth tellurides mentioned in the literature.

Found in hypothermal quartz veins at Tellurium mine, Fluva County, Virginia, and similarly at Field's vein, Dahlonega, Georgia. In Montana in flakes in a gold placer at Highland, and near Garnet with native gold in calcite. From the Little Mildred mine, Hachita, New Mexico, with tourmaline, hessite, and native gold in a quartz vein. In Colorado from Whitehorn and from Mt. Chipeta in Fremont County, with hessite and native gold at the Hamilton and Little Gerald mines on Mt. Sierra Blanca, San Luis County, with beegerite (?) at the Treasure Vault mine, Clear Creek County. Intergrown with tetradymite at Boliden, Sweden. In Japan at Oya, Miyagi prefecture.

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IDENTITY OF VANDIESTITE WITH TELLUROBISMUTHITE.

Vandiostite was described by Pearce (1902) as a telluride of bismuth and silver, approximately Ag₅BiTe₄, from the Little Gerald and Hamilton mines on Mt. Sierra Blanca, San Luis County, Colorado. A suite of specimens from the original locality was examined.³ The specimens exhibited foliated masses of the so-called vandiostite associated with quartz, abundant hessite, and minor amounts of native gold, pyrite, and chalcopyrite. Stains of a green alteration product, presumably montanite, are present on most specimens. In polished section the vandiostite was seen to be intimately intergrown with hessite, with occasional thread-like inclusions of native gold and specks of altaite (?). X-ray powder photographs of vandiostite taken from different specimens proved to be identical with tellurobismuthite.

A sample of vandiostite known to contain a small amount of admixed hessite was analyzed by Mr. F. A. Gonyer.⁴ The results of this analysis are tabulated together with the original analyses in Table 2. The new analysis may be recalculated

<table>
<thead>
<tr>
<th>Table 2. Analyses of Vandiostite.</th>
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<td>1</td>
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<tr>
<td>---</td>
</tr>
<tr>
<td>Bi</td>
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<tr>
<td>Pb</td>
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<tr>
<td>Au</td>
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<tr>
<td>Ag</td>
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<tr>
<td>Te</td>
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<tr>
<td>S</td>
</tr>
<tr>
<td>Insol.</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

1. Knight analysis in Pearce (1902).
2. Knight analysis in Pearce (1902).
3. Gonyer analysis, May 1937. Au, S, As, Sb, Cu and Fe not present.
4. Analysis 3 recalculated to 100 after deduction of the Ag as hessite, Ag₅Te₄.
5. Bi₅Te₄. Theoretical composition.

³ Loaned through the courtesy of Dr. W. F. Foshag, Curator, Division of Mineralogy, U. S. National Museum. Other specimens were examined from the collections of Harvard University and the American Museum of Natural History.

⁴ The writer is indebted to Prof. Walter H. Newhouse, Massachusetts Institute of Technology, for a grant to pay the cost of this analysis.
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into a mixture of 7.9 per cent hessite and 92.1 per cent tellurobismuthite and, in conjunction with the X-ray work, leaves no doubt of the identity of vandiestite with tellurobismuthite. Analysis 2 of Knight corresponds to a mixture of 1.75 per cent gold, 4 per cent altaite, 55 per cent hessite, and 36.5 per cent tellurobismuthite. It is surprising that a mixture of these proportions should have been taken as homogeneous; however, the hessite occurs in the interstices of thin interlocking plates of tellurobismuthite and is easily confused with that mineral or overlooked entirely.

References.


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