THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 31 NOVEMBER-DECEMBER, 1946 Nos. 11 and 12

MONTBRAYITE, A NEW GOLD TELLURIDE

M. A. PEACOCK AND R. M. THOMPSON,
University of Toronto, Toronto, Canada.

ABSTRACT[1]

Triclinic; $a=12.08$, $b=13.43$, $c=10.78$ kX, $\alpha=104°30\frac{1}{2}'$, $\beta=97°34\frac{1}{2}'$, $\gamma=107°53\frac{1}{2}'$; partings, $(\bar{1}10)$, $(01\bar{1})$, $(\bar{1}1\bar{1})$; $(01\bar{1}):(\bar{1}1\bar{1})=41°20'$, $(\bar{1}1\bar{1}):(\bar{1}10)=46°45'$, $(\bar{1}10):(01\bar{1})=69°31'$. Fracture flat conchoidal. Very brittle. $H=2\frac{1}{2}$. $G=9.94$. Lustre metallic. Colour yellowish white. Polished sections white, moderately anisotropic, and homogeneous, except for inclusions of tellurbismuth, altaite, and petzite. Analysis by J. R. Williams: Au 44.32, Te 49.80, Bi 2.81, Pb 1.61, Sb 0.90, Ag 0.55, Fe trace; total 99.99. Cell content near $12[Au_2Te_3]$. Strongest *x*-ray powder lines: 2.97 kX (8), 2.92 (8), 2.08 (10), 1.717 (2), 1.699 (2). Embedded with gold, tellurbismuth, altaite, petzite, melonite, chalcopyrite, pyrite, sphalerite, chalcocite, and marcasite, in the Robb-Montbray mine, Montbray township, Abitibi County, Quebec.

The mineral described in this paper is an arresting constituent of the rich masses of tellurides, sulphides, and free gold produced by the Robb-Montbray mine in Montbray township, Abitibi County, Quebec, during the period 1925–28. The history and geology of this group of prospects, which produced spectacular specimen material but no commercial quantity of ore, is described by Cooke, James & Mawdsley (1931, pp. 224–227). The late Professor Ellis Thomson (1928) gave a mineralographic description of a suite of specimens, and we have recently described melonite from the same locality (1946*b*). The present paper is concerned mainly with the specific properties of the new gold telluride for which we have proposed the name *montbrayite* (1945, 1946*a*).

Mr. H. S. Wilson, consulting geologist at Bourlamaque, Quebec, has been kind enough to send us some notes based on his recollection of the discovery of the rich ore. From these notes the high-grade pocket of gold and tellurides was a flat mass, perhaps six feet in length, three to four feet in width, and from one to two inches thick, which occupied a tensional fracture on one wall of a nearly vertical, partly gouge-filled slip between the first and second levels of the mine. The material at our disposal consisted of several fine specimens generously presented by

---

[1] Improving in some details the previously published abstracts (Peacock & Thompson, 1945, 1946*a*).

R. A. Bryce, Esq., President of the Macassa Mines Limited, and Dr. M. H. Frohberg, of the same company, and two handsome specimens, M 15815 and M 19883, kindly lent for study from the Royal Ontario Museum of Geology and Mineralogy by Dr. V. B. Meen. The first of these museum specimens comprised a dozen pieces representing the material which had been studied and described by Thomson (1928), while the second is perhaps the largest piece of the ore that has been preserved (500 gm.).

Physical and microscopical characters. The pieces of telluride ore are compact coarsely crystalline masses of metallic minerals almost wholly free from gangue, mostly somewhat tabular in shape, 1–2 cm. thick and up to 12 cm. wide. The broad surfaces which were apparently in contact with the wall-rock, are often dull and pitted and partially coated with a bluish-gray flour-like material which gave an x-ray powder photograph that could not be identified. Some of these surfaces are also encrusted with considerable amounts of coarse sponge and wire gold. Freshly broken surfaces show coarsely crystallized aggregates of metallic minerals, tellurbismuth (Bi_2Te_3), altaite (PbTe), montbrayite (Au_2Te_3), petzite (Ag_3AuTe_2), melonite ($NiTe_2$), and gold, with chalcopyrite, pyrite, sphalerite, chalcocite, and marcasite, all of which were definitely identified by physical, chemical, microscopical, and röntgenographic methods. Referring to the description by Thomson (1928), which was written in the earlier days of mineralography, it is clear that his "tetradymite" is tellurbismuth and his "krennerite" is the new montbrayite; pyrrhotite and a single example of coloradoite were mentioned by Thomson but not observed by us, while we have found small amounts of melonite and marcasite which were not noted by Thomson.

The gold telluride is abundant in some specimens, forming equidimensional masses sometimes exceeding 1 cm. in diameter. Occasionally such masses show perfect but interrupted planes of separation extending the full width of the mass and proving that it is structurally continuous. This appearance of a perfect cleavage, together with the general physical and chemical properties, at once suggest krennerite, but closer study showed that our mineral cannot be identified with that species.

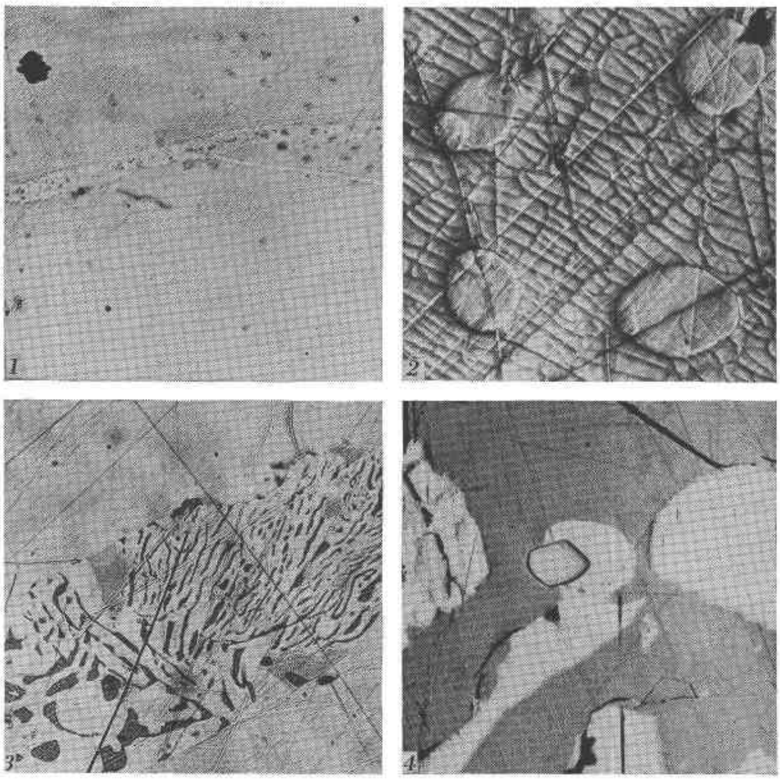
Montbrayite has a splendent metallic lustre and a yellowish-white colour which is slightly lighter than that of calaverite. The mineral is very brittle and it breaks with a flat conchoidal fracture. The hardness is $2\frac{1}{2}$ and the specific gravity is 9.94, which is the average of values ranging from 9.90 to 9.98 obtained on seven fragments measured separately on the Berman balance. This specific gravity is distinctly higher than that of any similar mineral and it was this property that first suggested a closer study of the gold telluride.

Montbrayite polishes to a smooth homogeneous surface which is creamy white in reflected light, like the colour of krennerite, and distinctly less white than altaite (Figs. 1, 3). Reflection pleochroism is rarely perceptible and the anisotropism is weak to moderate with polarization colours light gray, light yellow-brown, blue-gray, varying somewhat with the orientation. The mineral makes coarse solid mosaics with optically continuous areas often several millimeters in width. Crossed nicols reveal no evidence of twinning. The Talmage hardness is *C*.

The reactions to the standard etch-reagents are as follows: HNO_3 positive with effervescence; HCl, KCN, $FeCl_3$, KOH, $HgCl_2$, all negative. Short (1937) has given a detailed account of the etch-reactions with HNO_3 in various concentrations, for a set time, on oriented sections of calaverite, krennerite, and sylvanite. We were able to duplicate some of these results and we applied the same procedure to montbrayite. The etch-reactions on random sections are as follows: HNO_3 (1:1), strong effervescence; surface stains light yellow-brown with several small (50 micron) circular areas staining light gray. After the drop has been removed an "alligator-skin" etch-pattern develops leaving the circular areas in relief (Fig. 2). This pattern resembles the two-directional "etch-cleavages" illustrated by Short (1937), and it may be connected with the partings and flat conchoidal fracture of the mineral. HNO_3 (3:2), slower effervescence; surface stains light brown with development of small circular areas similar to the above which are also stained light brown. After the drop has been removed an etch-pattern develops with one prominent direction. An "epidermis" a few microns thick tends to come off and curl up at the edges; this may be completely removed with hard buffing, the surface again becoming apparently homogeneous. HNO_3 (conc.), very slow effervescence; surface stains uniformly light gray-brown. No etch-pattern develops after the drop has been removed; circular areas are absent.

The relatively unetched or little etched circular areas in montbrayite are similar to those described by Short in krennerite and calaverite, and it is natural to suppose that they are areas that differ in some way, perhaps very slightly, from the surrounding mineral. The areas are not distinguishable on an unetched surface and they are too small to be sampled for separate tests. Comparing all the microscopic characters of montbrayite with those of krennerite and calaverite it will be seen that there is little prospect of definitely distinguishing the three minerals by ordinary mineralographic methods.

The following minerals are found in contact with montbrayite or enclosed within the gold telluride: altaite, tellurbismuth, petzite, gold, chalcopyrite, and melonite (Figs. 1–4). Altaite, with small amounts of gold and petzite, occurs in thin stringers cutting montbrayite (Fig. 1). Tellurbismuth with subordinate altaite and small patches of petzite make ovoid inclusions with a eutectoid structure, irregularly distributed



Figs. 1–4. Montbrayite and associated minerals: polished sections in ordinary reflected light. Fig. 1. Homogeneous montbrayite traversed by a veinlet of altaite containing particles of gold and petzite. ×92. Fig. 2. Montbrayite etched with 1:1 HNO_3 for 40 seconds, showing "alligator-skin" etch-pattern and relatively little etched rounded areas in relief. ×197. Fig. 3. Ovoid inclusion of tellurbismuth (light gray), altaite (dark gray), and petzite (medium gray), in montbrayite; tellurbismuth and altaite show eutectoid relations; etched with HCl. ×92. Fig. 4. Subhedral crystal of melonite, with relief, in contact with montbrayite (light gray) and petzite (dark gray); the light gray areas to the right and below are gold. ×92.

through montbrayite (Fig. 3). In total bulk these inclusions might amount to 10 per cent of the montbrayite and in some cases they reach 1 mm. in diameter. In ordinary light the altaite shows as straight or curved bluish white bands within the tellurbismuth, which is faintly reddish white by contrast and not easily distinguished from the surrounding montbrayite. Crossed nicols emphasize the anisotropic tellurbismuth, and staining with HCl darkens the bands of altaite (Fig. 3). These inclusions have the appearance of exsolution products. Petzite occurs as irregular areas often surrounding and traversing patches of montbrayite, and occasionally cutting altaite, tellurbismuth and melonite. Subhedral hexagonal crystals of melonite, with or without partial rims of petzite, occur in montbrayite, but the best crystal outlines are shown by isolated plates of melonite in altaite. The chalcopyrite does not occur in the montbrayite itself but at the boundaries of altaite, tellurbismuth, petzite, and gold with montbrayite.

Crystallography. In the compact ore masses the gold telluride had no chance to develop a crystal form, but the plane separation surfaces developed on some broken masses and fragments offered an opportunity for crystallographic measurements. To discover whether a separation plane corresponds to the basal cleavage of krennerite, or the side-pinakoidal cleavage of sylvanite, a fragment was rotated about the normal to one of these mirror-like surfaces to give a rotation photograph. The picture was that of a single crystal in random orientation, showing that the gold telluride is not structurally similar to krennerite or to sylvanite, or to calaverite, which has no cleavage.

Among many fragments examined a few were found with two planes of separation meeting in an edge. Measurements of the interfacial angles on a dozen fragments gave three different angles, indicating that there are in fact three planes of separation, all of which were eventually found on a single fragment. The three planes of separation, *A*, *B*, *C*, gave good to excellent reflections and the following quite consistent interfacial angles on the reflecting goniometer:

BC=41°17′–41°32′ (3); weighted average 41°20′
CA=46°42′–46°48′ (4); weighted average 46°45′
AB=69°30′–69°34′ (5); weighted average 69°31′

These planes of separation are unlike crystal cleavages in several respects: they occur only on limited parts of broken surfaces and on the minority of broken fragments; they can rarely be developed at will; they sometimes pass in a curious way from a perfect plane into a warped fracture surface; and finally, the planes do not have the simplest symbols in the crystal lattice. The planes are therefore partings, rather than difficult cleavages, as given in the recent abstract (1945, 1946*a*). The possibility that two of these partings, or all three, might be crystallographically equivalent was constantly kept in mind, but no alternative was found to the conclusion that each is parallel to a different set of planes in a triclinic lattice.

Rotation photographs were taken with copper radiation on parting fragments turning around each of the three parting-edges, and Weissenberg resolutions were made of the zero and first layers about the edges C/A and A/B. The Weissenberg photographs were unusual in showing a relatively small number of unsystematically distributed strong spots while the remaining spots, including the rows from the parting planes, were quite faint. The projections gave asymmetric reciprocal lattice nets, offset on the first layers, indicating a triclinic lattice.

The most accurate lattice constants were considered to be the spacings of the parting planes and provisional axial planes $d(A)$, $d(B)$, $d(C)$, measured on the zero-layer Weissenberg photographs, and the interplanar angles BC, CA, AB, measured on the reflecting goniometer and verified on the Weissenberg photographs. From these constants the dimensions of a preliminary simple triclinic cell, a', b', c', α', β', γ', were calculated and the cell edges thus obtained were closely verified by values for a', b', c', measured on the three rotation photographs.

From zero-layer Weissenberg photos	Calculated	From rotation photos
$d(A)=10.24$ kX	$a'=14.96$ kX	$a'=14.98$ kX
$d(B)=9.34$ kX	$b'=15.05$ kX	$b'=15.06$ kX
$d(C)=7.41$ kX	$c'=15.36$ kX	$c'=15.42$ kX
$BC=41°20'$	$\alpha'=138°30\frac{1}{2}'$	
$CA=46°45'$	$\beta'=133°03\frac{1}{2}'$	
$AB=69°31'$	$\gamma'=70°00'$	
	$V'=1567.9$ kX^3	

This preliminary cell, shown with broken lines in Fig. 5, is unconventional since its edges are not the shortest lattice periods. The conventional cell, whose edges a, b, c, are the three shortest non-coplanar lattice periods, oriented with $c<a<b$, α and β obtuse, is related to the preliminary cell by the reversible transformations:

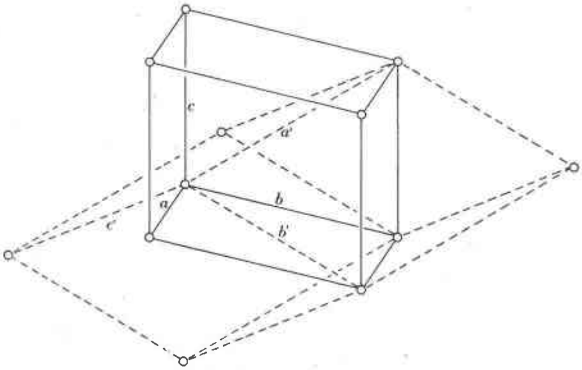


FIG. 5. Montbrayite: crystal lattice, showing the preliminary cell $a'b'c'$ and the conventional cell abc which are related by the transformation, preliminary to conventional: $\bar{1}0\bar{1}/111/0\bar{1}\bar{1}$.

Preliminary to Conventional: $\bar{1}0\bar{1}/111/0\bar{1}\bar{1}$
Conventional to Preliminary: $011/110/\bar{1}\bar{1}\bar{1}$

By calculation, the dimensions of the conventional cell are:

$$a=12.08,\ b=13.43,\ c=10.78\ \text{kX},\ \alpha=104°30\tfrac{1}{2}',\ \beta=97°34\tfrac{1}{2}',\ \gamma=107°53\tfrac{1}{2}'.$$

The volume of this cell is 1568.0 kX^3, in agreement with the volume of the preliminary cell, 1567.9 kX^3. The complete geometrical elements of the conventional cell are:

$$a:b:c=0.8998:1:0.8026;\ \alpha=104°30\tfrac{1}{2}',\ \beta=97°34\tfrac{1}{2}',\ \gamma=107°53\tfrac{1}{2}'$$
$$p_0:q_0:r_0=0.9074:0.8360:1;\ \lambda=72°02',\ \mu=76°54\tfrac{1}{2}',\ \nu=69°14'$$
$$p_0'=0.9623,\ q_0'=0.8866,\ x_0'=0.1329,\ y_0'=0.3272.$$

With reference to the conventional cell, the parting planes become $A(\bar{1}10)$, $B(01\bar{1})$, $C(\bar{1}1\bar{1})$, or their parallel opposites, $A'(1\bar{1}0)$, $B'(0\bar{1}1)$, $C'(1\bar{1}1)$, while the parting edges become $B/C=B'/C'=[011]$, $C/A=C'/A'=[110]$, $A/B=A'/B'=[\overline{111}]$. Thus none of the three sets of plane separations are among the three sets of lattice planes with the greatest spacings, and none of the three resulting edges are among the three shortest lattice periods. If the plane separations were true cleavages these conditions would be contrary to all previous experience. But parting planes, which might in the present case be planes of weakness due to stress accompanying a structural change in the solid state, need not be subject to the same conditions that govern normal planes of least cohesion.

Composition and cell content. The chemical composition of montbrayite was determined with the blowpipe, by qualitative and quantitative spectrographic analyses, and by chemical analyses. The qualitative pyrognostic tests are similar to those given by calaverite. On charcoal the mineral fuses easily with decrepitation giving a white coating of tellurium oxide and yielding a malleable yellow bead, which gave the specific gravity 19.1, as compared to 19.3 for pure gold. In this way a weighed fragment of montbrayite gave 45 per cent Au. Fused with borax in an open dish a metallic residue of 47 per cent was obtained. Semimicro determinations of Au and Te in the wet way yielded 44 per cent Au, 48 per cent Te.

Several qualitative spectrographic analyses were obtained; the most complete of these was kindly made under the direction of Dr. G. R. Harrison (Massachusetts Institute of Technology), who reported that two samples of the gold telluride are qualitatively identical, with the major constituents, Au, Pb, Te, Bi, Ni, Sb, Ag; minor constituents, Mg, Si, Fe, Cu, Ca; and traces of Sn, Na, K, Al.

A quantitative spectrographic analysis of montbrayite was kindly made by Dr. J. C. Rabbitt, in the Department of Mineralogy and Petrography, Harvard University, with the following percentage results:

Au		Sb	1.0 ±0.1	Ti	0.02 ±0.002
Te		Ni	0.6 ±0.06	Co	0.01 ±0.001
Bi	2.5±0.3	Ag	0.5 ±0.05	Cu	0.008±0.0008
Pb	1.5±0.2	Fe	0.02±0.002	Mo, Sn, Cr, V<0.001	

Finally a chemical analysis was made by J. R. Williams (Vancouver, British Columbia) on 0.6 gm. of the cleanest available material. From the polished sections, and the appearance of the fragments of this sample, it was clear that inclusions of the eutectoid intergrowth of tellurbismuth and altaite could not be avoided and that small amounts of petzite might also be contained in the analyzed material; but there was no indication that the sample was contaminated by significant amounts of the other associated minerals.

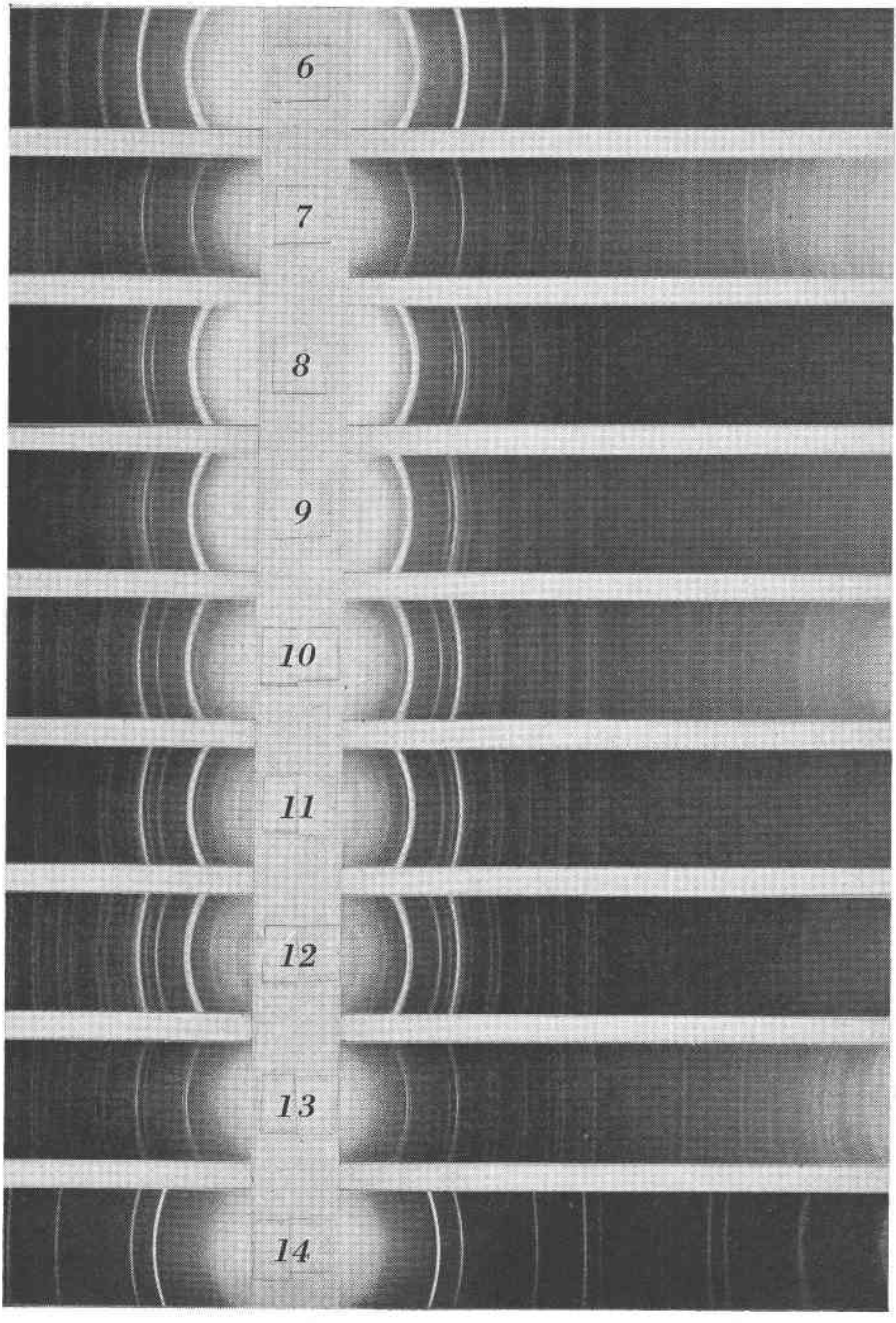
The chemical analysis and a discussion of the results are given in Table 1. If it is assumed that the reported elements (1) all belong to montbrayite the cell content (2) is obtained. This content approaches $12[Au_2Te_3]$ with Au partly replaced by Ag, Pb, Bi, Sb; but this interpretation cannot strictly apply at room temperature, in view of the observed inclusions in montbrayite. A better interpretation of the analysis is obtained by assigning Ag to Ag_3AuTe_2 (petzite), Pb to PbTe (altaite), and Bi to Bi_2Te_3 (tellurbismuth), leaving the remaining Au, Te, and Sb, to montbrayite. This procedure gives values (3, 4, 5) again leading approximately to the composition Au_2Te_3 (6) and the ideal cell content $12[Au_2Te_3]$. For descriptive purposes the formula Au_2Te_3 may then be used for montbrayite; at the same time it is probably not correct to infer the existence of a true compound of this composition. Both physically and chemically montbrayite has the character of a metallic phase, and this view is supported by a consideration of the Au-Te diagram and the attempts to prepare artificial montbrayite, described later.

Table 1. Montbrayite: Analysis and Cell Content

	1	2			3	4	5		6
Au	44.32	21.23	24.41	Au	43.99	48.50	23.66	24.44	50.77
Ag	0.55	0.48		Ag_3AuTe_2	1.32	—			
Pb	1.61	0.73		PbTe	2.60	—			
Bi	2.81	1.27		Bi_2Te_3	5.38	—			
Sb	0.90	0.70		Sb	0.90	0.99	0.78		
Te	49.80	36.89		Te	45.81	50.51	38.12		49.23
	99.99				100.00	100.00			100.00

1. Analysis of material with visible inclusions of tellurbismuth (Bi_2Te_3), altaite (PbTe), and petzite (Ag_3AuTe_2), by J. R. Williams.
2. Atoms in unit cell with $V=1568$ kX^3, $G=9.94$.
3. Analysis recast to give Ag_3AuTe_2, PbTe, Bi_2Te_3, and Au+Sb+Te for montbrayite.
4. Calculated composition of montbrayite.
5. Atoms in unit cell with $V=1568$ kX^3, $G=10.13$ (corrected for impurities).
6. Calculated composition of Au_2Te_3.

X-ray powder photographs. Montbrayite gives an *x*-ray powder pattern (Fig. 6) that shows some resemblance to the patterns of calaverite (Fig. 7), krennerite (Fig. 8), and sylvanite (Fig. 9), but differs distinctly from all of them. It was impractical to index the pattern on the triclinic lattice, owing to the fact that even the largest measured spacings could be referred to numerous different sets of lattice planes; but the relatively simple pattern made by the more prominent lines or pair of lines


6
7
8
9
10
11
12
13
14

can be indexed and approximately matched by spacings in a cubic lattice with $a=4.16$ kX (Table 2). This cubic lattice is apparently not a regular pseudocell of montbrayite, since its volume is not a simple aliquot part of the true cell; it may, however, represent a nearly cubic arrangement of the heaviest (Au) atoms, and it suggests that montbrayite may have originated by inversion in the solid state from a cubic high temperature phase. In this way a pseudocubic arrangement might be preserved, while the inversion to the lower, in this case triclinic, symmetry, might result in stresses which could cause the partings in the mineral.

Table 2. Montbrayite: *X*-Ray Powder Photograph
Pseudocubic; $a=4.16$ kX

I	θ (Cu)	d (meas.)	(hkl)	d (calc.)	I	θ (Cu)	d (meas.)	(hkl)	d (calc.)
1	5.9	7.48	—	—	½	24.75	1.836	—	—
2	9.9	4.47	—	—	½	25.5	1.786	—	—
½	10.9	4.07	—	—	2	26.6	1.717	—	—
½	11.65	3.81	—	—	2	26.9	1.699	(112)	1.698
½	12.6	3.52	—	—	2	31.05	1.490	—	—
1	13.8	3.22	—	—	2	31.8	1.459	(022)	1.471
8	15.0	2.97	(011)	2.942	½	32.2	1.443	—	—
8	15.25	2.92			½	33.5	1.393	(003) (122)	1.387
½	18.1	2.47	—	—					
1	18.9	2.37	(111)	2.402	½	35.05	1.339	—	—
1	19.75	2.27	—	—	1	35.55	1.322	(013)	1.315
1	21.3	2.12	—	—	2	35.95	1.309		
10	21.65	2.08	(002)	2.080	½	39.4	1.211	—	—
1	22.2	2.03	—	—	2	39.9	1.198	(222)	1.201
1	22.9	1.975	—	—	1	47.6	1.041	(004)	1.040
1	23.8	1.905	—	—	½	55.1	0.937	(024)	0.930
½	24.45	1.857	(012)	1.860	1	56.1	0.926		

Fusion experiments. The Au-Te diagram as given in Hansen (1936, p. 264), shows only one compound, $AuTe_2$ (calaverite, 56.4% Te by weight), which has no solid-solution range. This compound makes a eutectic with Au at 42% Te and a eutectic with Te at 82.5% Te. At 50% Te, corresponding to the composition of montbrayite, a melt would

---

Figs. 6–14. *X*-ray powder photographs with Cu radiation, Ni filter; camera radius, $90/\pi$ mm. ($1°\theta=1$ mm.); full size reproductions of contact prints. Fig. 6. Montbrayite, Montbray township, Quebec. Fig. 7. Calaverite, Cripple Creek, Colorado. Fig. 8. Krennerite, Cripple Creek, Colorado. Fig. 9. Sylvanite, Nagyág, Hungary. Fig. 10. Fused montbrayite, giving the patterns of calaverite and gold. Fig. 11. Fusion with the composition of the analysis of montbrayite, giving the patterns of calaverite and gold. Fig. 12. Fusion with the composition Au:Te=2:3, giving the patterns of calaverite and gold. Fig. 13. Calaverite. Fig. 14. Gold.

first give crystals of $AuTe_2$ and finally solidify as a mixture of $AuTe_2$ and Au.

Some fusion experiments, with weighed amounts of the powdered elements in evacuated silica glass tubes, gave results in keeping with previous work. Mixtures corresponding to the analysis of montbrayite, and to the idealized composition Au_2Te_3, gave two-phase products whose powder patterns (Figs. 11, 12) are alike and consist of combinations of the pattern of calaverite (Fig. 13) and of gold (Fig. 14). Fragments of montbrayite heated under like conditions first shattered and then fused to give similar intergrowths of calaverite and gold (Fig. 10). This showed, as was expected, that montbrayite will not form under fusion conditions, and that the mineral represents an unstable phase formed under less drastic natural conditions. In this respect montbrayite resembles krennerite and sylvanite, neither of which we were able to reproduce under fusion conditions. An even closer analogy exists between montbrayite and the recently described new bismuth telluride, hedleyite (Warren & Peacock, 1945), which breaks down into Bi and a solid solution of Bi in Bi_2Te_3 on fusion and recrystallization in vacuum.

REFERENCES

COOKE, H. C., JAMES, W. F. AND MAWDSLEY, J. B. (1931), Geology and ore-deposits of the Rouyn-Harricanaw Region, Quebec: *Geol. Surv. Canada*, Mem. **166.**

HANSEN, M. (1936), *Der Aufbau der Zweistofflegierungen*, Berlin. [Edwards Bros., Ann Arbor, Mich., 1943.]

PEACOCK, M. A. and THOMPSON, R. M. (1945), Montbrayite, a new gold telluride (abstract). *Bull. Geol. Soc. Am.*, **56,** 1189.

——— (1946*a*): Montbrayite, a new gold telluride (abstract): *Am. Mineral.*, **31,** 204.

——— (1946*b*), Melonite from Quebec and the crystal structure of $NiTe_2$: *Univ. Toronto Studies*, Geol. Ser., no. **50,** 63–73.

SHORT, M. N. (1940), Microscopic determination of the ore minerals: *U. S. Geol. Surv.*, Bull. **914.**

THOMSON, E. (1928), A new telluride occurrence in Quebec: *Univ. Toronto Studies*, Geol. Ser., no. **27,** 11–14.

WARREN, H. V. AND PEACOCK, M. A. (1945), Hedleyite, a new bismuth telluride from British Columbia, with notes on wehrlite and some bismuth-tellurium alloys: *Univ. Toronto Studies*, Geol. Ser., no. **49,** 55–69.