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## THE MANGANESE OXIDE MINERALS: A PRELIMINARY REPORT.<sup>1</sup>

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### ABSTRACT.

This paper summarizes the results obtained thus far in an intensive study of the manganese oxide minerals. X-ray powder photographs, supplemented by chemical tests, have proved to be the best means for identifying these minerals. Formulas are suggested. Physical properties and X-ray data are listed for the commoner minerals and those for which new data have been obtained. Rules of nomenclature for these minerals are suggested.

### INTRODUCTION.

AN intensive study of the so-called "manganese oxide" minerals was undertaken early in 1941 by the Chemical Laboratory of the U. S. Geological Survey as part of the strategic minerals studies of manganese ore deposits. It was hoped that X-ray and optical study would make possible the selection of homogeneous material for chemical analysis and thermal study, and that by a correlation of all these methods, the discrepancies and contradictions in the literature concerning these minerals could be explained and reconciled.

The results attained have demonstrated that these minerals can be differentiated and identified. The X-ray powder photograph method has proved to be the most effective method for this work, especially when supplemented by simple chemical tests. Optical study by reflected light as yet has proved to be of less value, chiefly

<sup>1</sup> Published by permission of the Director, Geological Survey, U. S. Department of the Interior.

because many samples are so fine-grained that they are apparently isotropic, hence are indistinguishable when examined by reflected light. Such samples have commonly been reported in the literature as amorphous. X-ray study shows that nearly all of these apparently isotropic specimens are crystalline. Over two hundred X-ray powder photographs of these minerals have been taken in the Geological Survey laboratory. About 90 per cent of the samples were identified by means of their pictures; about 5 per cent gave good pictures which have not yet been correlated with known minerals; and less than 5 per cent gave pictures so weak as to be unidentifiable. As it is now possible to identify the minerals present in manganese ore deposits with reasonable certainty, the primary objective of the work is accomplished. At the same time, progress has been made towards an understanding of the chemical compositions of the manganese oxide minerals, of their optical properties, and of their behavior when heated. Nevertheless, many problems remain to be solved and it is probable that some time will elapse before details can be completed and final publication will be possible. Published references<sup>2</sup> to this project have elicited requests for further information. It seems desirable, therefore, to present at this time a summary of the results, some of which are tentative and subject to revision.

#### PURITY OF MATERIAL STUDIED.

Specimens apparently homogeneous under the binocular microscope are X-rayed and a polished surface is examined by reflected light. If no inhomogeneity is revealed, a sample is prepared for analysis and the final preparation is again X-rayed. Even so, the chemical analysis does not necessarily give the true composition of the pure mineral. Two possible sources of error remain:

(1) A crystalline admixture may be present in a percentage too small to be detected by the X-ray powder pattern. The percentage

<sup>2</sup> Richmond, W. E., and Fleischer, Michael: Ranciéite, a valid mineral species. *Abs., Am. Min.* 27: 231, 1942.

Richmond, W. E., and Fleischer, Michael: Cryptomelane, a new name for the commonest of the "psilomelane" minerals. *Am. Min.* 27: 607-610, 1942.

of crystalline admixture which may escape detection is not known for mixtures of the manganese oxide minerals, but may well be appreciable, because of the similarities in the powder pictures of some of them.

(2) Amorphous material, which gives no X-ray powder picture, may be present, in small or large amount. Thus, for example, in an intergrowth of 50 per cent very fine-grained cryptomelane and 50 per cent amorphous material, both materials might appear to be isotropic; the sample might appear to be homogeneous by reflected light, would give the X-ray pattern of cryptomelane, and yet might have a composition markedly different from that of pure cryptomelane.

These possible sources of error may be the explanation of the divergence in composition found for some samples. The analysis of a number of samples, selected with the precautions stated above, should give a reasonably good approach to the chemical composition of the pure minerals.

#### NOMENCLATURE.

The nomenclature of the manganese oxide minerals has been in an unsatisfactory state, chiefly because the term "psilomelane" has come to be used to refer to any hard, massive, unidentified manganese oxide mineral. This usage is doubtless convenient in the field, where it is generally impossible to determine the mineral or minerals present, and some collective term is needed. However, as stated below, the term "psilomelane" should not be used in this sense, but should refer to only one of the several distinct minerals hitherto grouped under this designation.

The following rules of nomenclature are recommended:

(1) Massive, hard, heavy material not specifically identified should be referred to as belonging to the "psilomelane type." This term is to be understood to include several distinct minerals or mixtures of them, and no chemical formula should be given.

(2) Massive, soft material of low apparent specific gravity, not examined in the laboratory, should be referred to as "wad." Such

material also may be any one of several distinct minerals, may be a mixture, or may be unidentifiable and no chemical formula should be given.

(3) Definitely identified minerals should be named as listed below.

#### MINERALOGY OF THE MANGANESE OXIDES.

The following list includes all the recognized manganese oxide minerals with the exception of a few very rare species and some of doubtful validity. The formulas marked (?) are new and subject to revision. The four minerals marked with asterisks are by far the most common, judging by the specimens studied in this laboratory.

- Bixbyite— $(\text{Mn}, \text{Fe})_2\text{O}_3$ .  
 \*Braunite— $3(\text{Mn}, \text{Fe})_2\text{O}_3 \cdot \text{MnSiO}_3$ .  
 Cesarolite— $\text{Pb Mn}_3\text{O}_7 \cdot \text{H}_2\text{O}$ . Rare.  
 Chalcophanite— $(\text{Mn}, \text{Zn})\text{Mn}_2\text{O}_5 \cdot 2\text{H}_2\text{O}$ . Rare.  
 Coronadite— $\text{Pb R}_2\text{O}_{16}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Cu, Zn.  
 Crednerite— $\text{Cu Mn}_2\text{O}_4$ . Rare.  
 \*Cryptomelane— $\text{KR}_8\text{O}_{16}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Zn, Co.  
 Galaxite— $(\text{Mn}^{\text{II}}, \text{Fe}^{\text{II}})(\text{Al}, \text{Fe}^{\text{III}})_2\text{O}_4$ . Rare.  
 Hausmannite— $\text{MnMn}_2\text{O}_4$ .  
 Hetaerolite— $\text{ZnMn}_2\text{O}_4$ .  
 Hollandite— $\text{BaR}_8\text{O}_{16}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Fe}^{\text{III}}$ ,  $\text{Mn}^{\text{II}}$ , Co.  
 Jacobsite— $(\text{Mn}^{\text{II}}, \text{Fe}^{\text{II}}, \text{Mg})(\text{Mn}^{\text{III}}, \text{Fe}^{\text{III}})_2\text{O}_4$ .  
 Lithiophorite— $\text{Li}_2(\text{Mn}^{\text{II}}, \text{Co}, \text{Ni})_2\text{Al}_5\text{Mn}^{\text{IV}}_{10}\text{O}_{35} \cdot 14\text{H}_2\text{O}$  (?).  
 Manganite— $\text{MnO}(\text{OH}) = \text{Mn}_2\text{O}_3 \cdot \text{H}_2\text{O}$ .  
 Manganosite— $\text{MnO}$ . Rare.  
 Polianite = Pyrolusite. The name polianite should be dropped.  
 \*Psilomelane— $\text{BaR}_8\text{O}_{16} \cdot 2\text{H}_2\text{O}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Co.  
 Pyrochroite— $\text{Mn}(\text{OH})_2$ . Rare.  
 \*Pyrolusite— $\text{MnO}_2$ .  
 Quenselite— $\text{Pb}_2\text{Mn}_2\text{O}_5 \cdot \text{H}_2\text{O}$ . Rare.  
 Ramsdellite— $\text{MnO}_2$  (dimorph of pyrolusite).  
 Ranciéite— $(\text{Ca}, \text{Mn}^{\text{II}})\text{Mn}^{\text{IV}}_4\text{O}_9 \cdot 3\text{H}_2\text{O}$  (?).  
 Sitaparite = Bixbyite.<sup>3</sup> The name sitaparite should be dropped.

More detailed descriptions of the commoner minerals and of those for which new data have been obtained are given below.

<sup>3</sup> Mason, Brian: Bixbyite from Långban. The identity of sitaparite with bixbyite. *Geol. For. Forh.* (Stockholm) 64: 117-125, 1942.

*Braunite*— $3(\text{Mn}, \text{Fe})_2\text{O}_3 \cdot \text{MnSiO}_3$ . Tetragonal. Color and streak dark brownish-black. Hardness 6–6½. Sp. gr. 4.8. Occurs in well developed crystals resembling octahedrons and in compact granular masses. Common in the United States. Decomposed by HCl, leaving a residue of gelatinous silica.

*Coronadite*<sup>4</sup>— $\text{PbR}_8\text{O}_{16}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Cu, Zn. This formula is obtained by analogy to the formulas of hollandite and of cryptomelane, which give almost identical X-ray powder photographs. The analyses of coronadite agree only approximately with this formula. Most samples contain 1–5 per cent of non-essential water. Probably triclinic, pseudotetragonal. Color steel-gray to dull black. Streak black. Hardness 6. Sp. gr. 5.2–5.6. Occurs in irregular or cellular or botryoidal masses. The validity of coronadite as a mineral species was recently demonstrated by Frondel and Heinrich.<sup>5</sup>

*Cryptomelane*— $\text{KR}_8\text{O}_{16}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Zn, Co. Most samples contain 2–4 per cent non-essential water. Most of the analyses correspond fairly well to this formula, but some differ considerably from it. A satisfactory explanation for these discrepancies has not yet been found. Tetragonal. Color steel-gray to black, tarnishes black. Streak dark brownish-black. Hardness most commonly 6–6½, but the apparent hardness of cleavable and fibrous varieties may be as low as 1. Sp. gr. approximately 4.3.

Cryptomelane is probably the commonest of these minerals excepting pyrolusite. It occurs in a number of habits:

- (1) Most commonly as very fine-grained steel-gray dense compact masses showing marked conchoidal fracture.
- (2) Less commonly as botryoidal masses.
- (3) Uncommonly as coarse cleavage masses that would not ordinarily be labelled "psilomelane type." This variety has an

<sup>4</sup> A paper on coronadite is in preparation by Dr. Clifford Frondel of Harvard University and Dr. Charles Milton of the Geological Survey, to whom we are indebted for the use of their data. They are not to be held responsible, however, for the formula here proposed.

<sup>5</sup> Frondel, Clifford and Heinrich, E. W.: New data on hetaerolite, hydrohetaerolite, coronadite and hollandite. *Am. Min.* 27: 48–56, 1942.

apparent hardness of 3–4. Known only from Tombstone, Arizona, Deming, New Mexico, and Sitapur, India.

(4) As distinct crystals. Known only from Romanèche, France, where the crystals occur on massive psilomelane. Specimens from Tombstone, Arizona, and Lake Valley, New Mexico, show filament-like fibers of cryptomelane. Similar material from Nassau, Germany, has been described by Ramsdell.<sup>6</sup>

Cryptomelane was first distinguished as a distinct mineral species by Ramsdell,<sup>7</sup> who referred to it as "true psilomelane." The name cryptomelane was recently proposed by us.<sup>8</sup>

*Hausmannite*— $\text{MnMn}_2\text{O}_4$ . Tetragonal. Color brownish-black to reddish. Streak reddish-brown. Hardness 5–5½. Sp. gr. 4.9. Occurs in well developed crystals resembling octahedrons, and in granular masses. Commonly twinned.

*Hollandite*— $\text{BaR}_8\text{O}_{18}$  (?), R =  $\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Fe}^{\text{III}}$ ,  $\text{Mn}^{\text{II}}$ , Co. Usually anhydrous, but may contain a little non-essential water. A partial solid solution series between hollandite and cryptomelane exists, but the limit of isomorphous replacement is not known. Probably triclinic, pseudotetragonal. Color silvery-gray to dull black. Streak black. Hardness 6 in most specimens, but the apparent hardness may be as low as 2. Sp. gr. 4.5–5.0. Occurs as well developed crystals, broad cleavage masses, dense compact masses with conchoidal fracture, or as botryoidal masses.

The statement, frequently made in the literature, that hollandite is the crystalline equivalent of colloidal or amorphous psilomelane is incorrect. X-ray study shows that both minerals are crystalline and distinct, though closely related. Dehydration of psilomelane at 500–600° C. gives hollandite as the chief product.

*Lithiophorite*— $\text{Li}_2(\text{Mn}^{\text{II}}, \text{Co}, \text{Ni})_2\text{Al}_8\text{Mn}^{\text{IV}}_{10}\text{O}_{35} \cdot 14\text{H}_2\text{O}$  (?). Color dull black, commonly with a distinct bluish tinge (mark of high cobalt content) particularly noticeable on fresh fracture. Streak black. Sp. gr. 3.1. Commonly in botryoidal masses.

<sup>6</sup> Ramsdell, L. S.: An X-ray study of psilomelane and wad. *Am. Min.* 17: 143–149, 1932; Ramsdell, L. S.: The unit cell of cryptomelane. *Am. Min.* 27: 611–613, 1942.

<sup>7</sup> Ramsdell, L. S.: *op. cit.*, p. 144.

<sup>8</sup> Richmond, W. E. and Fleischer, Michael: *op. cit.*, p. 607.

Lithiophorite is listed in most textbooks as a variety of psilomelane. Ramsdell<sup>9</sup> found that it gave a distinctive X-ray powder photograph. The validity of lithiophorite as an independent species has been confirmed by us.

*Manganite*— $\text{MnO}(\text{OH})$ . Monoclinic; pseudo-orthorhombic. Color dark steel-gray to iron-black. Streak chocolate-brown. Hardness 4. Sp. gr. 4.3. Occurs in prismatic crystals. Commonly partly altered to pyrolusite.

*Psilomelane*— $\text{BaR}_6\text{O}_{18} \cdot 2\text{H}_2\text{O}$  (?),  $\text{R} = \text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}$ , Co. The water is essential (difference from hollandite, whose composition is very similar). Orthorhombic. Color and streak black. Hardness usually 6, but in some specimens the apparent hardness is lower, down to 2. Sp. gr. 4.4–4.7. A common mineral; only pyrolusite and cryptomelane are encountered more frequently. Most commonly in botryoidal masses, which in some instances consist of concentric layers. The layers may be psilomelane, psilomelane and pyrolusite, or psilomelane and cryptomelane. Also occurs in irregular or cellular masses, and rarely as long prismatic crystals (pseudomorphs ?) resembling a common variety of pyrolusite.

X-ray and chemical studies of type specimens by Vaux<sup>10</sup> proved that the mineral named psilomelane by Haidinger<sup>11</sup> is a distinct species, a hydrous barium manganate. Our X-ray study and new chemical analyses confirm Vaux's findings. The formula here given is a variant of that proposed by Vaux,  $\text{R}_2\text{Mn}_6\text{O}_{18} \cdot 2\text{H}_2\text{O}$ ,  $\text{R} = \text{Ba}, \text{Mn}^{\text{II}}$ . The name psilomelane should be used only to refer to this particular mineral; unidentified material should be referred to as "psilomelane type."

*Pyrolusite*— $\text{MnO}_2$ , commonly with a little non-essential water. Tetragonal. Color iron-gray to black. Streak dead black. Hardness nearly always  $2-2\frac{1}{2}$ , but in some specimens higher, up

<sup>9</sup> Ramsdell, L. S.: op. cit., p. 145.

<sup>10</sup> Vaux, George: X-ray studies on pyrolusite (including polianite) and psilomelane. Min. Mag. 24: 521–526, 1937.

<sup>11</sup> Haidinger, William: Mineralogical account of the ores of manganese. Royal. Soc. Edinburgh Trans. 11: 119–174, 1831.

to  $6\frac{1}{2}$ . Sp. gr. 4.9-5.0 pure, 4.7-4.8 for most specimens. The commonest manganese oxide mineral, occurring in several habits:

(1) Compact, fine-grained, dense masses with a tendency to fracture conchoidally.

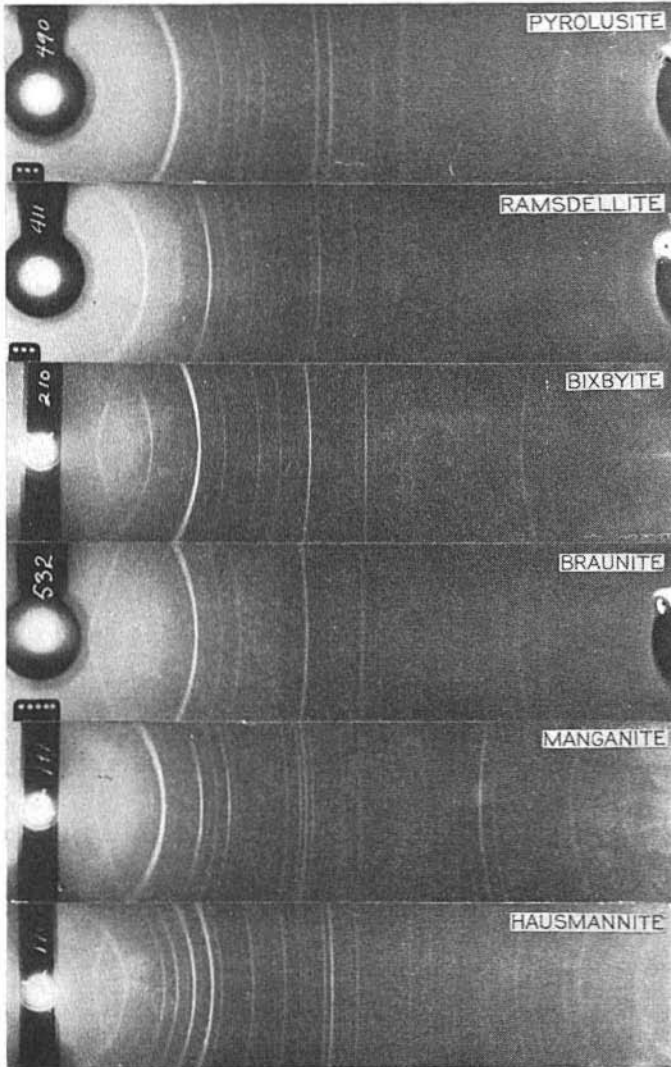


FIG. 1. X-ray powder photographs of some manganese minerals.



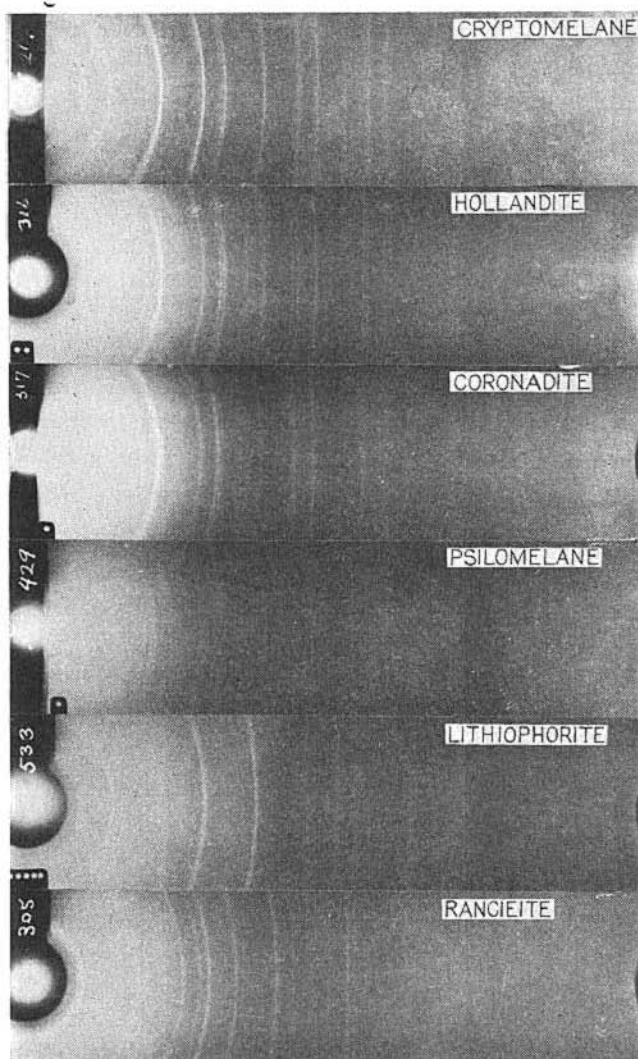


FIG. 2. X-ray powder photographs of some manganese minerals.

(2) Massive, friable, with grain size usually somewhat larger than the compact variety. Easily broken down with the fingers.

(3) Botryoidal, occurring in radiating crystals or crystallized masses with an external form resembling clusters of grapes, which may be large or small. There may be several composite bands

making up each "grape." In many of the finely banded specimens composed of harder and softer bands, the softer portion is pyrolusite, and the harder portion may be pyrolusite, cryptomelane, or psilomelane.

(4) Crystals, commonly as pseudomorphs after manganite; in long prismatic crystals which may have several terminal forms, or may have only the base, or may taper to a sharp wedge. Good tetragonal crystals with well-developed terminal forms are known only from Platten, Bohemia ("polianite").

*Ramsdellite*<sup>12</sup>— $\text{MnO}_2$ . Orthorhombic. Color iron-gray to black. Streak black. Hardness 3. Sp. gr. 4.7. Occurs as thick tabular crystals and as massive material that has a platy appearance, owing to two cleavages at right angles. Commonly mixed with pyrolusite (transformation product?). Inverts to pyrolusite when heated at 300°.

*Ranciéite*— $(\text{Ca}, \text{Mn}^{\text{II}})\text{Mn}_4^{\text{IV}}\text{O}_9 \cdot 3\text{H}_2\text{O} (?)$ . Color silver-gray, brown, brownish-black. Streak purplish-brown. Very soft. Sp. gr. 3.3, but the apparent specific gravity is very low. Occurs as silver-gray incrustations and thin flakes, as brown, compact masses which would probably be termed "wad" in the field, also as brownish-black friable masses.

Ranciéite is usually listed as a variety of psilomelane. Our X-ray and chemical study shows it to be an independent species.

*Accessory Elements*.—Cobalt is commonly present in cryptomelane, psilomelane, and hollandite, with CoO ranging from 0 to 2.5 per cent. Cobalt is present in appreciable percentage in all samples of lithiophorite examined. Nickel has been found in appreciable percentage only in lithiophorite. Zinc is commonly present only in very small percentages, but up to 8 per cent ZnO has been found in samples of cryptomelane, and up to 1.5 per cent ZnO in coronadite. Tungsten is present in some psilomelane samples, most commonly less than 1 per cent  $\text{WO}_3$ , but psilo-

<sup>12</sup> This is the first use of this name in print. The mineral was described in 1932 by Ramsdell (op. cit., p. 148) as a possible dimorph of pyrolusite. Examination of new material and of Ramsdell's specimen has established the validity of this mineral species. A more detailed description is in preparation.

melane from Sodaville, Nevada, contained 4.88 per cent  $WO_3$ .<sup>13</sup> Tungsten is not present in most samples of cryptomelane, but Gonyer reported 2.24 per cent  $WO_3$  in a sample from Golconda, Nevada.<sup>14</sup> Small percentages of copper, arsenic, strontium and vanadium have been found in some specimens.

#### IDENTIFICATION.

It is evident that identifications based on physical properties are highly uncertain, owing to the variability of these properties and their overlapping. Hardness is a particularly poor criterion. The streak may be helpful, but must be used with caution. A detailed discussion of the optical properties of the minerals is reserved for later publication; however, it may be said that identification of well-crystallized material is possible, but that identification of fine-grained material is as yet uncertain.

Qualitative tests for lead, barium, potassium, lithium, calcium and aluminum may be helpful. A flame test, made by introducing the powdered mineral directly into the flame on a platinum or nichrome wire, may give useful information. A strong potassium flame (use of a blue glass or Merwin screen may be necessary) is a fairly good indication of cryptomelane; a crimson flame of lithiophorite. The barium manganates give little or no barium flame when tested in this way. If the powdered mineral on the wire is moistened with hydrochloric acid and held in the flame, a strong green flame (caused by manganese chloride) is observed which disappears in a few seconds and is followed by the persistent barium flame.

X-ray powder pictures are the only certain means of identifying many samples. Qualitative chemical tests must also be made to identify cryptomelane, hollandite, or coronadite, whose X-ray powder photographs differ only slightly. In order that others

<sup>13</sup> Analyzed by F. A. Gonyer and described by Kerr, P. F.: Tungsten-bearing manganese deposit at Golconda, Nevada. G. S. A., Bull. 51: 1359-1390, 1940. This is his No. 4, Table 3, p. 1382.

<sup>14</sup> Described by Kerr, op. cit., p. 1382, Table 3, No. 1. We are indebted to Dr. Kerr for furnishing these samples for X-ray study.

TABLE 1.

$D$  = spacings in Angstrom units;  $I$  = estimated intensities.  
All photographs were made with Fe radiation.

*Bixbyite*, Thomas Range, Utah.

$D$	$I$	$D$	$I$	$D$	$I$
4.671	1	1.716	2.5	1.255	2
4.204	1	1.654	9	1.194	2
3.824	6	1.614	2	1.175	4
3.346	1	1.564	2	1.155	4
2.985	3	1.527	3	1.139	3
2.716	10	1.480	2	1.123	3
2.506	2	1.451	3	1.105	3
2.350	4	1.418	8	1.091	3
2.206	2	1.385	4	1.077	7
2.104	1	1.356	3	1.075	4
2.004	4	1.327	1	1.050	6
1.920	1	1.304	2	1.048	2
1.869	4	1.279	3	1.037	1

*Braunite*.

$D$	$I$	$D$	$I$	$D$	$I$
4.66	1	1.83	1	1.22	1
4.21	1	1.80	1	1.18	2
3.48	3	1.73	3	1.17	3
3.32	1	1.65	9	1.15	1
2.96	2	1.525	3	1.10	1
2.72	6	1.49	2	1.08	2
2.68	10	1.46	2	1.075	7
2.48	1	1.42	8	1.07	2
2.33	5	1.41	6	1.051	5
2.14	6	1.37	1	1.05	2
1.86	2	1.355	4	1.049	1

*Coronadite*, Coronado vein, Graham Co., Arizona (type material).

$D$	$I$	$D$	$I$	$D$	$I$
3.487	9	1.83	7	1.37	3
3.327	1	1.74	2	1.36	6
3.113	10	1.68	3	1.30	2
2.387	7	1.63	7	1.24	3
2.198	8	1.53	8	1.22	3
2.159	6	1.42	1	1.20	2
1.940	3	1.39	3	1.18	4

*Cryptomelane*, Mowry Mine, Patagonia dist., Arizona.

$D$	$I$	$D$	$I$	$D$	$I$
6.863	9	2.097	1	1.385	0.5
4.892	8	1.961	1	1.347	5
3.445	3	1.917	2	1.289	1
3.105	10	1.820	5	1.230	0.5
2.445	3	1.633	4	1.209	0.5
2.387	7	1.618	4	1.190	0.5
2.305	1	1.544	1	1.135	0.5
2.183	4	1.528	6	1.073	1
2.145	5	1.423	2	1.052	1

TABLE 1—(Continued).

*Hausmannite*, Långban, Sweden.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
4.851	7	1.626	1.5	1.224	3
3.048	5	1.568	6	1.213	1
2.869	2	1.534	8	1.187	3
2.736	9	1.459	1	1.173	3
2.465	10	1.431	5	1.140	1
2.331	5	1.402	1	1.126	4
2.020	6	1.375	1	1.093	1
1.809	1	1.337	2	1.073	5
1.775	5	1.320	3	1.051	3
1.686	2	1.236	1		

*Manganite*, Ithfeld, Harz.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
3.700	1	1.694	5	1.208	1
3.385	10	1.661	9	1.179	4
3.096	1	1.629	5	1.152	4
2.883	1	1.493	5	1.130	8
2.616	9	1.428	1	1.109	4
2.506	2	1.424	4	1.094	3
2.406	6	1.414	1	1.076	3
2.359	0.5	1.316	4	1.052	1
2.310	0.5	1.287	2	1.024	8
2.263	7	1.275	1	1.022	2
2.186	3	1.257	1		
1.771	6	1.239	2		

*Psilomelane*, Schneeberg, Saxony.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
4.205	1	2.663	1	1.734	2
3.825	1	2.402	8	1.712	2
3.488	8	2.364	1	1.636	2
3.318	2	2.251	3	1.562	4
3.217	1	2.191	10	1.524	1
2.972	1	2.138	2	1.424	4
2.842	4	1.816	5	1.403	6

*Hollandite*, Kajlidongri, Jhabua State, India.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
4.95	1	1.82	3	1.35	6
3.48	7	1.75	1	1.31	1
3.10	10	1.69	1	1.30	1
2.38	4	1.64	5	1.29	2
2.19	5	1.62	5	1.17	2
2.14	4	1.53	8	1.16	2
1.95	1	1.43	1	1.15	2
1.93	1	1.42	1	1.09	6
1.91	1	1.395	1	1.08	6
1.83	3	1.36	6		

TABLE 1—(Continued).

*Lithiophorite*, White Oak Mt., Bradley Co., Tenn.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
9.407	9	2.27	1	1.38	5
5.13	1	2.12	1	1.23	6
4.70	10	2.04	1	1.18	2
3.13	3	1.87	8	1.14	2
2.48	1	1.55	6		
2.35	9	1.44	7		

*Pyrolusite*, Platten, Bohemia.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
4.08	2	2.190	3	1.434	2
3.425	2	2.108	4	1.387	3
3.346	1	1.964	4	1.356	5
3.096	10	1.785	1	1.158	1
2.651	0.5	1.708	1	1.120	2
2.537	1	1.618	8	1.098	2
2.396	6	1.550	7	1.053	3

*Ramsdellite*, Lake Valley, New Mexico.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
4.08	10	1.95	1	1.35	5
3.20	1	1.88	5	1.31	2
3.10	9	1.82	2	1.30	3
2.53	8	1.64	6	1.27	1
2.40	4	1.60	7	1.25	1
2.32	4	1.53	3	1.16	1
2.13	5	1.52	2	1.12	1
2.09	3	1.46	5	1.07	3
2.04	2	1.42	3	1.05	3

*Ranciéite*, Oriente Province, Cuba.

<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>	<i>D</i>	<i>I</i>
7.508	10	2.053	4	1.349	1
3.786	1	1.988	2	1.322	1
3.737	8	1.840	2	1.277	0.5
3.113	0.5	1.747	5	1.247	0.5
2.956	0.5	1.649	5.5	1.229	0.3
2.698	9	1.486	2.5	1.211	0.5
2.454	3	1.443	1	1.165	0.5
2.331	7	1.416	6	1.101	0.7
2.137	1	1.390	3	1.072	0.5

may identify these minerals, spacings and estimated intensities are given in Table 1 for the commoner minerals and for those for which new data are presented in this paper. The data in Table 1 were obtained by Dr. Clifford Frondel of Harvard University. Our own measurements agree well with these values, but are less precise. We are grateful to Dr. Frondel for his kindness in allowing us to publish his values.

LIST OF MANGANESE OXIDE MINERALS STUDIED IN THE  
GEOLOGICAL SURVEY LABORATORY.*Bixbyite*

New Mexico, Catron Co.  
India, Sitapur ("sitaparite").

*Braunite*

Arizona, Cochise Co., Bisbee.  
California.  
Humboldt Co., Ft. Seward Mine.  
Plumas Co.  
Stanislaus Co., Buckeye Mine.  
Maine, Aroostook Co.  
Missouri, Shannon Co., Seaman No. 1 prospect.  
Nevada, Humboldt Co., Golconda.  
Texas, Mason Co., Spiller Mine.  
Colombia, Antioquia, Las Mercedes Mine.  
Costa Rica, Chanchoz.  
Cuba, Oriente Province.

*Cesarolite*

Algeria.

*Coronadite*

Arizona, Pinal Co., Superior Mining dist., Magma Mine.  
California, Inyo Co., Modoc Mining dist.  
Morocco, Bou Tazoult.

*Cryptomelane*

Alabama, Clay Co.  
Arizona, Cochise Co., Tombstone, Oregon-Prompter Mine.  
Arkansas, Polk Co., Sugar Stick prospect near Mena.  
Missouri, Shannon Co., Seaman No. 1 prospect.  
Montana  
Granite Co., Philipsburg.  
Madison Co., Cherry Creek.  
Nevada, White Pine Co., Ely.  
New Jersey, Sussex Co., Franklin.  
New Mexico  
Luna Co., Deming.  
Sierra Co., Lake Valley.  
Pennsylvania, Bedford Co., Shannon Valley.  
Tennessee  
Mountain City dist., Belle Hawkins tract.  
Stony Creek Valley.  
Virginia  
Augusta Co.  
Lyndhurst Mine near Sherando.  
Robinson Hollow.  
Stuarts Draft, Mt. Torrey Mine.  
Bland Co., Virginia Hardwood Lumber Co. Mine.  
Campbell Co.  
Flat Creek, Bell Mine.  
Lawyers.  
Mortimer Mine.

- Piedmont Mine.
- Page Co., Stanley Mine.
- Rockbridge Co., Mine Bank Mine.
- Brazil, Mato Grosso, Urucum.
- Cuba, Oriente Province.
- France, Romanèche.
- India, Sitapur.
- Garbham, Madras.
- Hausmannite*
  - Arkansas, Independence Co., Batesville, Ozark No. 1, Dave Dunnegan shaft.
  - Washington, Olympic Peninsula.
  - Sweden, Långban.
- Hollandite*
  - Missouri, Reynolds Co., Tucker-Nash prospect.
  - Montana, Madison Co., Cherry Creek.
  - New Mexico, Socorro Co., near Socorro.
  - Tennessee, Shady Valley.
  - Brazil, Goyaz, San José de Tocantins.
  - India, Jhabua State, Kajlidongri.
  - South Africa, Postmasburg.
- Jacobsite*
  - Washington, Olympic Peninsula.
- Lithiophorite*
  - Alabama, Cherokee Co.
  - Tennessee
    - Bradley Co., White Oak Mt.
    - Hickman Co., Coble.
  - Dominican Republic, Loma Caribe.
  - Silesia, Rengersdorf.
- Manganite*
  - Michigan, Marquette Co., Negaunee, Lucy Mine.
  - Utah, Emery Co., Green River.
  - Cuba, Oriente Province.
  - Germany, Ihlfeld.
- Manganosite*
  - New Jersey, Sussex Co., Franklin.
- Psilomelane*
  - Alabama, Cherokee Co.
  - Arizona, Yavapai Co., Castle Creek.
  - Graham Co.
  - California, Paymaster dist., Tolbard Mine.
  - New Mexico
    - Dona Anna Co., Rincon, Morgan Mine.
    - Luna Co., Deming.
  - Nevada, Mineral Co., Sodaville.
  - Tennessee, Shady Valley.
  - Texas, Jeff Davis Co., Chispa, Mayfield prospect.
  - Utah, Daggett Co., Manila.
  - Virginia
    - Appomattox Co., Hancock-Ferguson Mine.
    - Campbell Co., Lynchburg, Pribble Mine.



- Frederick Co., Mineral Ridge Mine.  
 Page Co.  
     Compton, Compton Mine.  
     Stanley Mine.  
 Vesuvius Co., Hogpen Hollow prospect.  
 Wythe Co.  
 Cuba, Oriente Province.  
 France, Romanèche.  
 Germany, Schneeberg.
- Pyrochroite*  
 Jugoslavia, Ljubija.
- Pyrolusite*  
 Georgia, Cartersville district.  
 Montana, Granite Co., Phillipsburg.  
 Nevada  
     Humboldt Co., Golconda.  
     White Pine Co., Ely.  
 New Mexico  
     Grant Co., Silver City, Boston Hill Mine.  
     Sierra Co., Lake Valley.  
 Tennessee  
     Mountain City dist., Belle Hawkins tract.  
     Washington Co., Embreeville.  
 Utah  
     Drum Mts.  
     Emery Co., Green River.  
 Virginia  
     Appomattox Co., Stonewall Mine.  
     Augusta Co.  
         Black Shaft.  
         Crimora.  
         Stuarts Draft, Mt. Torrey Mines.  
     Campbell Co., Piedmont Mine.  
     Frederick Co., Mineral Ridge Mine.  
     Rockbridge Co.  
         Hogpen Hollow prospect.  
         Mine Bank Mine.  
         Vesuvius Mine.  
     Tazewell Co., Bluefield, Suiter Mine.  
 Wyoming  
     Albany Co.  
         J. B. C. Mine.  
         Mule Creek.  
 Africa, Gold Coast.  
 Bohemia, Platten.  
 Brazil, Morro da Mina.  
 Costa Rica, Pavones.  
 Cuba, Oriente Province.  
 Nova Scotia, Pictou Co., East River.  
 Russia, Caucasus.
- Quenselite*  
 Sweden, Långban.

*Ramsdellite*

New Mexico, Sierra Co., Lake Valley.  
Nova Scotia, Pictou Co., East River.  
Turkey, Roumelia, Moustapha Pasha, Kodjas Karil Mine.

*Ranciéite*

Arkansas, Independence Co., Batesville.  
North Dakota, Rolette Co., Dunseith.  
Cuba, Oriente Province.

APPLICATIONS.

It is hoped that the data here presented will make possible a new approach to some technical problems involving the manganese oxide minerals. For example, X-ray study may throw light on the reasons, at present unknown, why some ore makes good dry cells, whereas other ores of higher  $MnO_2$  content do not.<sup>15</sup> Likewise, identification of the manganese mineral or minerals present in an ore may be helpful in working out methods of beneficiation not purely empirical.

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<sup>15</sup> Chambers, G. H.: *Industrial Minerals and Rocks*. 1937. P. 450.