MANGANESE DEPOSITS NEAR BROMIDE, OKLAHOMA.

By D. F. Hewett.

FIELD WORK.

During 1917, when there was a prospective shortage of manganese ore, the attention of the United States Geological Survey was called to manganese deposits near Bromide, Johnston County, Okla. In October of that year it was possible for the writer, in company with George E. Burton, then assistant director of the Oklahoma Geological Survey, to devote three days to the examination of the deposits. Although the deposits are small and can not yield large quantities of high-grade ore, their relations and the minerals they contain are so uncommon that a record of their features is warranted.

SITUATION AND ACCESSIBILITY.

Five manganese deposits or groups of deposits are known near Bromide. The most extensive and probably the largest deposit is near the settlement of Springbrook (formerly Viola), in the SW. ¼ sec. 13, T. 2 S., R. 7 E., about 4 miles southwest of Bromide. The other deposits lie along the valley of Moseley Creek, from 1 to 5 miles northeast of Bromide, in the SW. ¼ sec. 28, the NE. ¼ sec. 20, the SE. ¼ sec. 17, and the NE. ¼ sec. 17, T. 1 S., R. 8 E. Bromide is 6 miles northwest of Wapanucka, with which it is connected by a spur of the Missouri, Oklahoma & Gulf Railway. (See fig. 48.)

Bromide lies at the northern edge of the broad valley of Delaware Creek, near the eastern limit of the Arbuckle Mountains. In this region the mountains consist of a poorly defined dissected plateau that attains an altitude of about 1,000 feet above sea level several miles northwest of Bromide. The principal streams flow in narrow valleys cut 150 to 200 feet below the plateau. The valley of Delaware Creek, however, which rises northwest of Bromide and flows generally southeast, is about 3 miles wide near Bromide and is made up of two terraces 150 and 175 feet below the level of the adjacent plateau. The valley of Moseley Creek is narrower and is cut only about 100 feet below the level of the plateau.

Most of the thick growth of oak that once covered the plateau has been cut, and large areas are tilled or used for pasture. The bottom lands of the valleys are covered with farms.

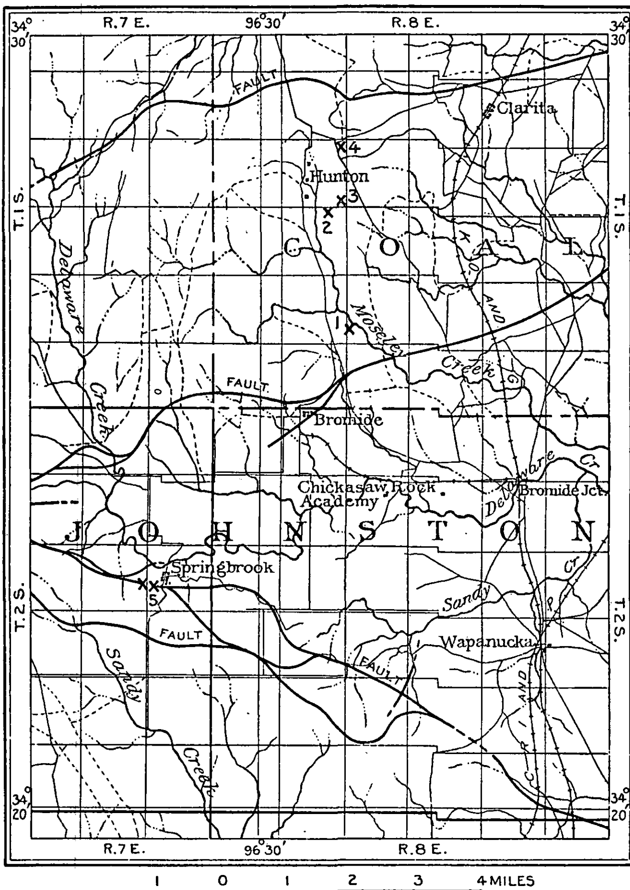

FIGURE 48.—Map showing location of manganese deposits near Bromide, Okla. 1-4, Moseley Creek deposits Nos. 1-4; 5, Springbrook deposit.

HISTORY.

According to Weeks,[1] manganese ore was discovered near Hunton, on Moseley Creek, 5 miles northeast of Bromide, in 1890. Although Weeks [2] refers to the shipment of 206 tons of ore from the deposits in his report for 1891, more information is given in the report for 1892, from which the following is quoted:

Some two years ago manganese ore was discovered about 15 miles west of Lehigh, Ind. T. The ore exists in the forms of black oxides and carbonates. Both varieties

[1] Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources, 1892, p. 196, 1893.
[2] Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources, 1891, p. 134, 1892.

exist together in the same bed, or pockets, averaging say 20 per cent black oxide and 80 per cent carbonate. The deposits lie apparently on the Lower Silurian limestone and have been covered by the Middle Silurian limestone. The black oxides are found mostly in the uppermost parts of the pockets, but they are also found in the bottom and under the carbonates. The carbonates are red, brown, and gray. By surface indications, this manganese belt has been traced some 12 miles north and south. Three openings have been made, about 1 mile from the other, out of which 17 carloads were shipped to the Illinois Steel Co., with the following result. [Shown in the table on p. 327.] * * *

Not much work has ever been done to ascertain the full extent of these deposits. At one opening [Moseley Creek No. 4?] the surface soil has been removed from 2 to 6 feet in depth for a space of say 30 by 70 feet, and ore taken out to a depth of say 10 feet. At another opening [Moseley Creek No. 3?] the surface soil is not over 2 feet deep; from this opening, which is say 20 by 100 feet, was taken 97 tons of black oxide of manganese and about 300 to 400 tons of carbonates, large quantities of which are still in sight not taken out.

At another opening ore is shown to be about say from 2 to 4 feet thick. From this place about 10 tons of ore have been shipped (all black oxide of manganese), and about 50 tons remain in sight.

From the first opening mentioned there was shipped about 93 tons of black oxide, and nearly 2,000 tons of carbonates remain on the surface and in sight. * * *

On a hill not over 300 yards from one of the openings mentioned is found a deposit of manganese [Moseley Creek No. 2?] entirely different from the others, the base material being flint rock in which is found a very pure kind of black oxide of manganese in nodular form, averaging 66 per cent manganese, 0.35 silica, 1.23 iron, and 0.023 phosphorus.

The deposits are mentioned again by Weeks in the chapters on manganese in Mineral Resources of the United States for 1894 and 1895, but he states that no more work had been done.

In 1910 Reeds [3] described the deposits briefly and stated that they were explored in 1891 and 1905.

In 1917 Snider [4] presented a description of the Springbrook deposit, based on an examination made during that spring by George E. Burton, of the Oklahoma Geological Survey.

It is reported that the present owner of all the deposits near Bromide is Robert Galbreath, of Tulsa, Okla.

GENERAL GEOLOGY.

The geologic features of the region near Bromide have been described in several reports by Taff.[5] For a detailed description of the rocks of the region, their structure and other features, the reader is referred to these reports. The location of three manganese deposits is indicated on the maps of the Atoka folio, but they are not described.

[3] Reeds, C. A., Geological and mineral resources of the Arbuckle Mountains, Okla.: Oklahoma Geol. Survey Bull. 3, pp. 55–59, 1910.

[4] Snider, L. C., Geography of Oklahoma: Oklahoma Geol. Survey Bull. 27, pp. 121–123, 1917.

[5] Taff, J. A., Preliminary report on the geology of the Arbuckle and Wichita mountains: U. S. Geol Survey Prof. Paper 31, 97 pp., 1904; U. S. Geol. Survey Geol. Atlas, Atoka folio (No. 79), 1902; U. S. Geol. Survey Geol. Atlas, Tishomingo folio (No. 98), 1903.

The rocks near Bromide include granite and several varieties of sedimentary rocks that range in age from pre-Cambrian to Carboniferous. The units that have been recognized are briefly described in the accompanying table:

Generalized section of the sedimentary rocks exposed near Bromide, Okla.

[Compiled from U. S. Geol. Survey Geol. Atlas, Atoka and Tishomingo folios, by J. A. Taff.]

System.	Formation.	Thickness (feet).	Character.
Carboniferous.	Wapanucka limestone.	100-150	White oolitic and blue limestones, shales, and locally cherty calcareous sandstone. Forms a persistent ridge southeast of Bromide and was quarried as a building stone.
	Caney shale.	1,500	Blue shale with thin sandy lentils and small ironstone concretions. Near the base black fissile shale with dark-blue fossiliferous limestone concretions. Underlies the Delaware Creek valley south of Bromide.
Devonian.	Woodford chert.	600	Thin-bedded chert and black fissile shales, with large blue flint lentils at the base. Underlies low hills near Springbrook.
Silurian.	Hunton limestone.[a]	0-200	White and yellowish limestone with flint and chert concretions in upper part. Underlies the ridge east of Moseley Creek.
Ordovician.	Sylvan shale.	50-300	Blue clay shale. Exposed south of Springbrook.
	Viola limestone.	750	White and bluish limestones with flint concretions in the middle. Makes up the hills north of Bromide.
	Simpson formation.	1,600	Bituminous and calcareous sandstone and shale with thin fossiliferous limestone near the top; limestone, sandstone, and shale near base. Crops out southeast of Springbrook.
	Arbuckle limestone.	4,000-6,000	Massive and thin-bedded white and blue limestones with chert concretions; sandstones near base. A belt of this limestone underlies the plain south of Springbrook.
Cambrian.	Reagan sandstone.	50-150	Coarse dark-brown sandstone at base; calcareous sandstone and shale at top. Crops out near Reagan but is not found near Bromide.
Pre-Cambrian.	Tishomingo granite.		Coarse red granite with dikes of basic rocks. Exposed in a large area south of Springbrook.

[a] Since the publication of the Atoka and Tishomingo folios the "Hunton limestone" has been subdivided by C. A. Reeds (Am. Jour. Sci., 4th ser., vol. 32, pp. 256-268, 1911) into four formations, as follows:

Devonian { Bois d'Arc limestone (Helderbergian fossils).
Haragan shale (Helderbergian fossils).

Silurian { Henryhouse shale (Niagaran fossils).
Chimneyhill limestone (Brassfield fossils).

Although the sedimentary rocks in this region were originally laid down as nearly horizontal beds, they have been much folded and broken. Consequently they are now steeply inclined over large areas, and locally, along faults, beds of widely divergent age are in contact.

The scope of this report does not demand a detailed discussion of the distribution of the rocks. Figure 48 shows the faults that have been located in the region and the distribution of the known manganese deposits. In a broad way the rock exposures fall into four belts marked off by faults. The northernmost belt lies north of Bromide and is bounded by two northeastward-trending faults, the southern of which passes near the town of Bromide. Within this belt the beds trend north and dip slightly eastward, so that in walking eastward along the belt the Viola limestone and successively younger beds are crossed. The second belt extends to the persistent southeastward-trending fault south of Springbrook. It coincides with the broad flat south of Bromide in which Delaware Creek flows. In this area the Caney shale is exposed at the surface, and both the shale and the underlying rocks are sharply upturned in the zone adjacent to the limiting faults. The third belt is about three-fourths of a mile wide and is included between the two extensive southeasterly faults south of Springbrook. The surface rocks in this belt are beds of the Arbuckle limestone that dip gently northward. In the southernmost belt, south of the Arbuckle limestone, only the Tishomingo granite is exposed. From the relations of these belts, it will be apparent that the Caney shale area represents the outcrop of a triangular block that has dropped about 2,000 feet lower than that north of it and about 9,000 feet lower than the granite area south of it.

The studies of Taff indicate that the faults in this region were developed at the end of the Carboniferous period. No post-Cambrian igneous rocks are known in the region. During early Mesozoic time the Arbuckle Mountains were reduced by erosion to an extensive plain, which was later covered by Cretaceous beds. These beds have been removed only recently, so that the underlying plain, cut across the Paleozoic rocks, has again been exposed at the surface.

THE DEPOSITS.

MINERALS.

These deposits are especially interesting on account of the uncommon minerals they contain. Several of these minerals have been identified with considerable assurance, but the complete identification of some specimens would demand chemical analyses, which have not been warranted by the circumstances.

In three of the five deposits described in this report (Springbrook, Moseley Creek No. 1, Moseley Creek No. 4) the commonest mineral is a carbonate of manganese, calcium, and magnesium. It occurs as irregular fine-grained masses that range in color from pale gray through light reddish and light reddish brown to dark reddish brown. It is intimately intergrown with delicate plumose masses of hausmannite, and the two minerals appear to have been the first that were deposited. Terminated crystals have not been recognized. The pure manganese carbonate, rhodochrosite, has not been observed in any of the deposits.

Calcite occurs in the three deposits in which manganiferous carbonates are common. It forms white to colorless clear crystalline masses and veinlets. It appears to be the last mineral that was deposited.

Siderite is commonly associated with the manganiferous carbonates. At the Springbrook and Moseley Creek No. 4 deposits it forms pale yellowish to greenish minute crystalline aggregates in the midst of masses of reddish manganiferous carbonates. It uniformly contains some manganese.

Hausmannite is abundant at the Springbrook, Moseley Creek No. 1, and Moseley Creek No. 4 deposits. At the first two it occurs as aggregates of closely packed minute octahedral crystals on the borders of the masses of brown manganese carbonate. Here and there druses are lined with octahedral crystals, as much as 1 millimeter in diameter. At Moseley Creek deposit No. 4 hausmannite forms plumose aggregates in calcite. The preliminary identification of this mineral was based on the recognition of numerous octahedral crystals which showed a perfect cleavage and a chestnut-brown streak.[6] Later W. T. Schaller, of the Geological Survey, determined the percentage of manganese and silica in selected material. Although the sample contained a little adhering carbonate, the manganese content was 66.73 per cent and the silica 0.71 per cent. Pure hausmannite contains 72.05 per cent of manganese and no silica; whereas braunite contains 62 per cent of manganese and 8 to 10 per cent of silica. The identification of the mineral as hausmannite is therefore satisfactorily established.

Psilomelane was observed only at the Moseley Creek deposit No. 3, where it made up most of the material recovered.

Quartz is present in the Springbrook and Moseley Creek No. 1 deposits. At the former it fills the space remaining after the other minerals were deposited, and at the latter it replaces the limestone in the fracture zone. An uncommon variety of reddish-brown and yellowish-green chalcedony is associated with the quartz. The color of the chalcedony is due to minute arborescent growths of an oxide of iron.

Pyrite is present at the Springbrook and Moseley Creek No. 1 deposits. At the former minute grains of pyrite are scattered through the brown manganiferous carbonate, and at the latter it locally nearly fills the fractures that bound the deposit.

Chalcopyrite is present in the Moseley Creek deposit No. 4 as minute grains in the brown manganiferous carbonate.

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[6] Miser, H. D., and Fairchild, J. G., Hausmannite in the Batesville district, Ark.: Washington Acad. Sci. Jour., vol. 10, pp. 1-8, 1920.

GEOLOGIC RELATIONS.

The known deposits of this region may be classified into three types on the basis of the structural associations and minerals contained, which indicate their origin.

1. The Springbrook and Moseley Creek No. 1 deposits are lenticular bodies of hausmannite and several uncommon carbonates of manganese, calcium, and magnesium that lie along faults. The Springbrook deposit crops out 50 to 100 feet below the level of the plateau, but the Moseley Creek No. 1 crops out only 10 feet above the bed of the creek and more than 100 feet below the level of the plateau. In both deposits the manganese carbonates are fresh within a few feet of the outcrop, and the adjacent rocks are not weathered. An interesting feature of the Moseley Creek deposit No. 1 is the progressive increase in the percentage of manganese, iron, and magnesium in samples of the limestone collected successively nearer the fracture zone in which the deposit occurs.

2. The Moseley Creek deposits Nos. 3 and 4 appear to contain the same groups of minerals as the deposits of the first type, but the lenses of which they are made up lie parallel with the bedding of the inclosing rocks, and no fractures or faults are known in the neighborhood. Both deposits crop out above the stream and below the level of the plateau. As in the deposits of the first type, manganiferous carbonates are fresh near the surface and the rocks are relatively unweathered.

3. The Moseley Creek deposit No. 2 is made up of nodules of psilomelane sporadically distributed through clay that fills solution cavities in limestone. It lies at the level of the plateau that was once extensive throughout this region but is now greatly dissected by the principal streams.

GENESIS.

The minerals that are present and the structural associations of the Moseley Creek deposit No. 2 leave little doubt that it has been formed by the weathering of some manganese mineral, possibly a disseminated carbonate in the limestone, and by the local concentration of the manganese as the common hydrous oxide in residual clay. Such deposits are commonly considered residual. They are probably distributed sporadically over the plateau and probably persist only to the lower limit of rock weathering, which generally coincides approximately with the ground-water level. Such deposits are found here and there in a belt that extends from the Cartersville district in Georgia [7] through Tennessee [8] into Virginia [9] and Maryland.

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[7] Hull, J. P. D., LaForge, Laurence, and Crane, W. R., Manganese deposits of Georgia: Georgia Geol. Survey Bull. 35, 1919.

[8] Stose, G. W., and Schrader, F. C., Manganese deposits in east Tennessee: Resources of Tennessee, vol. 8, Nos. 3, 4, 1918.

[9] Stose, G. W., Miser, H. D., Katz, F. J., and Hewett, D. F., Manganese deposits of the west foot of the Blue Ridge, Va.: Virginia Geol. Survey Bull. 17, 1919.

The other deposits contain an assemblage of minerals that is unknown elsewhere in the United States, although several are known to occur separately. The only other places in the United States at which hausmannite has been found are the W. T. Gray and Club House mines, in the Batesville district, Ark.,[10] and Plumas County, Calif.[11] Miser concluded that in the Batesville district hausmannite, with other manganese oxides, was deposited by cold meteoric waters. Manganocalcite is reported from the Belmont mine, Nev.,[12] and from Franklin Furnace, N. J.,[13] and, although the genesis was not specifically considered, the mineral was probably deposited under deep-seated conditions at these localities. Manganiferous calcite is more widespread; several occurrences of the mineral are described by Jones.[14]

The progressive alteration of the normal limestone in which the Moseley Creek deposit No. 1 occurs to a carbonate rock containing about 45 per cent of magnesium, iron, and manganese carbonates is also uncommon. The nearest resemblance to this variety of alteration is that found near many lead-zinc deposits in the Rocky Mountains that have been formed by the replacement of limestone, adjacent to igneous intrusions. The alteration of the dolomitic white limestone at the Tucson mine, Leadville, Colo., normally containing 27 per cent of calcium oxide, 17 to 20 per cent of magnesium oxide, and 7 to 11 per cent of silica, to a material containing 1 to 8 per cent of calcium oxide, 24.3 per cent of iron, 16.2 per cent of manganese, and 16.2 per cent of insoluble matter is described by Argall.[15]

The mineralogy of the Bromide deposits, the alteration of the wall rocks, and the association of several of the deposits with faults are highly suggestive that they have been formed by waters rising from depth along the faults. The structural relations of the Springbrook deposit and Moseley Creek deposit No. 1 are such that surface waters could have entered the limestone beds from the south and west, respectively, have flowed along the beds until the fractures were met, and then have risen and deposited the manganese minerals. It can not be determined with assurance whether the waters were warm or cold; probably they were warm.

To summarize the facts set forth above there seems to be good reason for believing that all the Bromide deposits except Moseley Creek No. 2 were formed by the deposition of manganese minerals by warm waters rising along fractures.

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[10] Miser, H. D., Hausmannite in the Batesville district, Ark.: Washington Acad. Sci. Jour., vol. 10, pp. 1-8, 1920.

[11] Larsen, E. S., jr., personal communication.

[12] Eakle, A. E., Minerals of Tonopah, Nev.: California Univ. Dept. Geology Bull., vol. 7, pp. 1-20, 1912.

[13] Levison, W. G., Am. Mineralogist, vol. 1, p. 5, 1916.

[14] Jones, E. L., jr., and Ransome, F. L., Deposits of manganese ore in Arizona: U. S. Geol. Survey Bull. 710, pp. 122, 161, 170, 174, 1920.

[15] Argall, Philip, Siderite and sulphides in Leadville ore deposits: Min. and Sci. Press, vol. 109, pp. 50-54, 128-134, 1914.

ECONOMIC IMPORTANCE.

Under normal conditions makers of ferromanganese desire raw material that contains 45 per cent or more of manganese, but their schedules provide for accepting material that contains as little as 40 per cent. During the World War, however, considerable material containing only 35 per cent of manganese was accepted. Exclusive of the Moseley Creek No. 2 and No. 3 deposits, the first of which appears to be small and the second exhausted, the material of average grade in the deposits ranges from 20 to 40 per cent of manganese. With careful sorting, however, each of the deposits is susceptible of yielding a product containing 40 to 45 per cent, or even more. Whether these deposits can be worked at a profit, however, will depend on the cost of mining, sorting, and transportation.

The two deposits that obviously contain the highest-grade material, the Springbrook and Moseley Creek No. 1, occur in fractures in the rocks and offer promise of persistence in depth. Of these, the Springbrook is the more attractive for exploration, because several shoots have been exposed already. If these deposits are compared with others in Arkansas, Georgia, Virginia, and Montana, which were a source of ore during the war, they must be regarded as too small to warrant exploration except in a most conservative manner. In connection with any plan for exploring the deposits farther, it would be advisable to search for other deposits along the faults previously located by Taff.

DESCRIPTIVE DETAILS.

SPRINGBROOK DEPOSIT.

The explorations on the Springbrook deposit extended about 1,000 feet westward from a point about 1,000 feet southwest of the settlement of Springbrook (formerly Viola), in the SW. ¼ sec. 13, T. 2 S., R. 7 E. Their extent is shown in figure 49, which is based upon a compass survey by the writer. The openings include one trench nearly 450 feet long with a maximum width of 20 feet and a maximum depth of 18 feet and six other trenches from 20 to 80 feet long, 5 to 15 feet wide, and 5 to 10 feet deep. This group of trenches extends generally northwest and therefore cuts across several spurs from the upland to the south and the intervening ravines. The highest point on the surface of any of these spurs is about 40 feet below the level of the upland, which near by ranges from 850 to 900 feet above sea level. Water flows in the ravines that cross the group of trenches, and explorations below the ravines encounter considerable water.

The work of Taff between 1897 and 1900, before any explorations were made here, indicated that there is in this locality an extensive fault between beds of the Arbuckle limestone on the south and the Viola limestone on the north. The observations made in these trenches in 1917 indicate that they follow this fault. Although typical Arbuckle limestone, apparently dipping toward the fault, occurs near by, none is exposed in the trenches. On the north side of the trenches a white to cream-colored limestone that is probably a part of the Viola limestone is continuously exposed. Toward the fault it presents a corrugated surface that is inclined 65°–75° S. It is dense and porcelain-like and locally contains small aggregates of white calcite crystals. Here and there it is intricately crushed, and brown wad is deposited along the fractures. In some places near the fault blocks of limestone 5 to 10 inches on a side are largely replaced by wad, but in general such replacement decreases with increasing distance from the fault and rarely is noticeable 10 feet from the fault. On the other hand, the south walls of the trenches show only drab to cream-colored clay with laminations parallel to the fault. Here and there the clay contains hard concretions, but no manganese oxides replacing the clay were noted. The

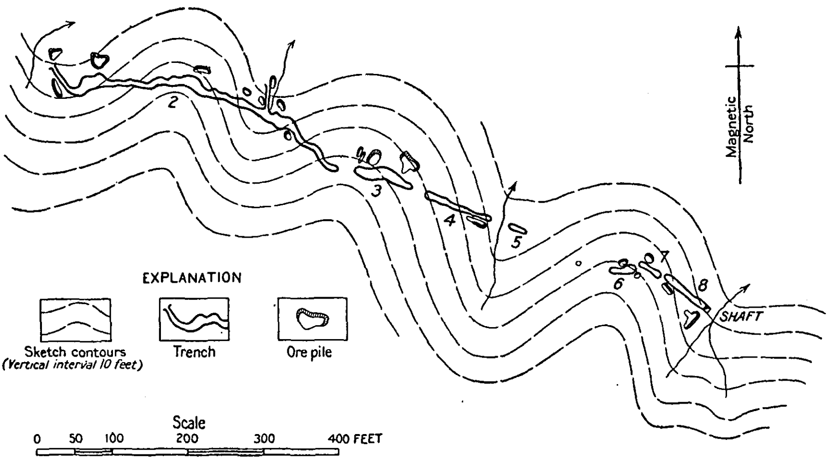

FIGURE 49.—Sketch map showing openings on the Springbrook manganese deposit, near Bromide, Okla. Numbers correspond to those used in the text.

nearest limestone outcrops south of the trenches are 10 to 20 feet distant. The local as well as the regional observations leave no doubt that the explorations have followed an extensive fault and indicate that the rocks on the north side, including the Viola limestone and underlying rocks, have dropped about 2,000 feet below the outcrop of the Arbuckle limestone on the south.

The trenches were badly caved at the time of examination, and the manganese-bearing materials that appear to make up the deposit are exposed at only a few places. On the other hand, there were 17 piles of manganiferous material near by which were so distributed as to indicate that all but two of the eight trenches have been the source of some of the material.

The explorations have disclosed material of two distinct classes. The eastern group of trenches, including Nos. 4, 6, 7, and 8, has yielded only masses of earthy brown wad, which locally replaces the Viola limestone. A sample of clear white Viola limestone selected from an exposure several feet north of the fault has been analyzed by J. G. Fairchild, of the United States Geological Survey, with the following result:

Analysis of Viola limestone from north wall of Springbrook manganese deposit near Bromide, Okla., in the SE. ¼ sec. 14, T. 2 S., R. 7 E.

Analysis.		Recalculation.	
CaO	41.82	$CaCO_3$	74.68
MgO	6.02	$MgCO_3$	12.59
FeO	4.02	$FeCO_3$	6.41
MnO	.60	$MnCO_3$	.97
CO_2	42.25	Insoluble, etc. (by difference)	5.35
	94.71		100.00

The composition of the normal Viola limestone is not known, but it would appear that a large part of the iron and manganese content represents material that was added to the limestone during the deposition of the manganese minerals in the fault. The weathering of such a limestone would yield manganese in solution, which would tend to accumulate as wad or other oxide near the surface. The wad that is observed to replace the limestone, however, is probably derived partly from the manganese in the limestone and partly from that in the carbonates in the fault.

The material of the second class is an uncommon mixture of several manganiferous carbonates and hausmannite, an oxide of manganese. It forms highly irregular lenses in the clay that fills the fault; locally it forms irregular pockets in the Viola limestone footwall. The largest body was explored in trench No. 3, which is 80 feet long, 15 feet wide, and 10 feet deep. Three piles of material near by, probably representing all that came out of the trench, were estimated to contain 150 tons. Trench No. 2 is about 450 feet long, 20 feet wide in several places, and 18 feet deep in two places. It apparently contained several lenses of manganiferous rock, and the nine piles of material near by were estimated to contain 200 tons. Trench No. 1, 200 feet northwest of No. 2, crosscuts the beds, and from the bottom a shaft extends to a depth of 20 feet. No manganese minerals were found, but the shale that forms the country rock contains many cubic crystals of pyrite. The material that lies on the dumps and apparently makes up a large part of the deposits appears in hand specimens to be largely a mottled mixture of black, reddish-brown, and pale-pink minerals, without any orderly arrangement. From blowpipe tests, etching tests of polished surfaces, and the examination of several thin sections, it appears that the dark-brown and reddish-brown minerals are carbonates of calcium (magnesium?), iron, and manganese, the darker color being due largely to an increase in the proportion of minute particles of manganese oxides (hausmannite?). The mineral next in abundance is hausmannite, which appears as terminated octahedrons in druses and as minute veinlets which cut the brown carbonate. Quartz is present as clear to white masses that largely fill druses. A pale-red, slightly manganiferous dolomite forms veinlets, which cut all the other minerals. The order of deposition of these minerals appears to be as follows:

1. Calcium (magnesium?), iron, and manganese carbonates with hausmannite.
2. Hausmannite.
3. Quartz.
   Fracturing.
4. Calcium-magnesium carbonate.

An examination of the available material indicates that this mineral aggregate replaces the Viola limestone. The clay in which the masses are embedded is probably the residue left after the solution of the carbonates in the limestone.

Some other masses that lie near by but are not intimately associated with the manganiferous carbonates and hausmannite are made up of a pale-reddish earthy calcium (magnesium?)-manganese carbonate, through which grains of pale yellowish-green crystalline iron carbonate (siderite), also manganiferous, are distributed.

The composition of a number of samples of the mixed carbonate-oxide material from this deposit is shown in the following table. The samples were collected in 1917 by G. E. Burton and were analyzed in the chemical laboratories of the University of Oklahoma.

Analyses of material from the Springbrook manganese deposit, secs. 13 and 14, T. 2 S., R. 7 E., Okla.

	11	12	13	18	20	21a	21b	28
MnO	18.60	43.73	27.66	73.49	46.05	59.65	16.28	70.93
(Mn)	(14.40)	(33.84)	(21.42)	(56.88)	(35.64)	(46.26)	(12.60)	(54.90)
FeO	20.35	6.28	7.06	6.28	5.50	25.90	32.94	7.85
(Fe)	(15.85)	(4.88)	(5.49)	(4.88)	(4.27)	(20.13)	(25.60)	(6.10)
P_2O_5	.23	.11	.12	.32	.0	.57	.69	.65
(P)	(.10)	(.05)	(.054)	(.14)	.0	(.25)	(.30)	(.29)
SiO_2	39.83	18.44	22.71	13.09	15.02	2.03	8.72	1.91
Undetermined (CaO, MgO, CO_2, etc.)	20.99	31.44	42.45	6.82	33.43	11.85	41.37	18.66

Two of these samples (Nos. 18 and 28) were obviously made up largely of hausmannite; two others (Nos. 11 and 21b) were probably largely carbonates of iron, manganese, and calcium.

At the time of examination no material had been shipped from this deposit. The quantity of material removed to the dumps from the existing trenches indicates that about 5,000 tons containing 35 to 40 per cent of manganese may be recovered within 100 feet of the surface.

MOSELEY CREEK DEPOSIT NO. 1.

A deposit which greatly resembles that at Springbrook lies on a flat spur in a bend of Moseley Creek in the SW. ¼ sec. 28, T. 1 S., R. 8 E., 1½ miles northeast of Bromide. It was probably worked in the early nineties, as it appears on Taff's map made in 1897. The only opening is a trench 40 feet long, 15 feet wide, and a maximum of 8 feet deep.

In the trench and along the channel of Moseley Creek beds of pale-yellowish earthy limestone, 6 inches to 2 feet thick, that trend slightly west of north and dip 10° E., are exposed. The beds appear to be the lower part of the "Hunton limestone." The outcrop of the deposit lies scarcely 10 feet above the bed of Moseley Creek, at an

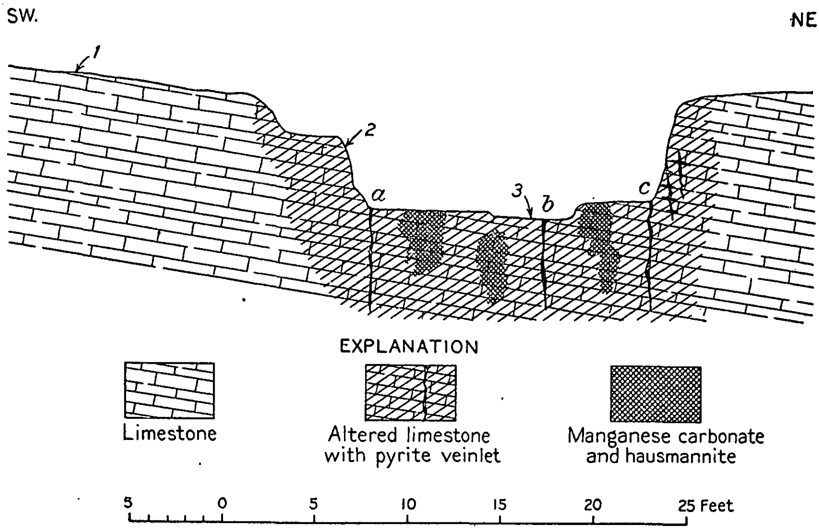

FIGURE 50.—Vertical cross section of the Moseley Creek manganese deposit No. 1, near Bromide, Okla. *a, b, c,* Fissures in limestone; 1, 2, 3, points where samples were taken for analysis.

elevation of about 700 feet, and it is therefore about 200 feet below the level of the upland north of Bromide.

The deposit is made up of irregular masses of hausmannite and several obscure carbonates of manganese, calcium, and magnesium, which with other minerals lie in a fracture zone in the limestone. The general relations of the minerals to the fracture are shown in figure 50. There may be a small displacement of the limestone beds along the fracture, but this can not be determined with assurance.

The trench follows a crushed zone in the limestone that trends N. 60° W. The crushed zone is limited by two nearly vertical fissures (*a, c,* fig. 50) about 15 feet apart, and a third fissure (*b*) lies between these. These fissures are about 1 inch wide and are filled with cubic pyrite and several carbonates.

Three classes of material are found in the crushed zone. The most abundant is a dense gray carbonate of calcium (magnesium?), iron, and manganese, of which an analysis is given on page 325 (No. 3). It probably represents altered "Hunton limestone." Here and there in the gray carbonate are areas of mottled reddish and white crystalline carbonates, which appear from simple chemical tests to contain calcium, magnesium, and manganese, but in proportions that differ from those in the gray material. Minute crystals of pyrite are scattered through these mottled areas.

The next most abundant material is an intimate mixture of a brownish manganiferous carbonate and hausmannite and constitutes that which was sought as a source of manganese. About 100 tons of this material has been removed from the trench and lies scattered over the surface south of it. Examined casually, this material appears to contain three substances—(1) a dark-brown substance with dull earthy luster, which generally forms irregular patches but locally forms mammillary masses; (2) a black substance with metallic luster, which forms veinlets in the brown substance as well as layers of octahedral crystals in druses; (3) a pale-reddish to white finely crystallized substance which fills veinlets and the interstices between the other substances. By further close examination of polished surfaces under the microscope and chemical tests it has been determined that the dark-brown substance is composite and contains delicate plumose masses of crystals of hausmannite embedded in a light-brown carbonate of calcium, magnesium, and manganese. The black crystals are hausmannite, and the pale-reddish substance is also a carbonate of calcium, magnesium, and manganese.

In the altered limestone between the fractures, most abundantly between those marked *a* and *b* in figure 50, there are round nodules and large irregular masses of gray quartz, which are intimately intergrown with the inclosing altered limestone. Some of the quartz nodules contain small reddish-brown and greenish patches whose color is probably due to inclusion of ferric and ferrous oxides. Here and there the altered limestone also contains small drusy masses of crystalline siderite.

The normal "Hunton limestone" in this region is buff to pale gray, is rather porous, and has a dull earthy luster. On close examination it is seen to contain numerous fossils—corals, brachiopods, and crinoid stems. In the vicinity of the fractures, however, as especially well exposed on the south side of the fracture zone, the limestone is progressively harder, denser, and more coarsely crystalline as the fracture is approached. The hardest varieties are distinctly reddish. On the surface the limestone is irregularly replaced to a depth of a few inches by brown wad, an impure hydrous oxide of manganese, in such a way as to suggest that the source of the manganese is the altered limestone itself. The zone within which this replacement has occurred is about 15 feet wide. In order to determine whether the change in appearance corresponds with a change in composition and whether the altered limestone is the source of the manganese in the wad, several samples were collected at the points marked 1, 2, and 3 in figure 50, and analyses of these samples have been made by J. G. Fairchild, of the United States Geological Survey, with the results shown in the following table:

Analyses of unaltered and altered "Hunton limestone" collected near the Moseley Creek manganese deposit No. 1, in the SW. ¼ sec. 28, T. 1 S., R. 8 E.

	1	2	3
CaO	40.56	29.02	29.02
MgO	.30	12.15	14.35
FeO	.28	3.45	4.02
MnO	.39	9.08	6.42
CO_2	32.30	43.79	44.89
	73.83	97.49	98.70
Recalculation.			
$CaCO_3$	72.42	51.82	51.82
$MgCO_3$	.63	25.41	30.01
$FeCO_3$	.44	5.50	6.41
$MnCO_3$	.63	14.71	10.40
Difference (insoluble, etc.)	25.88	2.56	1.36
	100.00	100.00	100.00

1. Unaltered "Hunton limestone" from surface 15 feet south of fracture *a* (fig. 40). Contains considerable insoluble matter.
2. Altered "Hunton limestone" from surface 2 feet south of fracture *a* (fig. 40).
3. Altered "Hunton limestone" from fracture zone.

These analyses indicate that the normal unaltered "Hunton limestone" is largely calcium carbonate, slightly siliceous but low in magnesia. Near and within the fracture zone the limestone is altered to a carbonate rock in which about one-third of the calcium carbonate is replaced by magnesium, iron, and manganese carbonates. As the percentage of insoluble matter (silica, etc.) is much lower in the carbonate rock in and near the fracture zone, it appears that the silica originally present in the limestone is segregated into the masses of quartz that were observed. The significance of the alteration is discussed under "Genesis" (p. 318).

If the manganiferous material persists 100 feet below the surface, as appears likely, the deposit is probably capable of yielding about 1,000 tons. It was estimated that the 100 tons of material on the dumps contains about 40 per cent of manganese.

MOSELEY CREEK DEPOSIT NO. 2.

The Moseley Creek deposit No. 2 lies on the top of a low spur about 70 feet above a ravine near by on the west, in the NE. ¼ sec. 20, T. 1 S., R. 8 E. The position is marked on Taff's map made in

1897. According to Taff the deposit occurs near the base of the "Hunton limestone." The workings expose thin-bedded gray limestone in beds 1 to 2 feet thick.

The deposit has been explored by two trenches. The larger one is 120 feet long, 45 feet wide, and 5 feet deep, and the smaller one is 40 feet long, 6 to 10 feet wide, and 6 feet deep. The larger trench was made by plowing the decomposed surface clays and appears to have yielded some ore, as about 1 ton, containing about 40 per cent of manganese, now lies on the dump. Some rounded boulders of limestone were encountered in the clay. The smaller trench follows a solution channel in limestone, which was filled with reddish-brown clay. The only manganese mineral that was found in these trenches was psilomelane in botryoidal nodules; hausmannite and the manganese carbonates characteristic of the Springbrook deposit and Moseley Creek deposit No. 1 were not found.

The nodules of manganese oxides in clay undoubtedly represent concentrations of manganese that was once more widely disseminated, although the source is not apparent. The source may be some manganese carbonate in a near-by fracture zone or manganese disseminated through the limestone. If either of these is the source, the deposits are probably not large. On the other hand, the deposit occurs on a remnant of the plateau that was once extensive in this region, and the manganese oxides may have been concentrated during the period of formation of the plateau.

The extent of the known deposit is not apparent, but it probably does not contain more than several hundred tons of oxides.

MOSELEY CREEK DEPOSIT NO. 3.

In an area about 100 feet square near the southeast corner of sec. 17, T. 1 S., R. 8 E., there are several open cuts, from which some manganiferous material has been removed. The largest open cut is about 40 feet in diameter and 10 feet deep.

At the bottom of these open cuts is a bed of pale-reddish crystalline limestone 6 to 12 inches thick, which is made up of red calcite crystals in a cream-colored matrix. The same bed forms the floor of the stream bed 25 feet west and the dip slope of the hill beyond. It trends north and dips 10° E.

Although no manganese oxides or carbonates may be seen in the open cut, the location of the deposit corresponds with that from which 17 carloads (about 197 tons) of ore was mined and shipped to Chicago in 1892.[16] In the following table the analyses of these shipments are given:

[16] Weeks, J. D., op. cit.

Analyses of manganese ore shipped from Moseley Creek deposit No. 3.

Cars.	Weight (pounds).	Iron (per cent).	Silicon (per cent).	Phosphorus (per cent).	Manganese (per cent).	Moisture (per cent).	Price per ton.
2	44,003	6.00	1.40	0.055	39.66	4.05	$10.32
2	53,226	6.15	1.45	.066	39.67	4.75	10.31
2	49,807	5.72	1.70	.060	43.18	3.25	12.09
2	45,816	6.76	1.20	.053	38.54	4.05	10.02
5	156,738	8.50	1.50	.050	40.50	3.70	10.93
4	93,910	8.09	....	....	35.78	5.00	8.95

The portion of the content that is not accounted for in the analyses and the low percentage of phosphorus indicate that the manganese and iron were, in part at least, present as carbonates. The geologic associations also resemble those at Moseley Creek deposit No. 4. If they are similar, the lens was no larger than the open cut.

MOSELEY CREEK DEPOSIT NO. 4.

A deposit which contains the minerals found in the Springbrook and Moseley Creek No. 1 deposits and yet has very different structural relations is situated in the NE. ¼ sec. 17, T. 1 S., R. 8 E., about 4 miles north of Bromide. The position of the deposit is marked on Taff's map made in 1897, and it appears to be the "prospect No. 2" of Reeds's report.[17] The deposit has been explored by an open cut 100 feet long, 40 feet wide, and a maximum of 8 feet deep at the south end.

The deposit is a lenticular body composed of several manganiferous carbonates, siderite, calcite, and hausmannite. The thickness of the lens ranges from 1½ feet at the north end to 8 feet at the south end, 100 feet distant. It lies roughly parallel to the bedding of the inclosing limestone, which trends north and dips 5°–10° E. According to Taff, the deposit lies east of the base of the "Hunton limestone" and is therefore inclosed in it. An interesting stratigraphic feature, which probably has no relation to the manganese deposits, however, is the well-defined unconformity between the limestone that overlies the manganese deposits and the higher drab thin-bedded shaly limestone. The relations of the beds do not suggest faulting, and no fractures were observed near the deposit. Figure 51 shows a cross section of the open cut.

Although the same minerals are present in this deposit, in the Moseley Creek deposit No. 1, and in the Springbrook deposit, their relations here differ from those observed at the other two. At the north end of this deposit, where the lens is 18 inches thick, it is made up of two layers of calcite through which plumose aggregates of hausmannite are distributed. No manganiferous carbonates are

[17] Reeds, C. A., op. cit., p. 58.

present. The thickness of the lens increases toward the south end of the open cut, however, and near the middle it is made up largely of an aggregate of black, brown, and gray carbonates. The black carbonate is crystalline and appears to be calcite in which there are many minute grains of a black oxide of manganese. The brown and gray carbonates are dense in texture and from simple chemical tests appear to be largely carbonates of manganese and calcium, although magnesium may be present. In the center of the lens, however, there are irregular lenses of mottled pale-reddish, yellowish-green,

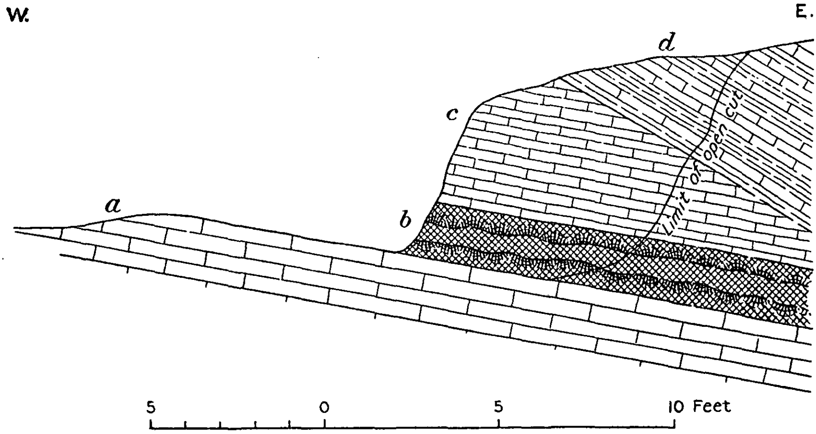

FIGURE 51.—Vertical cross section of the Moseley Creek manganese deposit No. 4, near Bromide, Okla. *a*, Dense gray limestone; *b*, manganiferous zone; *c*, thin-bedded gray limestone, with crinoid stems; *d*, drab shaly limestone.

and white carbonates. Each contains manganese and calcium, and the yellowish-green carbonate contains considerable iron.

At the south end of the open cut, where the lens is about 8 feet thick, it is made up largely of several layers of white calcite, which contains plumose hausmannite.

Reeds[18] quotes the following analysis of material apparently collected from this deposit:

Analysis of material from Moseley Creek deposit No. 4.

Manganous oxide	22.88
Ferrous oxide	13.86
Calcium oxide	24.20
Magnesium oxide	Trace.
Aluminum oxide	.40
Silica	1.60
Loss on ignition (CO_2, etc.)	32.80
Moisture	1.08
Phosphorus pentoxide	.30
	97.12

[18] Reeds, C. A., op. cit., p. 58.

In composition this material resembles the altered "Hunton limestone" at the Moseley Creek deposit No. 1, except that here magnesium is practically absent.

In order to obtain ore with 45 per cent or more of manganese for shipment, the crude material would have to be carefully sorted and a considerable part rejected. Several hundred tons of material containing 15 to 20 per cent of manganese has been removed from the deposit, and several thousand tons may still remain. The experience in mining the Moseley Creek deposit No. 3 indicates that such lenses are not persistent along the bedding of the inclosing limestone.