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The Manganese Deposits of the Turtle Mountains, North Dakota

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THE MANGANESE DEPOSITS OF THE TURTLE MOUNTAINS, NORTH DAKOTA.[1]

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ABSTRACT.

The principal manganese spring deposits in the Turtle Mountains of North Dakota were investigated and mapped in detail. One of these, Mineral Spring, located in the N½ NE¼ Section 22, T. 162 N., R. 73 W., was found to contain approximately 16,000 tons of manganese ore in the form of the mineral ranciéite in calcareous tufa with an average manganese content of about 10 per cent. The source of the manganese appears to be in manganiferous limonitic concretions in the Fort Union formation which underlies the glacial drift in the Turtle Mountains.

INTRODUCTION.

General Statement. The manganese deposits of the Turtle Mountains have been known for many years but no detailed report of these deposits has been published. Manganese at present is classified as a strategic metal and search for domestic supplies has therefore been accelerated. Parts of the deposits of the Turtle Mountains, though small, are of considerable scientific interest.

Location. The Turtle Mountains are located in the northwestern part of Rolette County and the northeastern part of Bottineau County, North Dakota, in townships 161–164 north and ranges 70–77 west; they extend into the province of Manitoba, Canada.

Three of the spring deposits contain abundant evidences of manganese. These are: Mineral Spring (N½ NE¼ Section 22, T. 162 N., R. 73 W.), Holy Spring (SE¼ Section 25, T. 162 N., R. 72 W.), and an unnamed spring north of Dunseith (NE¼ NW¼ Section 30, T. 162 N., R. 72 W.).

[1] Published by permission of the Director, Geological Survey, United States Department of the Interior.

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Method of Study. The deposits were surveyed with a plane table and alidade. At selected localities, bore holes, hand-drilled with a four-inch post-hole auger, were put down to determine the thickness of the deposits. Samples were taken at several places to obtain an average manganese content of the deposit.

Physiography. The area occupied by the Turtle Mountains is an oval-shaped upland 25 miles in width by 40 miles in length extending into the province of Manitoba, Canada. The "mountains" attain altitudes of as much as 2,300 feet above sea level and stand 400–700 feet above the surrounding plain.

Geologically, the Turtle Mountains consist of a core of bedrock of the Fort Union formation (Paleocene) mantled by a thick covering of glacial debris. The glacial till is in the form of recessional moraines which, on the mountains proper, exhibit typical recessional moraine topography, knobs and kettles, some of which contain lakes whereas others are only undrained depressions. The surface of the mountains is definitely youthful, as well-integrated drainage has yet to be established.

The plain surrounding the mountains, particularly on the south, appears to be a mixture of ground moraine and glacial outwash. In many places, the ground moraine seems to have been partly covered by the outwash. The plain near the mountains is studded with lakes and undrained depressions, due perhaps either to buried pre-glacial drainage or to the melting of buried ice blocks, or both.

STRATIGRAPHY.

Tertiary.

Paleocene.

Fort Union formation. The bed rock in the Turtle Mountains is so effectively covered with glacial drift that very little is known about it. Because of the occurrence of lignite in the area[4] it has been inferred that the bed rock immediately below the drift is a part of the Fort Union formation. The lignite, however, has been seen in only one exposure and so little else is known of the bed rock in the Turtle Mountains that it will not be extensively discussed in this report.

The single outcrop is located in the SW¼ NW¼ Section 7, T. 162 N., R. 76 W., along State Route 14, 5 miles north of Carbury, Bottineau County, North Dakota. Lignite has been reported[5] as occurring two miles north of Dunseith, Rolette County, in an old mine shaft. The lignite had a dip of 30° to the north according to Babcock.[6] Mr. Gottbreht, who was financially interested in the mine, reports that the lignite was apparently a "slide." The possibility of faulting should also be tentatively considered, particularly in view of the fact that the manganese-bearing springs are situated along a line approximately parallel to a projection of this "slide."

The Fort Union formation consists predominantly of light, ash-gray, yellow to brown-colored sands and clays with darker lignitic shales and lignites. The sands are fine-grained and usually not well indurated except in certain areas where quartzitic concretions due to case-hardening have been formed. The clays are thin-bedded and at places contain considerable amounts of bentonite. Owing to the fact that the Fort Union formation is predominantly

[4] Babcock, E. J.: North Dakota Geol. Surv. 1st Bienn. Rept., p. 71, 1901. Wilder, F. A.: The lignite coal fields of North Dakota. North Dakota Geol. Surv. 2nd Bienn. Rept., p. 162, 1902. Leonard, A. G.: The geological formations of North Dakota. North Dakota Geol. Surv. 3rd Bienn. Rept., p. 154, 1904.

[5] Babcock, E. J.: op. cit. Wilder, F. A.: op. cit. Leonard, A. G.: op. cit. Personal communication from Mr. William Gottbreht of Dunseith, N. Dakota.

[6] Babcock, E. J.: op. cit., p. 71.

continental, the beds are characteristically lenticular. The color does not change much on weathering, the brown and gray being largely retained.

The character and composition of the bed rock are important, as it is one of the possible sources, if not the most probable source, of the manganese in the Turtle Mountain deposits. In the outcrop north of Carbury, there is a considerable thickness of gray, fine-grained sand, brown, fine-grained sand and gray and brown shale with some thin lignitic shale stringers. Interbedded with the shales and sands are a few limonitic concretionary layers which contain a trace of manganese.[7]

Pleistocene.

Late Wisconsin. The glacial deposits of the Turtle Mountains are practically unstudied and very little detailed information is available. The deposits are primarily glacial recessional moraine of late Wisconsin age with glacial outwash forming a more or less regular apron around the mountains, particularly to the south. Interspersed in this apron of outwash are what appear to be irregular patches of ground moraine. The glacial deposits of the Turtle Mountains have been reported by Leonard [8] as being from 100 to 200 feet thick. At certain places, such as at the well located in the SE¼ Section 36, T. 164 N., R. 73 W., the drift is much thicker. At this locality gravel is reported to be 455 feet below the surface with the possibility that 20 feet more may also be glacial till. This excessive thickness may be due to the filling of a pre-glacial valley.

THE MANGANESE DEPOSITS.

All three of the manganese deposits investigated in the Turtle Mountains have been formed around cold springs. The manganese is in the form of ranciéite,[9] a finely flaky, soft, brownish-

[7] The sample was tested by Miss Adelynn Magnusson, analyst, of the School of Mines at the University of North Dakota at Grand Forks.

[8] Leonard, A. G.: The surface features of North Dakota and their origin. Univ. North Dakota Bull. 14, no. 1: 20, 1930.

[9] Fleischer, Michael and Richmond, W. E.: The manganese oxide minerals, a preliminary report. Econ. Geol., 38: 269–286, 1943.

black, hydrous calcium-manganese oxide, mixed with calcium carbonate in the form of calcareous tufa.

Mineral Spring. The most important manganese deposits investigated are those at Mineral Spring located in the N½ of the NE¼ of Section 22, T. 162 N., R. 73 W. The manganese in this locality is found in two different deposits about 150 feet apart (Fig. 1). The deposit farthest west is a circular mound 50 feet in diameter and about 6 feet above the surface of the swamp surrounding it. The center of the mound is so swampy that the depth was not determined. The outside of the mound consists entirely of porous, dry, earthy manganese oxide and calcareous tufa. Owing to the hardness of tufa, the depth of this deposit could not be determined with the post-hole auger.

The main manganese deposit at Mineral Spring lies about 150 feet east of the above-mentioned mound. This deposit is approximately rectangular in shape, with an effective length of 260 feet and a width of 150 feet. From data gathered from holes put down by hand auger, it appears that the deposit has a maximum thickness of 15 feet, and is lens-shaped in cross-section.

This main deposit is in the form of a layer of porous wad and calcareous tufa blanketing the hillside. The upper part where the water from the present spring opening emerges is basin-shaped. The rim of this basin is about 2 feet above the present water level of the spring basin, suggesting that either there is less water now, or that the rim of the basin has been breached.

Using the figures above-mentioned (260 × 150 feet) and assuming an average thickness of 10 feet, this deposit on the east side of the road (Fig. 1) contains 390,000 cubic feet. According to a Department of the Interior Press Memorandum,[10] about 25 cubic feet of this material constitutes a ton. This would mean that there are 15,600 tons of manganese and calcareous tufa in the main part of the deposit. Using a diameter of 50 feet and a height of 6 feet for the mound on the west side of the road, it was found that this mound should contain 472 tons. The total tonnage of the two deposits, then, is approximately 16,000 tons.

[10] U. S. Dept. Interior Press Mem. 158359.

The Mineral Spring deposit is interesting because of the rather clear indications that the spring has had more than one opening. It would appear that the mound (Fig. 1) on the west was the first

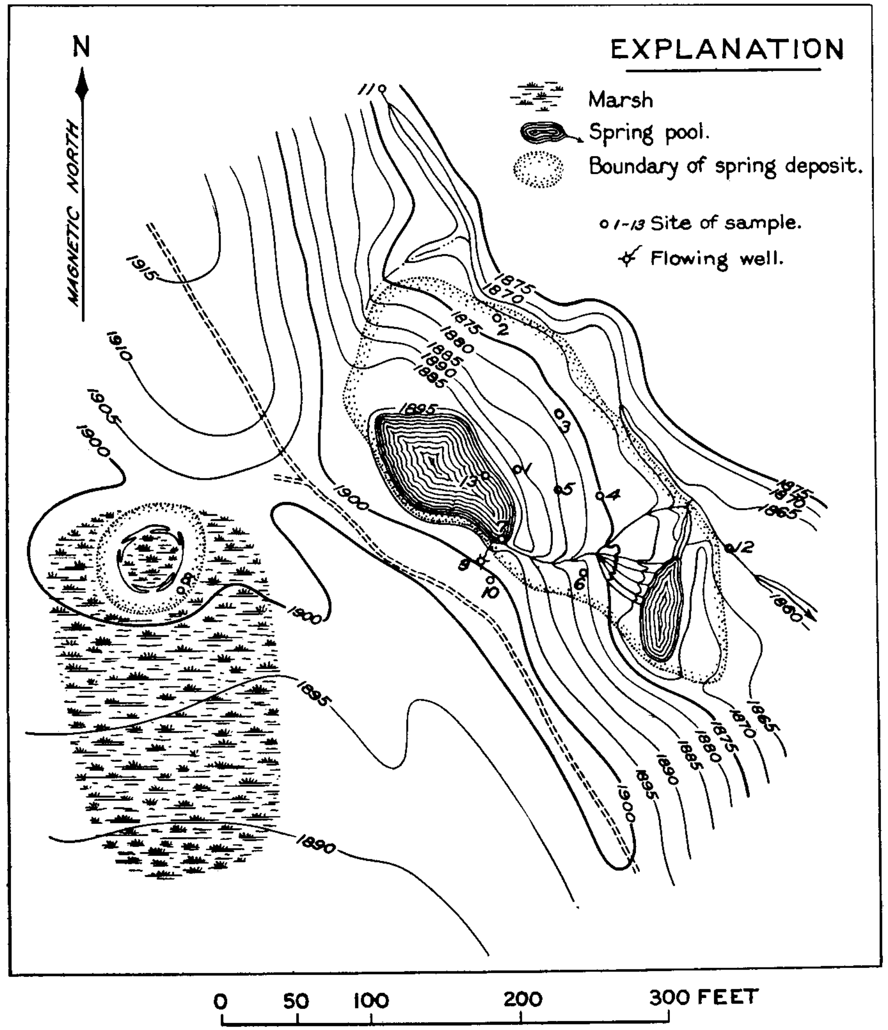

FIG. 1. MAP OF MINERAL SPRING, NE. ¼ Sec. 22, T. 162 N., R. 73 W., Dunseith Quadrangle, North Dakota, T. A. Hendricks and W. R. Wagner.

opening of the spring and that the spring flowed from that opening until the deposition of the manganese and calcareous tufa had built the mound so high that the hydrostatic pressure was no longer sufficient to force the water out that opening. It then broke out at a lower level, forming the main deposit 150 feet east of the mound. The swampy character of the center of the mound and the area surrounding it indicates that the water is still very near the surface on the west side of the road, although the main flow of the spring is on the east side of the road.

There is some evidence of another spring basin 25 feet below the present spring opening. This is shown on Figure 1 southeast of the main spring deposit. A low ridge containing slight amounts of manganiferous tufa is present on the southeast side of a small pool. This basin may be a minor subsidiary opening to the main spring or it may be a former opening of the spring which is not now functioning at full capacity. The more likely explanation seems to be that this is a subsidiary opening.

From the fact that the manganese deposits are resting on glacial till, as was determined by auger holes, it is evident that these deposits have been formed since late Wisconsin time; in fact, as the main deposit is resting on the side of a valley cut in the glacial till, it would appear that there had been some erosion prior to the formation of the main spring deposit.

Spring North of Dunseith. About 1 mile north of Dunseith in the NE¼ of the NW¼ of Section 30, T. 162 N., R. 72 W., there is a spring with a fairly well-developed mound showing traces of manganese. The mound here is roughly elliptical in shape and is about 225 feet in length by 125 feet in width. The center of the mound where the spring emerges is about 10 feet above the surrounding swamp surface. The whole mound is so saturated with water that it was impossible to hand-auger down more than 5 feet. No reliable estimate of the thickness of this deposit, therefore, can be given; the only basis for an estimate is the above-mentioned fact that the mound stands about 10 feet above the surrounding swamp surface.

From surface indications this deposit consists mainly of calcareous tufa with only slight amounts of manganese. It would be advisable, however, to make more exhaustive borings before a totally negative report on this deposit is given.

Holy Spring. This manganese-bearing spring is located in the SW¼ of the SW¼ of Section 25, T. 162 N., R. 72 W., 5½ miles east of Dunseith, North Dakota. This spring has a larger flow of water than the other springs investigated, but no mound of manganese or calcareous tufa was found immediately around the spring opening. About 50 or 60 feet below the spring opening and along the stream issuing from the spring there are indications of manganese but in no large amounts.

South of the spring in the NW¼ of the NW¼ of Section 36, T. 162 N., R. 72 W., the stream valley opens into a flat about 500 feet wide. In this flat in two places in the stream, deposits of calcareous tufa were found, but little if any manganese. That the stream is now depositing calcareous material is evidenced by the deposition of that material around sticks and on glacial boulders in the stream bed. As it does not appear that there is manganese in commercial quantities in this deposit, this spring was not mapped.

MODE OF ORIGIN OF THE DEPOSITS.

There appear to be two possible sources of the manganese of the Turtle Mountains; namely, the glacial drift and the bed rock. Samples of the glacial drift were tested for manganese and a trace was found to be present (sample No. 10, Table 1).

As has been noted previously in this report, the bed rock immediately underlying the drift is considered to be Fort Union (Paleocene) in age. If the stratigraphic sequence is normal, the Fort Union should be underlain by the Hell Creek formation of Cretaceous age. Both of these formations in other parts of the State contain ironstone concretions which contain small amounts of manganese. In the files of the North Dakota Geological Survey there are records of analyses made on some "ironstone" concretions from Burleigh County which were collected from either the Fort Union or the Hell Creek. These concretions average 4.8

TABLE 1.

MANGANESE SAMPLES COLLECTED BY T. A. HENDRICKS FROM SECTION 22, T. 162 N., R. 73 W., ROLLETTE COUNTY, NORTH DAKOTA (analyses by Victor North of the Chemical Laboratory, Geological Survey, and checked by analyses by Rolla Experiment Station. Bureau of Mines, United States Department of the Interior).

	1	2	3	4	5	6	8	10 Glacial Till	15
Mn	23.76	3.18	5.32	5.07	18.31	13.76	7.51	0.10	2.91
SiO_2	1.48	0.31	0.72	0.41	1.62	0.71	1.20		0.52
Fe_2O_3	0.23	0.09	0.11	0.03	0.13	0.04	0.08	2.60	0.65
Al_2O_3	0.36	0.21	0.33	0.11	0.42	0.06	0.39		0.67
CaO	26.71	50.38	47.65	48.39	26.20	35.76	42.38	17.8	49.80
P_2O_5	0.04	0.03	0.07	0.06	0.05	0.01	0.05	0.12	0.02

per cent manganese. The concretions collected in the outcrop of the Fort Union north of Carbury contained only a trace of manganese. It would appear, therefore, that the immediately underlying bed rock was the most probable source of the manganese.

Similar manganese spring deposits are reported by Spector [11] from the Riding Mountains in the province of Manitoba, Canada. Here, however, the source was clear, as the Odanah beds (upper Pierre age), which crop out in the Riding Mountains, contain manganiferous concretions. The analysis of one concretion from the Odanah shale contained 4.44 per cent of manganese dioxide.[12] Hewett [13] points out there is no good evidence that excessive accumulations of manganese in sedimentary deposits depend on excessive percentages in the rocks surrounding the basin in which the waters entering the basin rise; therefore, even the trace of manganese reported in the concretion from the Fort Union north of Carbury, North Dakota, might be sufficient for the Turtle Mountain deposits.

Hewett [14] also states that manganiferous carbonates are much more widespread in unweathered sediments than the oxides. If

11 Spector, I. H.: Manganese deposits in the Riding Mountain area, Manitoba. The Pre-Cambrian, July, 1941, pp. 49–51.

12 Idem., p. 51.

13 In Twenhofel, W. T.: Treatise on Sedimentation, 2nd edit. Williams and Wilkins Co., Baltimore, 1932, p. 578.

14 Idem., p. 563.

the manganese is in this form in the bed rock, then carbonated waters circulating through the bed rock could leach the manganese out of the nodules and carry it in the form of manganese bicarbonate. According to Savage[15] this manganese bicarbonate would remain in solution until the water issued from a spring where the solution would become slightly alkaline through the action of aeration, the presence of calcium carbonate, or thread bacteria. Zappfe[16] has shown that once the manganese oxide began to form it would act as a catalyst in precipitating additional manganese oxide from solution.

Possibly reactions similar to those occuring in the Riding Mountains of Canada took place in the Dunseith Mineral Spring deposits; however, in view of the fact that the mineral of the Mineral Spring deposits appears to be the rather rare species of manganese determined by mineralogists of the United States Geological Survey[17] to be ranciéite, the reactions are not in every respect identical. Ranciéite is a hydrous calcium-manganese oxide. The manganese may originally have been in solution as manganese bicarbonate; the calcium may have entered into the compound when the ground water bearing the manganese bicarbonate solution came in contact with the glacial till, as the till is very calcareous.

Apparently ranciéite does not have the same catalytic effect on manganese in solution as pyrolusite (MnO_2) has. Zappfe[18] has shown that pyrolusite causes immediate and apparently complete precipitation of all manganese in solution when the manganese-bearing solution comes in contact with it. The waters of the stream below Mineral Spring (sample No. 12, Table 2), however, were found to contain 7 parts per million of precipitated manganese. When the sample was taken, the water was clear so the precipitation apparently took place after sampling. This precipitate would indicate that the ranciéite does not have the same catalytic effect that pyrolusite does.

[15] Savage, W. S.: Solution, transportation and precipitation of manganese. Econ. Geol., 31: 292, 1936.

[16] Zappfe, C.: Deposition of manganese. Econ. Geol., 26: 824, 1931.

[17] Fleischer, Michael, and Richmond, W. E.: op. cit.

[18] Op. cit., pp. 816, 824.

TABLE 2.

Partial Analysis of Water from Near Dunseith by N. A. Talvities.

	Parts per Million			
	7	9	11 Above Spring	12 Below Spring
Manganese (Mn)				
In solution	0.3	2.0	0	0
Precipitated	1.9	0.08	0.04	7.00
Bicarbonate (HCO_3)	530.00	540.00	334.00	486.00
Sulphate (SO_4) Approx.	340.00	360.00	400.00	440.00
Chloride (Cl)	6.00	7.00	4.00	7.00
Total hardness as $CaCO_3$	678.00	720.00	624.00	744.00

It was thought in the field that part of the manganese in the waters below Mineral Spring might have come from other sources. To test this possibility, a sample of water from the stream above the spring was taken (sample No 11, Table 2) and found to contain only 0.04 part per million of precipitated manganese. It would thus appear that the greater part of the manganese in the water below the spring undoubtedly came from Mineral Spring.

The exact cause of the precipitation of ranciéite is not known, but it may be suggested that the escape of hydrogen sulphide (H_2S) and the deposition of calcium carbonate ($CaCO_3$) in the form of calcareous tufa caused a change in the pH of the water which, together with aeration, resulted in precipitation of some of the manganese and calcium as ranciéite.

ANALYSIS OF THE ORE.

The analyses of the manganese ore at Mineral Spring show that it is definitely of low grade. The manganese content of the samples can be seen by reference to Table 1. The manganese content of these samples (neglecting sample No. 10, which is a sample of glacial till) ranges from 3.18 to 23.76 per cent and averages 9.97 per cent. It will be noted that in the samples showing a high manganese content the percentage of calcium carbonate is relatively low; conversely where the percentage of calcium carbonate is high the manganese content is low. The ores can thus be divided roughly into two types; a "soft" ore high in manganese and a "hard" ore lower in manganese and higher in calcium carbonate in the form of tufa.

A sample of the crude ore was supplied to Mr. S. M. Shelton, Supervising Engineer of the Rolla Experiment Station of the Bureau of Mines, United States Department of the Interior. Mr. Shelton kindly prepared, by flotation with sodium oleate and dextrin, a concentrate free of calcium carbonate or other impurities in significant amounts. A sample of this pure material was photographed with x-rays and found to give the diffraction pattern of ranciéite. A complete chemical analysis of the sample was then made by Michael Fleischer of the Chemical Laboratory of the Geological Survey. It is quoted below.

Analysis of a flotation concentrate of ranciéite from Mineral Spring.

MnO_2	66.26	TiO_2	None
MnO	1.37	CO_2	2.60
Al_2O_3	0.19	P_2O_5	None
Fe_2O_3	0.30	NiO	0.12
MgO	0.97	CoO	0.06
CaO	9.43	BaO	0.07
Na_2O	0.74	Li_2O	0.005
K_2O	0.74	CuO	None
H_2O-	3.95	PbO	0.05
H_2O+	10.45	Bi_2O_3	0.17
		Insol	3.65 (largely organic matter)
		Total	101.42

The total of 101.42 is in excess of 100 per cent because the insoluble organic matter gives off water, making the figure for water too high. Of the 9.43 per cent of CaO, 3.31 per cent is present as calcium carbonate that was not eliminated from the concentrate in the flotation process.

The analysis and the x-ray lattice spacing of ranciéite indicates that its composition is $(Ca, Mn^{II}) Mn_4^{IV}O_9 . 3H_2O$.

April 14, 1943.