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THE IRON ORES OF SOUTHEASTERN MINNESOTA

by

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INTRODUCTION

Iron ores have been reported from nearly every county in southeastern Minnesota. The early settlers found layers of iron oxide in their dug wells or they plowed up loose chunks while cultivating the land. The earliest geological surveys of the region include references to widely scattered deposits. Shumard[1] reported iron ore two feet in thickness lying on ferruginous sandstone in the region south of Mankato, and Winchell[2] noted similar deposits near Rapidan. The most extensive deposits were discovered by Mr. C. C. Temple while digging a well in the SE$\frac{1}{4}$, Sec. 8, T102N, R13W, Fillmore County. After throwing out a quantity of limestone and "ochreous limonite" he claimed to have drilled 36 feet into iron ore.[3] Similar beds occur in Iowa where they have been mined at Waukon, and they extend also into Wisconsin where they have been utilized on a small scale in a furnace at Spring Valley.

These iron deposits lie on rocks of various ages from Upper Cambrian to Upper Cretaceous, although most of them appear to be older than the Ostrander gravels of Minnesota in which there are many concretionary iron crusts. At Mankato and Kasota the iron oxides cover the old weathered surface of the Oneota formation and descend into the ancient caves and sinks that were developed during the post-Ordovician-pre-Cretaceous erosion interval, to form crusts on their walls. Here and there the iron-bearing solutions penetrated the siltstone floor of the caves and infiltrated the upper part of the Jordan sandstone. At the Osceola bridge in Chisago County 8 feet of yellow to brown iron ore is separated from the Jordan sandstone by 9 feet of sandy gray shale that may be a remnant of the Blue Earth siltstone. At this place the ore is overlain by an old gray drift sheet, probably Kansan in age.

The most extensive ore deposits occur in Fillmore County in the region southeast of Spring Valley. This region was explored in detail in 1930 but no mining operations were undertaken at that time. In 1941, however, the demand for iron ore was increasing and the economic possibilities of the deposits became apparent. Soon large areas were leased and mining operations began in 1942.

1/ Shumard, B. F.: Owen's Geological Survey of Wisconsin, Iowa and Minnesota, 1852. P. 487.

2/ Winchell, N. H.: Geological and Natural History Survey of Minnesota. 2nd Ann. Rpt. 1874. Pp. 133-134.

3/ Winchell, N. H.: Geology and Natural History Survey of Minnesota. Vol. I, 1884. P. 310.

The overburden, which is from 2 to 10 feet thick, is removed with a scraper and "bull-dozer" and the ore is loaded into trucks with electric shovels. The trucks haul the ore to a washing plant and from there the concentrated ore is trucked to the village of Ostrander where it is loaded into ore cars for shipment to the blast furnace at East St. Louis.

GEOGRAPHY OF THE REGION

The deposits that are being mined at present are located in Fillmore County. They occur 4 miles south of Spring Valley and both to the north and to the south of the site of the inland village of Etna. There is no railroad near the mines but the Chicago and Great Western Railway line passes through the village of Ostrander which is four miles west and one mile north of Etna, and the Chicago, Milwaukee and St. Paul Railway Company has an east-west line through Spring Valley. The paved north-south U. S. Trunk Highway (No. 63) south of Spring Valley passes the ore producing area that occurs along the valley of the South Branch Root River. By the summer of 1948 the pits both north and south of Etna were abandoned, but new pits were opened in the NW¼, Sec. 22, T102N, R13W.

STRATIGRAPHY

The geographic distribution of the ore is almost coextensive with the Paleozoic rocks of the southeastern part of the state. Over this region the ore rests on rocks ranging in age from Cambrian to Devonian with the later stages spilling over on the Cretaceous. In the Etna region the ore lies on the Cedar Valley limestone of Upper Devonian age which is laid bare in the major pits by the removal of ore. At the north side of Bly pit located north of Etna, the section is as follows:

Section of Bly Open Cut Mine

	Thickness
Drift	
5. Sand, gravel and boulders	3 feet
Cretaceous	
4. Clay, blue to white, soft, with a few patches of gravel	5 feet
Cretaceous-Devonian	
3. Iron ore, hard vesicular limonite	18 feet
Devonian	
2. Limonite, hard, brown with Devonian fossils	2 feet
1. Limestone, buff to brown, massive, fossiliferous	2 feet
TOTAL	30 feet

Another section a mile east of Etna, in the E. Vanderbosch quarry, Sec. 30-102-12, shows the relationship of the Devonian to the Ordovician which latter is represented by the Maquoketa shale.

	Thickness
Drift	
7. Covered to the woods above	3 feet
Devonian (Cedar Valley limestone)	
6. Limestone, dolomitic, buff to yellow, fossiliferous	7 feet
5. Limestone, dolomitic, thick beds, cavernous, gray to buff	10 feet
4. Limestone, dolomitic, massive, gray to buff, fossiliferous	10 feet
Ordovician (Maquoketa shale)	
3. Shale, light gray, and gray limestone beds	5 feet
2. Shales and limestones, partly covered	15 feet
1. Covered interval to creek level by barn at highway	13 feet

Above the ore the Cretaceous comes in as partly contemporaneous with it but usually showing a distinct break and the deposition of the Ostrander gravels, sands and clays. At most of these gravel pits in Fillmore County the gravel and sandstone are underlain by clay. The permeation of the gravel by yellow iron stain, the cementing of sands by iron, the general occurrence of the typical "iron conglomerate" and the iron crusts in and on the Ostrander member suggest that the accumulation of ore continued during at least a part of the Cretaceous.

The contact of the Ordovician and the Devonian is sharp and without indication of iron deposition at any place where it is known in the state. This would seem to suggest that the major part of iron accumulation was post-Devonian and probably connected with the long weathering period between upper Devonian and Upper Cretaceous. In the section at the Bly Mine, therefore, the iron is designated as belonging in that interval. It is the only record left by that long erosion interval. Where the ore rests on older rocks, such as the Oneota or the Jordan, it is probable that the younger formations were never deposited or they were removed by the weathering and erosion during the long interval of land conditions that mark the later Paleozoic and much of the Mesozoic eras in the region.

THE ORES

Occurrence and Composition. The bottom of the ore rests on an uneven surface of limestone. Numerous masses of limestone extend up nearly to the top of the orebodies. Residual limestone boulders in the ore show all stages of leaching from limestone to residual, calcareous quartz silt. Locally there are depressions filled with clayey siliceous silt which is partially infiltrated with iron oxide.

Much os the ore is soft and porous with many of the pores partially filled with clay and silt. Irregular concretionary masses with concentric deposition around clayey centers are typical. The hard ore occurs in solid masses or in honeycombed, ramifying chunks, boulders, and nodules. The harder portions are light to dark brown in color, usually showing a dull luster on smooth, freshly broken surfaces. Many of the cavities are lined or partially filled with a yellow ocherous powder, or with fine siliceous silt.

Mineralogically the ores are impure mixtures of hydrated oxides of iron containing varying amounts of limonite and goethite. The most undesirable impurities are silica and phosphorus. The silica content varies from 5 to 35 per cent, and phosphorus is rarely less than 0.1 per cent and may be as high as 2 per cent. The percentage of alumina is low, indicating that the clayey material in the ore is mainly residual siliceous quartz silt, not aluminum silicate. The analyses in Table 1 are typical.

There is no apparent variation in the composition of the ore with depth. Samples taken 2 feet below the surface may contain as much silica as those from a depth of 10 to 15 feet. At most places there is no sharp contact between ore and rock. The physical character of the ore determines whether or not the silica can be washed out and the iron oxides concentrated. Where irregular nodules of iron oxides occur in loose, uncemented silt, the silt is washed out readily. However, some of the soft ore is a physical mixture of earthy iron oxides and siliceous silt. Such fine-textured ore tends to be washed away at the concentration plant. In some ore-pockets the silica content of such soft ore is too high to be utilized without concentrating the iron oxides. The washing process removes approximately 35 per cent of the run of mine ore. The 60 to 70 per cent that is recovered, contains about 50 per cent iron.

TABLE 1

Analyses of Brown Iron Ores From Southeastern Minnesota

Sample No.	Fe	SiO_2	Al_3O_2	P	Mn	S	Ign. Loss.
1	44.77%	19.34%	2.18%	0.408%	0.31%	0.014%	11.80%
2	55.42	5.32	0.34	0.269	0.33	0.002	13.42
3	56.58	4.70	0.24	0.257	0.36	0.002	12.84
4	52.49	8.14	1.78	0.239	0.47	0.004	12.86
5	52.49	9.06	1.16	0.237	0.57	0.007	12.60
6	52.79	10.22	0.74	0.153	0.91	0.007	11.62
7*	55.38	8.06	0.32	0.235	0.51	nd	11.52
8*	49.37	14.24	1.15	0.212	0.59	nd	15.12
9*	41.52	27.06	1.25	0.219	0.41	nd	11.60
10*	35.89	35.86	1.06	0.197	0.63	nd	11.52
11	49.50	15.26	0.65	0.074	nd	0.032	nd

1. Fine-grained, porous, yellow ore from test pit near south ¼ corner of Sec. 15, T102N, R13E.
2. Coarse, well-cemented limonitic ore. Location same as sample 1.
3. Similar to No. 2. Taken from test pit 200 feet farther east.
4. From test pit 10 feet deep that bottomed in Devonian limestone. SE¼, SE¼, Sec. 22, T102N, R13E.

5. Same pit as No. 4.
6. From test pit on LaSalle farm. Sec. 1, T101N, R13W.
7. Bly pit, 10 feet below surface. SE $\frac{1}{4}$, Sec. 23, T102N, R13W.
8. Location same as No. 7. From ore pocket 18 feet below the surface.
9. Location same as No. 7. Two feet below the surface.
10. Location same as No. 7. Four feet below surface.
11. From near the village of Goodhue.

*Analyses through courtesy of Winston Bros. Company, Mpls. Minn.

ORIGIN OF THE ORE

In view of the fact that much of the ore shows evidence of deposition from solution, it is not a true residual deposit. Some secondary processes of concentration must have contributed to the local accumulation of iron oxides. This conclusion is supported by the fact that the amount of residual iron that could possibly have been furnished by the weathering of the beds of the Cedar Valley limestone would not approach in magnitude the ore deposits at the Bly and LaSalle pits. Numerous partial analyses of various facies of the Cedar Valley formations indicate that the average iron content is about 1 per cent. Even by making a liberal estimate of the original thickness of the Devonian strata, their decay would not yield a residual product as thick as the orês in the Spring Valley region.

The structure and texture of the ore give no evidence of bog precipitation and sedimentation. On the other hand, the presence of rounded flint and chert pebbles and boulder-like, silicified stromatoporoid fossils in the ore, suggests some transportation and concentration by surface waters. Underground waters undoubtedly played a major role also.

The concentric tendency of iron oxides is seen in many oxidized mineral deposits, often even in the weathering of pebbles and boulders. Such concentric banding is conspicuously developed in the residual limestone boulders in the iron ore and in the limestone strata under the ore at the west end of the Bly pit. During the process of concentration some iron may have been transported as colloidal ferric hydroxides. These permeated the limestone in which they were deposited as typical concentric structure.

As the weathering of the limestone in the surrounding area continued, some of the primary iron carbonate may have been leached out and carried away as a bicarbonate solution. This reaction is more apt to take place at depths where the oxygen supply is limited. Such iron-leaching waters, percolating laterally and downward, would encounter fresher limestone which would tend to precipitate the iron carbonate, while calcium carbonate would go into solution. Such a process leads to the replacement of limestone by iron carbonate. When erosion later brought the enriched iron carbonate horizon into the zone of active oxidation, the carbonate was altered to limonite and goethite, or to indefinite mixtures of various hydroxides of iron.

<u>Tonnage.</u> The total amount of ore scattered over the known area of distribution in the southeastern part of Minnesota probably amounts to several million tons but the available tonnage may not be much more than a half million tons. This is concentrated chiefly in Fillmore County where the overburden is thin and the localities are readily accessible by truck. Some of the deposits farther to the southeast run higher in silica and are more difficult to utilize. Still others lie on high bluffs and extend back under a heavy overburden. Approximately 500,000 tons of iron ore were shipped from the Bly pit near Etna, and 300,000 tons have been shipped from the pits in section 22, north of the Root River and east of Highway 63.