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Report Of Investigations 113

A RECONNAISSANCE STUDY OF MANGANESE POTENTIAL IN SOUTH DAKOTA

by

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and

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INTRODUCTION

During the fall of 1985 a reconnaissance of the manganese potential of the James River Valley was initiated by the South Dakota Geological Survey. The results of this brief study were submitted by Lynn S. Hedges (coordinator) of the South Dakota Geological Survey in a proposal to Walden P. Pratt (coordinator) of the Midcontinent Strategic and Critical Mineral Project of the U.S. Department of Interior, Geological Survey in April of 1986. Subsequently, the U.S. Department of the Interior, Geological Survey funded a program of outcrop sampling of Upper Cretaceous and younger rocks throughout the entire state of South Dakota. This preliminary study was not designed to delineate ore deposits but to lay groundwork for an ongoing assessment of the manganese potential of the state.

Acknowledgements

We thank Marjory Coker and Jane Metzner for the timely manner in which they processed and analyzed the samples submitted for this study. Their prompt reports gave direction to sample procurement. Marjory Coker authored the **METHODS OF ANALYSES** section of this report. In addition, Colleen Odenbrett, Word Processor, expeditiously organized the tables and body of the report.

HISTORY OF MANGANESE EXPLORATION IN SOUTH DAKOTA

The existence of low grade manganese deposits in the Missouri River Valley region of South Dakota has been known for over a half century (Hewitt, D. F., 1930). However, these deposits generated little interest until events dealing with World War II mandated that domestic supplies be investigated. A report by Gries and Rothrock (1941) focused on the nodule-rich Oacoma member of the Pierre Shale between Chamberlain and Pierre, South Dakota. They included results of sampling by means of excavating a number of 4 x 4 foot shafts through nodule-bearing zones (Gries and Rothrock, 1941, Table XVIII). Results of analyses shown on this table indicated that the average manganese content of the nodules was 15.7 percent and the average yield of manganese from a cubic yard of excavated material was 25.8 pounds. Gries and Rothrock (1941, Table XIX-II) indicate the average thickness of zones tested was 14 yards.

The remains of a pilot-test plant that was subsequently built near Oacoma still exist today. However, the ending of hostilities in Europe in 1944 and in the Far East in 1945, resulted in reestablishment of supply lines for foreign sources of manganese. Interest in the Chamberlain-Pierre area withered before a practical method of separating the nodules from the enclosing shale could be developed although final studies of the area were published as late as February, 1949 (Pesonen and others, 1949). The report of Pesonen and others (1949) provides a more detailed account of history of exploration.

In the late 1950's the Pittsburgh Pacific Company of Hibbing, Minnesota, became interested in the manganese-iron nodule content of the Pleistocene gravels on the higher terraces near Fort

Thompson, South Dakota. Preliminary tests appeared favorable and a concentrating plant was built in the SE¼ sec. 9, T. 107 N., R. 72 W. (approximately 1 mile west of Fort Thompson) and field tests were conducted over a period of several months. However, field tests did not establish that an economic operation could be conducted and most of the option agreements covering several thousand acres were allowed to lapse.

The site of the concentrating plant was visited during the course of the present study and it was noted that the nodule content of the gravels was quite low. This was in agreement with the October 17, 1988, written communication of J. D. Boentje, Jr. (President of Pittsburgh Pacific Company) stating, "Our work indicated that the gravels analyzed about 1-2% Mn." In describing the concentration of the manganese Mr. Boentje related, "Discarding the plus 4" and minus 4 mesh material would leave about 25% of the gravel analyzing $\pm$ 3.8% Mn. It was possible to make a concentrate from this -4"x+4 mesh material analyzing 7-10% Mn, representing about 12% of the original weight and 70-80% of the manganese. Laboratory tests indicated that an electrostatic concentration of the ... concentrate yielded an 18-20% Mn product."

SAMPLING PROGRAM AND PROCEDURES

This study was designed to randomly sample outcrops on a statewide basis. A total of 331 samples were collected for analyses and included rocks of the Upper Cretaceous Graneros, Carlile, Niobrara, Pierre, Interior, Hell Creek and Fox Hills Formations, the Tertiary Chadron, Brule and Valentine Formations and Pleistocene deposits. The locations of these samples are shown on plate 1 and analyses of the samples appear in appendices A and B.

In addition to the outcrop sampling, samples were collected from a preexisting core taken from a test hole drilled by the U.S. Geological Survey (SE¼SE¼ sec. 19, T. 5 N., R. 26 E.) near Hayes, South Dakota (pl. 1). In this test hole Pierre Shale was continuously cored from 74 to 590 feet deep.

In the area west of the Missouri River, outcrops are generally extensive enough that unweathered or only slightly weathered samples can be obtained. Common procedure for collection of samples from surface exposures was to dig a hole at least 1 foot deep into the fresh shale and extract the sample for analysis from the bottom of the hole. This procedure helped eliminate enrichment from slope wash. All macro-nodules were isolated and analyzed separately from shale samples, however, minute nodules could have been disseminated throughout the shale matrix. East of the Missouri River bedrock outcrops are rare, and where present, are usually of small areal and vertical extent. Thus, most samples collected from east of the Missouri are partially to extensively weathered.

Due to the paucity of outcrops in the James Basin - Area A (pl. 1), sampling procedures were augmented by shallow-auger or core holes to obtain required samples.

METHODS OF ANALYSES

South Dakota Geological Survey Laboratory

Samples were received in cloth, Tyvek or zip-lock plastic bags in amounts averaging over 100 grams. Moist samples were air dried prior to pulverizing. Representative portions weighing several grams were selected and ground manually using a synthetic sapphire mortar and pestle. Occasionally large or stubborn samples were crushed with the aid of a Bico type UA pulverizer. Although some samples at the beginning of the study were ground to pass a 50-mesh sieve, most were reduced to 100 mesh for enhanced efficiency in digestion. Pulverized samples were stored in small plastic bottles or vials with screw caps.

An approximately 0.5-gram portion of each ground sample was accurately weighed on an analytical balance and digested with reagent or "trace metal" grade acids to bring manganese and iron into solution. A 1:3 mixture of nitric and hydrochloric acids was used in the initial stages of the project. As the study proceeded, this mixture was supplemented by small amounts of sulfuric acid to encourage the decomposition of colored material. Undigested residue was then filtered out of the digest prior to analysis. By the time a third of the samples had been analyzed, however, a hard digestion technique utilizing nitric, hydrofluoric and perchloric acids was adopted. This digestion was carried out at low heat in Teflon beakers and brought virtually the entire sample into solution, assuring a more complete assay. After evaporation to low volume, the residue was dissolved in dilute hydrochloric acid and brought to a volume of 100 milliliters. Analytical results for manganese did not vary significantly from one digestion technique to another while iron values may have been lower when sulfuric acid was utilized.

Manganese and iron were determined by direct aspiration on a single-channel Instrumentation Laboratory model 351 atomic absorption spectrophotometer. Standard solutions used to calibrate the instrument were prepared by dilution from aqueous elemental standards (Spex Industries). Most measurements required dilution of the sample digest. Deuterium arc background correction was utilized for iron. Calibration curves were prepared and unknown results evaluated with the aid of polynomial least-squares curve fitting on a microcomputer.

Steps undertaken to assure the quality of the data included duplicate grindings (to monitor sample representativeness), duplicate analyses, spiked samples and measurement of known (aqueous) reference samples. At least a third of the samples were ground in duplicate. Duplicate analyses and spikes were performed on at least 10 percent of samples, while a known was measured with each analytical run. The results of these quality-control measurements were reported with the sample data. The reproducibility of manganese values was superior to that of iron. Recovery of added manganese from sample digests which did not require dilution (those with the least manganese content) was slightly lower on the average than recovery from diluted digests.

Chemex Laboratory

The samples submitted to Chemex Labs., Inc., Sparks, Nevada, for analyses were subjected to Perchloric-Nitric-Hydrofluoric digestion prior to being identified by means of ICP spectroscopy. Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) embodies an electrically generated high-temperature excitation source that utilizes argon gas. When a sample is introduced into the argon plasma, elements within the sample become excited and emit light at characteristic wavelengths. Numerous wavelength channels in the spectrometer measure this emitted light, and the amount of light measured in each channel is directly proportional to the concentration of the element in the sample.

RESULTS OF ANALYSES OF SAMPLES FROM SPECIFIC SITES

Hayes Site

The Hayes sampling site is located about 30 miles west of Pierre, South Dakota (pl. 1). The samples were collected at 5-foot intervals from a continuously cored test hole that retrieved Pierre Shale from 74 to 590 feet. The subdivisions of the Pierre Shale penetrated in this test are believed to be the Elk Butte and Mobridge Members. From this site, samples of the combined shale and representative portions of macro-nodules were analyzed by the South Dakota Geological Survey Chemistry Laboratory. Due to missing intervals, a total of only 90 samples were submitted for analysis. The results of these analyses are shown as samples BS-N1 through HM-86-090 in appendix A.

Manganese content of samples ranged from a low of .02 percent for a number of samples to a high of 2 percent. The maximum value was reported from a depth of 390-391 feet (sample HM-86-057).

This specific site was originally selected for comprehensive sampling and analyses for two reasons. First, the cored interval represented more than half the thickness of the Pierre Shale at that point, and, second, if anomalous concentrations were noted, then direction for subsequent sampling could be projected. From the preceding paragraph, it is apparent that no anomalies were discovered.

Pilot-Plant Site

The now defunct pilot-plant of the General Manganese Corporation is located about 1 mile northwest of the town of Oacoma, South Dakota. Shale samples were collected at about 5-foot intervals from the base to the top of an approximately 60-foot high outcrop located about 200 feet east of the pilot plant. Macro-nodules were discarded so that only bulk shale samples were submitted for analyses. Location of the samples and results of analyses are reported in appendix A (samples OM-86-163 through OM-86-172). Manganese values for the bulk shale ranged from 0.319 to 4.61 percent. Average manganese content for the 11 samples was 1.83 percent.

The manganese content of the shale matrix reported here conflicts with the conclusion of Gries and Rothrock (1941, p. 65) who stated that manganese had not been detected in the shale. Subsequently Pesonen and others (1949, p. 86) reported, "There is no accurate means of arriving at an average manganese content of concretion-free shale in the manganiferous zones, however, the special samples taken would indicate that much of this material would contain somewhere around 1 percent manganese." The discrepancy in reported manganese content of the shale matrix cannot be ascertained at present. Perhaps another sampling collection should be made in the general area, but sufficiently far from the mill site to preclude the possibility of enrichment from past mining activities.

James Basin - Area A

Area A consists of four townships located in central Spink County, South Dakota. These are Townships 117 North, Ranges 60, 61, 62 and 63 West (pl. 1). This portion of the James Basin is very flat with no apparent outcrops from which unweathered samples can be obtained. However, shale is relatively shallow in this general area and excavation debris from numerous dug stock dams revealed nodules in the excavated shale. These weathered nodules (samples Mb1, Mb2, Mb3, Mc1, Mc2, Md1, Me1, Mf; app. A) averaged 23.8 percent manganese. This value should be compared to the average 17 percent manganese for nodules reported by Gries and Rothrock (1941, p. 79) in the Chamberlain-Pierre area. In the present study the entire nodule was ground, quartered and analyzed, whereas in the study of Gries and Rothrock (1941, p. 72) "No samples were collected at random from surface pieces and in all pieces the weathered outside of the concretions was discarded as far as possible. These samples, therefore, represent the manganese and iron percentages in fresh concretions."

On the basis of the high manganese content of weathered nodules found in excavated material from stock dams it was decided to drill into the Pierre Shale in the SE¼SE¼ sec. 1, T. 117 N., R. 63 W. to see if this high content was also evident in the shale. A test hole was drilled to a depth of 100 feet and samples from 60 to 100 feet were analyzed (see Analyses Mn-Mq in app. A). On the basis of the apparent higher manganese content from 8 to 26 feet, it was decided to core the Pierre Shale in an adjacent test. Samples designated Mr through My and BS-A through BS-M2 in appendix A are analyses of 1-foot increments of this core. The average manganese content of the interval from 8 to 15½ feet, including macro- and micro-nodules and enclosing shale, is 4.7 percent.

The coring operation at this site utilized a 2 15/16-inch Aker-Dennison core barrel which was capable of securing 5 feet of core per trip. Certainly this operation was not as accurate as sinking a 4 x 4 foot shaft, splitting the entire sample and analyzing the splits as reported by Gries and Rothrock (1941).

One cannot ascertain the areal extent or even project an accurate analysis of the Pierre Shale on the basis of one core hole. However, it can be suggested that if future prospecting for manganese is carried out in South Dakota, this is an area that may merit additional study.

The precise unit of the Pierre Shale that is represented by manganiferous shale is unknown. From records of water wells drilled in the area the manganiferous unit is approximately 200 feet above the top of the Niobrara Formation. Thus, it is believed this unit may be correlative with the Oacoma Member of the Pierre Shale in the Chamberlain area.

James Basin - Area B

Area B lies south of Area A and is located in Township 114 North, Range 62 West, and like area A, has little topographic relief. It was noted while traversing some of the secondary roads in this general area that the road metal appeared to contain a high percentage of manganiferous material. The source of this manganese-rich gravel was found to be a gravel pit located in the NW¼ sec. 14, T. 114 N., R. 62 W. A grab sample of the gravel face of the pit yielded an analysis showing 8 percent manganese. Realizing that the sampling may have been prejudiced, nine additional samples were collected from another face of the pit and analyzed. These analyses appear in appendix A as samples OM-86-008 through OM-86-016. Sample OM-86-008 is from the overlying glacial till in the area of the gravel pit. Samples OM-86-009 through OM-86-016 are from the gravel face and yielded an average manganese content of 4.81 percent. (Analyses 14A and 14B are two samples from the same interval.) If error does exist in samples OM-86-009 through OM-86-016, it is believed the error is of a conservative nature because in gathering the samples, large, obviously manganiferous pebbles and cobbles were discarded.

Because topographic relief in the area is low, the overburden effectively masks the areal extent of the gravel deposit. In order to obtain some idea regarding the extent of the gravels a series of 9 auger holes were drilled (fig. 1). Of these 9 holes, six intersected a sandy or gravelly unit believed to be an extension of the gravel deposit. These six test holes were sampled and analyzed and are represented in appendix A by sample numbers OM-86-179, OM-86-180a and b, OM-86-181, OM-86-183, OM-86-184a and b, and OM-86-185. Samples with an a and b designation merely indicate that two grab samples were analyzed from a particular test hole. Sample OM-86-182 was obtained from a test hole that is believed to lie beyond the boundaries of the gravel deposit and sample OM-86-178 is an analysis of the glacial till that overlies and blankets the gravel deposit.

The analyses of samples OM-86-005B, OM-86-006 and OM-86-007 are included under the heading of **James Basin - Area B** in appendix A because of their proximity to the manganiferous gravel deposit. The elevation of the Pierre Shale at these sample sites indicates the manganese nodules were concentrated in a Pleistocene stream valley that incised the Pierre Shale.

If all of the analyses from the gravel pit and auger test holes that penetrated the gravel are averaged, it is seen that the deposit contains approximately 5.07 percent manganese. It is believed this percentage is conservative in that contamination from the bore hole does occur; in addition, an augered bore hole usually yields a nonrepresentative sample of the finer fractions of a gravel deposit. It is suggested that future investigations trench sample the face of the gravel pit and that larger diameter core samples be retrieved. All samples collected should be pulverized, split and analyzed in order to obtain a more accurate measure of the concentration of manganese in the gravel deposit.

POTENTIAL MANGANESE RESOURCES OF JAMES BASIN - AREA B

Figure 1 is a plat of auger holes drilled and thickness of gravel penetrated. From this figure it is apparent that the gravel underlies approximately 400 acres with an average thickness of about 15 feet. Ordinarily gravel weighs about 3,000 pounds per cubic yard and if 5.07 percent of this weight is manganese, then each cubic yard would yield about 152 pounds of manganese.

Total projected manganese content of the gravel deposit can be estimated by using the following values:

Area of deposit - 400 acres or 1,936,000 square yards
Thickness of deposit - 15 feet or 5 yards
Weight of gravel - 3,000 pounds per cubic yard
Percentage of manganese - 5.07

Therefore:

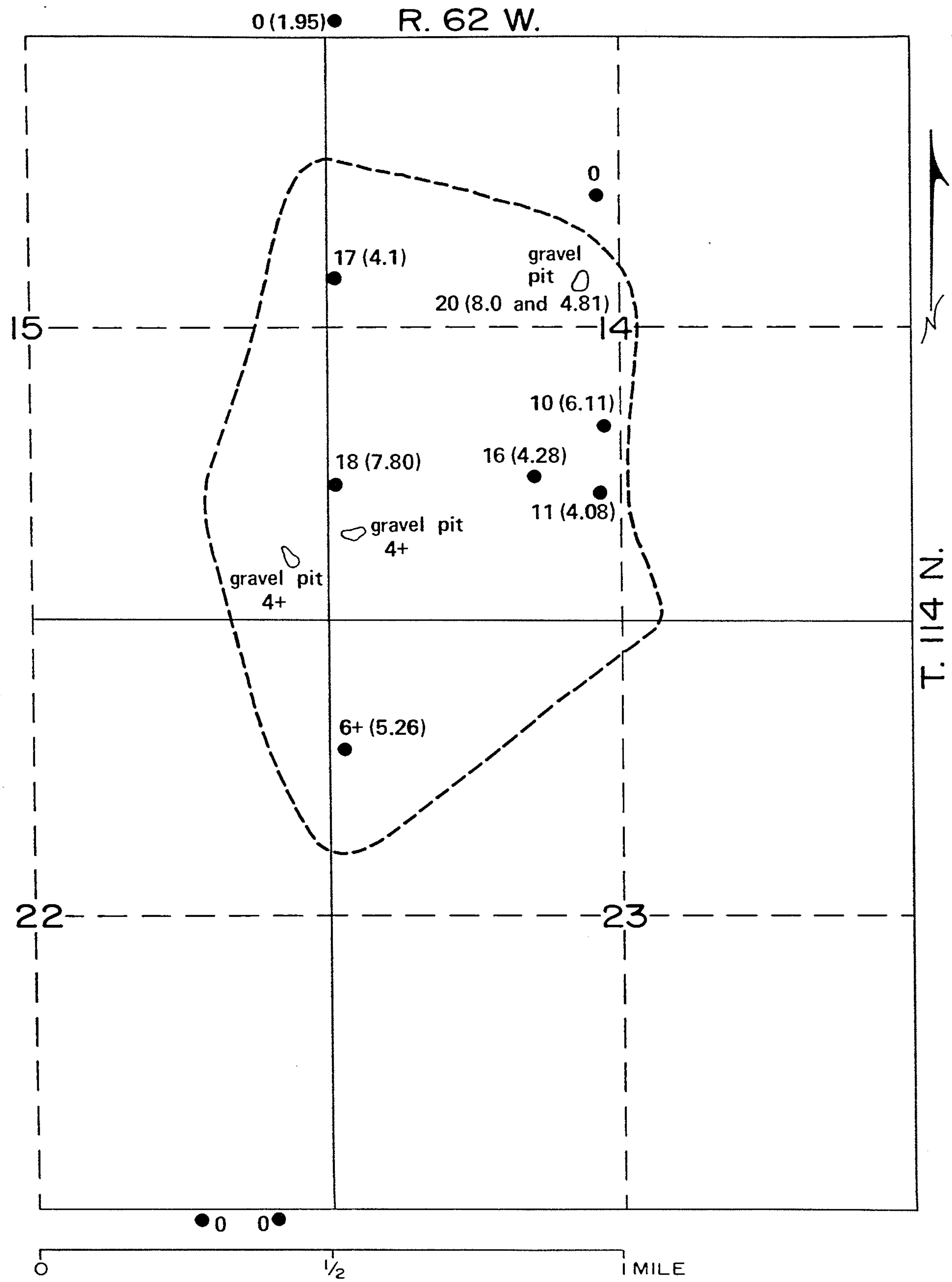
$$1{,}936{,}000 \text{ sq. yds.} \times 5 \text{ yds.} \times \frac{1.5 \text{ tons}}{\text{cu. yds.}} \times .0507 = \text{Manganese}$$

or

$$736{,}164 \text{ tons} = \text{Manganese}$$

The total manganese in the gravel deposit (736,164 tons) is small when compared to the amount estimated (850,000,000 tons) to be present in the 32 townships contained in the study of Gries and Rothrock (1941, p. 85). However, the gravel deposit is about 6 times richer (152.1 lbs./cu. yd. versus 25.8 lbs./cu. yd.) than the nodule zone near the Oacoma area. It should be noted that additional drilling may define a larger area of the gravel deposit; or, other similar deposits may be present in the James Basin.

NOTE: On August 1, 1988, Layne D. Schulz of the South Dakota Geological Survey located a gravel terrace in NE¼SE¼ sec. 15, T. 115 N., R. 61 W. that contained a concentration of manganiferous nodules similar to the James Basin - Area B gravel pit. On October 5, 1988, while in the vicinity of the James Basin - Area B on an unrelated matter, another manganiferous gravel outcrop was noted by one of the authors in the SE¼ sec. 8, T. 115 N., R. 62 W. (approximately 7½ miles NNW of the James Basin - Area B gravel pit). This gravel outcrop is approximately 7½ feet thick and appears to have a somewhat lower nodule content than the James Basin - Area B gravel pit. This lends credence to the statement in the preceding paragraph that "other similar deposits may be present in the James Basin."



17 (4.1) ● Auger test hole. Number is thickness of gravel, in feet; a + sign indicates minimum thickness. Number in parentheses is percentage of Manganese content of gravels.

--- Area of known gravel deposits.

Figure 1. Location of auger test holes in James Basin–Area B.

These three locations were sampled and analyzed for manganese in 1989. The results were as follows:

Location	Percent Manganese
NW¼ sec. 14, T. 114 N., R. 62 W.	3.91
SE¼ sec. 8, T. 115 N., R. 62 W.	6.65
SE¼ sec. 15, T. 115 N., R. 61 W.	6.77

MINERALOGY OF THE MANGANESE NODULES

A detailed mineralogic study of the manganese nodules was beyond the scope of this report. Scholl (1940, p. 13) reported, "A microscope's examination conducted by the Department of Chemical Engineering at the Wilson Dam, Alabama, indicated that the principal minerals present in the nodules were siderite ($FeCO_3$) and manganocalcite ($CaCO_3.MnCO_3$) together with small quantities of dolomite ($CaCO_3.MgCO_3$) and magnesite ($MgCO_3$)." International Minerals and Chemical Corporation (1943) reports on page 6 that an x-ray diffraction pattern indicates that $MnCO_3$ and $FeCO_3$ are present with some indication of a small amount of MnO_2.

Pahlman and Khalafalla (1988, p. 5) show that nodules from Lyman County, South Dakota, (near Chamberlain) contain the manganese minerals, manganocalcite, pyrolusite and manganite and principal gangue minerals of siderite, calcite, dolomite, quartz and clay.

RESULTS OF RANDOM SAMPLING AND ANALYSES

The reconnaissance study of manganese potential in South Dakota was proposed and initiated as a random sampling and analyzing program targeting the Upper Cretaceous and younger deposits. The results of this sampling and analyzing program are included in appendices A and B. The sampling sites are shown on plate 1. For the most part, appendices A and B are quite barren of manganiferous anomalies. Those anomalies that do exist in western South Dakota are analyses of manganese nodules enclosed in a shale matrix and, in all cases observed, are too sparsely disseminated to indicate a potential resource.

On the other hand, observation of plate 1 indicates that large areas exist which are not represented in appendices A and B. In addition, the program in western South Dakota was limited exclusively to sampling of outcrops. Gravel pits were not investigated nor was any effort made to locate potential placer deposits of manganese. Thus, under no circumstances should this study be considered a comprehensive report.

RECOMMENDATIONS

Hindsight suggests that the sampling program should have been concerned to a larger degree with the possibility of reworked Oacoma manganese nodules being deposited and concentrated in post-Cretaceous stream valleys. If a future study is so directed, it is recommended that the study concentrate on an area from slightly west of Chamberlain eastward along the erosional edge of the Pierre Shale (fig. 2). Preliminary work should consist of employing existing data, especially the extensive test drilling data and maps incorporated in the County Resources Investigations by the South Dakota Geological Survey, to determine where:

1. The Niobrara Formation is overlain by 200 feet or less of Pierre Shale (this stratigraphic interval would generally include the Oacoma member if present). Areas in Marshall, Roberts, Spink, Beadle, Brown, Faulk, Grant and Sanborn Counties should meet this condition.

2. Post-Cretaceous drainage systems were incised into the Pierre and Niobrara Formations.

3. The surface topography intersects, or nearly intersects, the horizontal plane where conditions 1 and 2 exist.

Figure 2 quite vividly illustrates areas where the aforementioned conditions may exist. In the James Basin, from Sanborn County northward to the state boundary, is an area where the Pierre Shale, the Niobrara Marl, and to a lesser extent, the Carlile Shale, have been incised by a post-Cretaceous drainage system. Where the Pierre and Niobrara subcrops are in close proximity, it is logical to assume that the manganese-bearing unit (Oacoma Member) of the Pierre Shale has been eroded and manganese nodules may be concentrated in nearby placer deposits. Depths to bedrock range from 0 to 90 feet over most of the area.

Further, it is probable that the manganiferous unit of the Pierre Shale in the low-lying James Basin, manganiferous talus at the foot of the incised valley walls, and preexisting manganese placer deposits, were scoured by glaciers during Pleistocene time. These deposits were subsequently redeposited as outwash by glacial streams. The gravel pits in section 14, T. 114 N., R. 62 W. are believed to be such deposits.

The gravel from the above-mentioned pits overlie a fine sand as much as 70 feet thick which may be a prediversional(?) sand. This suggests outwash streams, at least in part, followed preexisting valleys and these areas may be prime prospecting areas.

Figure 2 may also be used for proposed investigation of in situ manganese deposits in the Pierre Shale. Potential resources may exist wherever the subcrop of the Pierre Shale is sufficiently near the land surface to allow stripping of overburden such as would be possible at the James Basin - Area A site.

Because of the relatively high manganese content reported in the shale matrix and nodules, 4.7 and 23.8 percent respectively in Area A, it is recommended that additional samples be taken from around or within section 1, T. 117 N., R. 63 W. These samples should be obtained from large diameter core, or by digging a 4 x 4 foot shaft, in order to obtain more representative samples. If warranted, additional testing could then be conducted to delineate the extent and accessibility of the manganiferous shale.

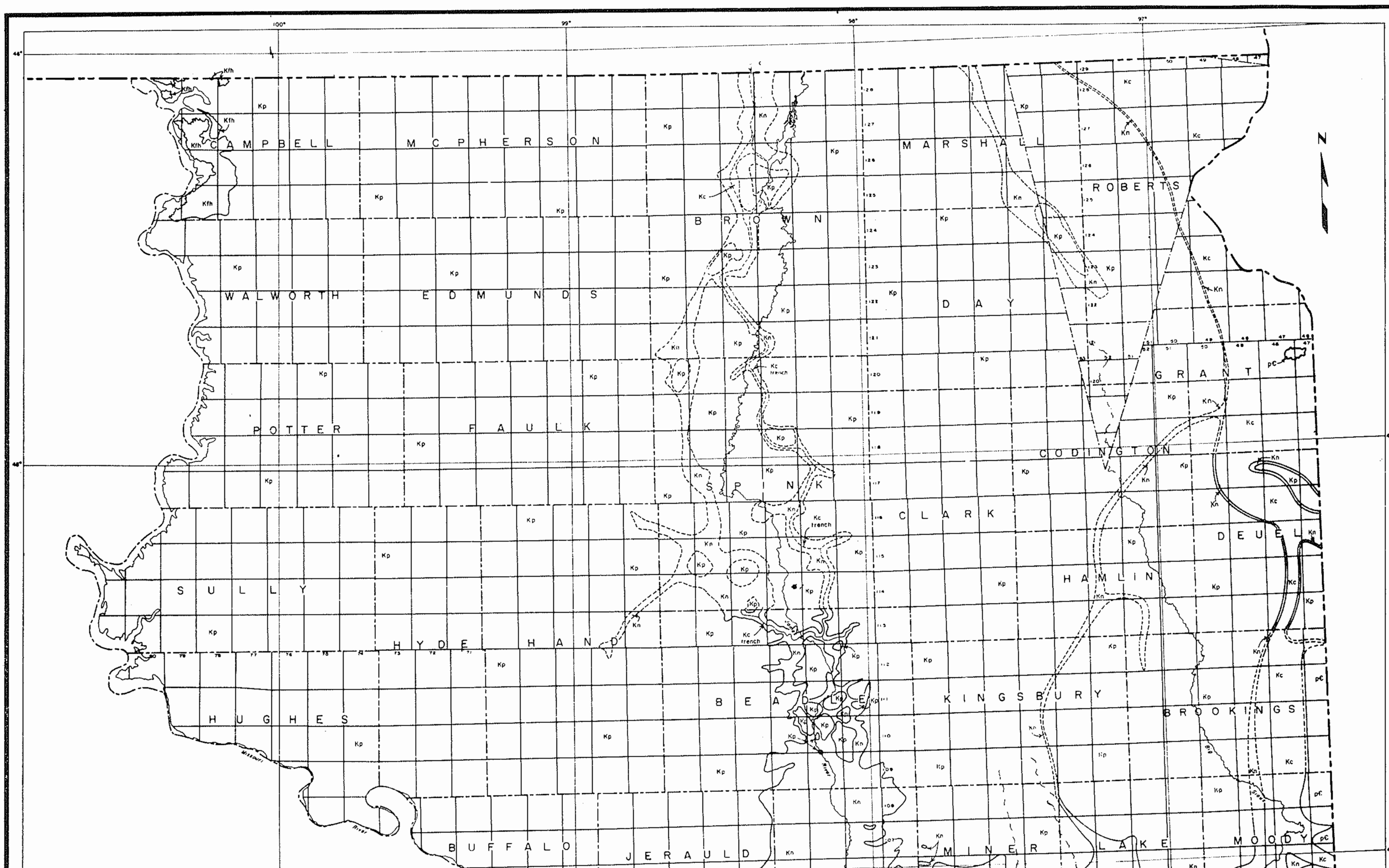


Figure 2. Map of eastern South Dakota showing distribution of bedrock units underlying glacial deposits (from Hedges, et al., 1982).

The major recommendation is to further investigate the potential of placer-type manganese concentrations in glacial outwash deposits such as those exposed in the gravel pits located in the James Basin - Area B (NW¼ sec. 14, T. 114 N., R. 62 W.) SE¼ sec. 8, T. 115 N., R. 62 W. and the SE¼ sec. 15, T. 115 N., R. 61 W. These sites should be further explored for areal extent, thickness and manganese content. There is a high probability that similar deposits exist in the upper James Basin in Marshall, Roberts, Spink, Beadle, Brown, Faulk, Sanborn, Miner and Grant Counties.

An additional recommendation is to research heap-leaching or in situ leaching technology to determine if it is economically feasible to recover manganese from manganiferous shales and gravels mentioned in this report. Inexpensive electric power from the Big Bend generating plant may be available for the electrolytic refining of the potential manganese ore.

CONCLUSIONS

This study was initiated to help lay a framework for future studies of the manganese potential of South Dakota. A review of the **RECOMMENDATIONS** section of this report indicates the study has been successfully completed. Areas believed to have potential manganese resources have been identified. For the most part, these areas have been described in a general manner; however, two areas (James Basin - Areas A and B) that appear to have a greater potential have been specifically located.

Additional work must be done in order to locate areal boundaries and to economically beneficiate the resource at sites A and B in the James Basin. More reconnaissance work is needed in order to locate additional specific sites in the upper James Basin where similar concentrations of manganese almost certainly exist.

The cliche "Mines are made, not found" seems an appropriate closing thought. Vast amounts of manganese are present in east-central South Dakota. Accessibility to mentioned deposits can be gained with ease. Overburden of the gravel deposits in all mentioned cases is less than 6 feet. An abundant and reliable supply of cheap electricity may be secured from the Big Bend Dam. Because the United States produces only about 2 percent of its manganese usage, it is quite apparent the need exists. It appears all that is needed is development of techniques to economically upgrade the potential manganese nodules ore from about 20 percent manganese to a product of about 40 percent manganese.

A technique recently described by Pahlman and Khalafalla (1988) may have significant bearing on the South Dakota manganese ores. They have discovered that ore batch-leaching of these ores with sulfur dioxide, extracts 76 percent of the contained manganese (Pahlman and Khalafalla 1988, table 3) and the rate of manganese solubilization was rapid (Pahlman and Khalafalla, 1988, p. 15). This suggests that 115.5 pounds of manganese could be recovered from a cubic yard of gravel from the James Basin - Area B locality and could be a significant step toward the "making of a mine."

An interesting aspect of this study has been the reviewing of analyses of the sampling programs and contemplating potentials beyond the scope of this report. For instance, sample OM-86-109 (app. B) from the Pierre Shale in section 1-1N-14E yielded an analysis of 8.5 parts per million silver. This indicates that 1 ton of Pierre Shale at this point would yield .272 ounces of silver. This concentration cannot be considered as a developable resource; however, it does give rise to speculation concerning additional samples from the area.

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Appendix A. Analyses of samples by the South Dakota Geological Survey

			PERCENT	
SAMPLE NO.	LOCATION	TYPE SAMPLE	MANGANESE	IRON
		<u>Core from Hayes, South Dakota</u>		
BS-N1	SE SE 19- 5N-26E	Pierre Shale Core: 74'- 80'	0.03	3.6
BS-O1	SE SE 19- 5N-26E	Pierre Shale Core: 85'- 90'	0.03	2.46
HMC-86-012	SE SE 19- 5N-26E	Pierre Shale Core: 90'- 95'	0.07	3.50
BS-P1	SE SE 19- 5N-26E	Pierre Shale Core: 90'- 92.5'	0.05	3.54
HMC-86-013	SE SE 19- 5N-26E	Pierre Shale Core: 95'-100'	0.05	3.62
BS-Q1	SE SE 19- 5N-26E	Pierre Shale Core: 110'-115'	0.09	2.92
HMC-86-014	SE SE 19- 5N-26E	Pierre Shale Core: 115'-120'	0.08	3.40
HMC-86-015	SE SE 19- 5N-26E	Pierre Shale Core: 120'-125'	0.19	4.01
BS-R1	SE SE 19- 5N-26E	Pierre Shale Core: 125'-130'	0.12	4.22
BS-S1	SE SE 19- 5N-26E	Pierre Shale Core: 130'-135'	0.29	3.12
HMC-86-016A	SE SE 19- 5N-26E	Pierre Shale Core: 135'-140'	0.08	3.67
HMC-86-017A	SE SE 19- 5N-26E	Pierre Shale Core: 140'-145'	0.16	5.50
BS-T1	SE SE 19- 5N-26E	Pierre Shale Core: 145'-150'	0.04	3.32
BS-U1	SE SE 19- 5N-26E	Pierre Shale Core: 155'-160'	0.07	3.14
BS-V1	SE SE 19- 5N-26E	Pierre Shale Core: 160'-165'	0.14	2.78
BS-W1	SE SE 19- 5N-26E	Pierre Shale Core: 165'-170'	0.19	3.56
BS-X1	SE SE 19- 5N-26E	Pierre Shale Core: 170'-175'	0.23	3.25
HMC-86-018A	SE SE 19- 5N-26E	Pierre Shale Core: 175'-180'	0.05	3.26
HMC-86-019A	SE SE 19- 5N-26E	Pierre Shale Core: 180'-185'	0.04	3.26
HMC-86-020A	SE SE 19- 5N-26E	Pierre Shale Core: 185'-190'	0.02	3.34
HMC-86-021A	SE SE 19- 5N-26E	Pierre Shale Core: 190'-195'	0.02	3.32
HMC-86-022A	SE SE 19- 5N-26E	Pierre Shale Core: 195'-195.5'	0.02	3.12
HMC-86-023A	SE SE 19- 5N-26E	Pierre Shale Core: 197.5'-200'	0.03	2.70
HMC-86-024A	SE SE 19- 5N-26E	Pierre Shale Core: 200'-210'	0.11	2.50
HMC-86-025A	SE SE 19- 5N-26E	Pierre Shale Core: 210'-215'	0.02	2.67
HMC-86-026A	SE SE 19- 5N-26E	Pierre Shale Core: 215'-220'	0.02	3.14
HMC-86-027A	SE SE 19- 5N-26E	Pierre Shale Core: 220'-225'	0.04	2.68
HMC-86-028A	SE SE 19- 5N-26E	Pierre Shale Core: 225'-230'	0.02	3.10
HMC-86-029A	SE SE 19- 5N-26E	Pierre Shale Core: 230'-235'	0.02	2.92
HMC-86-030A	SE SE 19- 5N-26E	Pierre Shale Core: 235'-240'	0.13	3.11
HMC-86-031A	SE SE 19- 5N-26E	Pierre Shale Core: 240'-245'	0.02	3.07
HMC-86-032A	SE SE 19- 5N-26E	Pierre Shale Core: 245'-248'	0.03	3.78
HMC-86-033A	SE SE 19- 5N-26E	Pierre Shale Core: 248'-250'	0.04	3.46
HMC-86-034A	SE SE 19- 5N-26E	Pierre Shale Core: 255'-260'	0.05	4.02
HMC-86-035A	SE SE 19- 5N-26E	Pierre Shale Core: 260'-265'	0.05	3.90

SAMPLE NO.	LOCATION	TYPE SAMPLE	PERCENT MANGANESE	PERCENT IRON
Hayes Core -- continued.				
HMC-86-036A	SE SE 19- 5N-26E	Pierre Shale Core: 265'-270'	0.04	3.32
HMC-86-037A	SE SE 19- 5N-26E	Pierre Shale Core: 270'-275'	0.03	4.16
HMC-86-038A	SE SE 19- 5N-26E	Pierre Shale Core: 275'-280'	0.07	3.94
HMC-86-039A	SE SE 19- 5N-26E	Pierre Shale Core: 280'-285'	0.04	3.66
HMC-86-040A	SE SE 19- 5N-26E	Pierre Shale Core: 285'-290'	0.02	3.50
HMC-86-041A	SE SE 19- 5N-26E	Pierre Shale Core: 290'-295'	0.02	2.96
HMC-86-042A	SE SE 19- 5N-26E	Pierre Shale Core: 295'-300'	0.03	3.00
HMC-86-043A	SE SE 19- 5N-26E	Pierre Shale Core: 305'-310'	0.69	7.26
HMC-86-044A	SE SE 19- 5N-26E	Pierre Shale Core: 315'-320'	0.09	3.88
HMC-86-045A	SE SE 19- 5N-26E	Pierre Shale Core: 320'-325'	1.21	10.90
HMC-86-046A	SE SE 19- 5N-26E	Pierre Shale Core: 325'-330'	0.08	4.46
HMC-86-047A	SE SE 19- 5N-26E	Pierre Shale Core: 330'-335'	0.05	4.19
HMC-86-048A	SE SE 19- 5N-26E	Pierre Shale Core: 335'-340'	0.04	3.96
HMC-86-049A	SE SE 19- 5N-26E	Pierre Shale Core: 340'-345'	0.03	4.03
HMC-86-050A	SE SE 19- 5N-26E	Pierre Shale Core: 345'-350'	0.02	3.96
HMC-86-051A	SE SE 19- 5N-26E	Pierre Shale Core: 355'-360'	0.10	3.74
HMC-86-052A	SE SE 19- 5N-26E	Pierre Shale Core: 365'-370'	0.07	4.12
HMC-86-053A	SE SE 19- 5N-26E	Pierre Shale Core: 370'-376'	0.03	4.20
HMC-86-054A	SE SE 19- 5N-26E	Pierre Shale Core: 376'-380'	0.04	3.52
HMC-86-055	SE SE 19- 5N-26E	Pierre Shale Core: 380'-385'	0.03	3.64
HM-86-056	SE SE 19- 5N-26E	Pierre Shale Core: 385'-390'	0.03	3.41
HM-86-057	SE SE 19- 5N-26E	Pierre Shale Core: 390'-391'	2.00	20.4
HM-86-058	SE SE 19- 5N-26E	Pierre Shale Core: 391'-395'	0.06	3.95
HM-86-059	SE SE 19- 5N-26E	Pierre Shale Core: 395'-400'	0.03	3.72
HM-86-060	SE SE 19- 5N-26E	Pierre Shale Core: 405'-410'	0.03	3.40
HM-86-061	SE SE 19- 5N-26E	Pierre Shale Core: 415'-420'	0.03	3.56
HM-86-062	SE SE 19- 5N-26E	Pierre Shale Core: 420'-425'	0.03	3.22
HM-86-063	SE SE 19- 5N-26E	Pierre Shale Core: 425'-430'	0.03	3.08
HM-86-064	SE SE 19- 5N-26E	Pierre Shale Core: 430'-435'	0.03	3.36
HM-86-065	SE SE 19- 5N-26E	Pierre Shale Core: 435'-440'	0.12	3.14
HM-86-066	SE SE 19- 5N-26E	Pierre Shale Core: 440'-445'	0.35	2.52
HM-86-067	SE SE 19- 5N-26E	Pierre Shale Core: 445'-450'	0.13	3.54
HM-86-068	SE SE 19- 5N-26E	Pierre Shale Core: 455'-460'	0.15	3.88
HM-86-069	SE SE 19- 5N-26E	Pierre Shale Core: 465'-470'	0.04	3.25
HM-86-070	SE SE 19- 5N-26E	Pierre Shale Core: 470'-475'	0.04	3.42
HM-86-071	SE SE 19- 5N-26E	Pierre Shale Core: 475'-480'	0.03	3.53
HM-86-072	SE SE 19- 5N-26E	Pierre Shale Core: 480'-485'	0.03	3.34
HM-86-073	SE SE 19- 5N-26E	Pierre Shale Core: 485'-490'	0.05	3.32
HM-86-074	SE SE 19- 5N-26E	Pierre Shale Core: 490'-495'	0.04	3.30

SAMPLE NO.	LOCATION	TYPE SAMPLE	PERCENT MANGANESE	PERCENT IRON
Hayes Core -- continued.				
HM-86-075	SE SE 19- 5N-26E	Pierre Shale Core: 495'-500'	0.03	3.06
HM-86-076	SE SE 19- 5N-26E	Pierre Shale Core: 500'-505'	0.04	3.00
HM-86-077	SE SE 19- 5N-26E	Pierre Shale Core: 505'-510'	0.03	3.22
HM-86-078	SE SE 19- 5N-26E	Pierre Shale Core: 515'-520'	0.09	3.28
HM-86-079	SE SE 19- 5N-26E	Pierre Shale Core: 520'-525'	0.10	3.08
HM-86-080	SE SE 19- 5N-26E	Pierre Shale Core: 525'-530'	0.28	3.36
HM-86-081	SE SE 19- 5N-26E	Pierre Shale Core: 530'-535'	0.02	3.07
HM-86-082	SE SE 19- 5N-26E	Pierre Shale Core: 535'-540'	0.03	3.23
HM-86-083	SE SE 19- 5N-26E	Pierre Shale Core: 540'-545'	0.02	6.35
HM-86-084	SE SE 19- 5N-26E	Pierre Shale Core: 545'-550'	0.06	3.24
HM-86-085	SE SE 19- 5N-26E	Pierre Shale Core: 555'-560'	0.31	3.22
HM-86-086	SE SE 19- 5N-26E	Pierre Shale Core: 565'-570'	0.95	3.22
HM-86-087	SE SE 19- 5N-26E	Pierre Shale Core: 570'-575'	0.18	3.32
HM-86-088	SE SE 19- 5N-26E	Pierre Shale Core: 575'-580'	0.92	3.56
HM-86-089	SE SE 19- 5N-26E	Pierre Shale Core: 580'-585'	0.58	3.64
HM-86-090	SE SE 19- 5N-26E	Pierre Shale Core: 585'-590'	0.11	3.38
		Samples from Pilot Plant Site		
OM-86-163	NE SE SE 14-104N-72W	Pierre Shale (Lowest)	1.52	3.78
OM-86-164	NE SE SE 14-104N-72W	Pierre Shale	2.59	4.30
OM-86-165A	NE SE SE 14-104N-72W	Pierre Shale	2.60	3.80
OM-86-165B	NE SE SE 14-104N-72W	Pierre Shale	2.52	3.59
OM-86-166	NE SE SE 14-104N-72W	Pierre Shale	1.26	4.05
OM-86-167	NE SE SE 14-104N-72W	Pierre Shale	0.319	3.07
OM-86-168	NE SE SE 14-104N-72W	Pierre Shale	0.414	3.46
OM-86-169	NE SE SE 14-104N-72W	Pierre Shale	2.85	3.96
OM-86-170	NE SE SE 14-104N-72W	Pierre Shale	4.61	3.59
OM-86-171	NE SE SE 14-104N-72W	Pierre Shale	0.738	3.04
OM-86-172	NW SE SE 14-104N-72W	Pierre Shale (Highest)	0.710	2.76
		Samples from James Basin - Area A		
Mb1	SE NE SW 21-117N-62W	Nodule No. 1	26.6	2.48
Mb2	SE NE SW 21-117N-62W	Nodule No. 1	20.2	1.89
Mb3	SE NE SW 21-117N-62W	Nodule No. 1	23.3	11.0
Mc1	SE NE SW 21-117N-62W	Nodule No. 2	26.3	5.6
Mc2	SE NE SW 21-117N-62W	Nodule No. 2	26.0	5.9

			PERCENT	
SAMPLE NO.	LOCATION	TYPE SAMPLE	MANGANESE	IRON
James Basin - Area A -- continued.				
Md1	NW NW 32-117N-63W	Nodules	22.8	9.7
Me1	NE SW 19-117N-60W	Nodules	22.9	1.8
Mf	SW NW NW 10-117N-60W	Nodules	22.4	2.0
Mn	SE SE 1-117N-63W	Pierre Cuttings: 60′- 70′	0.07	6.0
Mo	SE SE 1-117N-63W	Pierre Cuttings: 70′- 80′	0.09	5.5
Mp	SE SE 1-117N-63W	Pierre Cuttings: 80′- 90′	0.04	6.2
Mq	SE SE 1-117N-63W	Pierre Cuttings: 90′-100′	0.03	5.3
Mr	SE SE 1-117N-63W	Pierre Shale Core: 8′- 9′	8.8	3.5
Ms	SE SE 1-117N-63W	Pierre Shale Core: 9′- 10′	1.5	1.6
Mt	SE SE 1-117N-63W	Pierre Shale Core: 10′- 11′	4.4	2.8
Mu	SE SE 1-117N-63W	Pierre Shale Core: 3-inch nodule at 10′	10.3	2.4
Mv	SE SE 1-117N-63W	Pierre Shale Core: 11′- 12′	1.7	1.8
Mw	SE SE 1-117N-63W	Pierre Shale Core: 1-inch nodule at 13′	12.0	7.5
Mx	SE SE 1-117N-63W	Pierre Shale Core: 12′- 13	8.1	3.3
My	SE SE 1-117N-63W	Pierre Shale Core: 13′- 14′	2.0	2.5
BS-A	SE SE 1-117N-63W	Pierre Shale Core: 14′- 15′	0.6	3.0
BS-B	SE SE 1-117N-63W	1-inch nodule at 15′	15.5	11.4
BS-C1	SE SE 1-117N-63W	Red portion (Minor) 15′- 16′	16.4	11.0
BS-C2	SE SE 1-117N-63W	Gray portion (Major) 15′- 16′	0.4	2.5
BS-D	SE SE 1-117N-63W	Pierre Shale Core: 16′- 17′	0.3	2.1
BS-E1	SE SE 1-117N-63W	Pierre Shale Core: 17′- 18′	<0.1	2.4
BS-E2	SE SE 1-117N-63W	Pierre Shale Core: 17′- 18′	0.2	2.6
BS-F1	SE SE 1-117N-63W	Pierre Shale Core: 18′- 19′	10.1	1.6
BS-F2	SE SE 1-117N-63W	Pierre Shale Core: 19′- 20′	<0.1	2.1
BS-G2	SE SE 1-117N-63W	Pierre Shale Core: 19′- 20′	5.4	2.4
BS-H	SE SE 1-117N-63W	Pierre Shale Core: 20′- 21′	2.7	1.8
BS-I	SE SE 1-117N-63W	Pierre Shale Core: 21′- 22′	3.9	2.4
BS-J1	SE SE 1-117N-63W	Pierre Shale Core: 22′- 23′	3.7	2.2
BS-J2	SE SE 1-117N-63W	Pierre Shale Core: 22′- 23′	0.7	1.8
BS-K	SE SE 1-117N-63W	Pierre Shale Core: 23′- 24′	1.4	2.7
BS-L	SE SE 1-117N-63W	Pierre Shale Core: 24′- 25′	1.4	2.4
BS-M1	SE SE 1-117N-63W	Pierre Shale Core: 25′- 26′	<0.1	2.2
BS-M2	SE SE 1-117N-63W	Pierre Shale Core: 25′- 26′	1.6	2.5
		Samples from James Basin - Area B		
OM-86-001	Center 14-114N 62W	Gravel outcrop	4.34	2.86
OM-86-005B	Center 21-114N-62W	Pierre below dam site	0.038	2.19
OM-86-006	Center 21-114N-62W	Pierre above OM-86-005B	0.022	3.92

SAMPLE NO.	LOCATION	TYPE SAMPLE	PERCENT MANGANESE	PERCENT IRON
James Basin - Area B -- continued.				
OM-86-007	Center 21-114N-62W	Gravel above OM-86-006	0.71	2.99
OM-86-008	NW 14-114N-62W	Gravel pit - top, till	0.22	1.91
OM-86-009	NW 14-114N-62W	Gravel - descending	2.46	2.52
OM-86-010	NW 14-114N-62W	Gravel - descending	4.17	3.65
OM-86-011	NW 14-114N-62W	Gravel - descending	5.58	3.58
OM-86-012	NW 14-114N-62W	Gravel - descending	2.60	2.50
OM-86-013	NW 14-114N-62W	Gravel - descending	6.89	3.28
OM-86-014A	NW 14-114N-62W	Gravel - descending	5.21	5.17
OM-86-014B	NW 14-114N-62W	Gravel - descending	5.23	5.33
OM-86-015	NW 14-114N-62W	Gravel - descending	7.20	3.00
OM-86-016	NW 14-114N-62W	Gravel - descending	3.82	3.12
OM-86-178	NE SE NW 14-114N-62W	Glacial till	0.194	1.38
OM-86-179	SE NE SW 14-114N-62W	Gravel (auger sample)	6.11	3.98
OM-86-180A	NE SE SW 14-114N-62W	Gravel (auger sample)	4.08	3.26
OM-86-180B	NE SE SW 14-114N-62W	Gravel (auger sample)	4.14	3.20
OM-86-181	NW SW SW 14-114N-62W	Gravel (auger sample)	7.80	6.44
OM-86-182	SW SW SW 11-114N-62W	Sand (auger sample)	1.95	2.50
OM-86-183	NW NE SE SW 14-114N-62W	Gravel (auger sample)	4.28	4.18
OM-86-184A	SW SW NW 14-114N-62W	Gravel (auger sample)	4.12	4.00
OM-86-184B	SW SW NW 14-114N-62W	Gravel (auger sample)	3.72	4.20
OM-86-185	SW NW NW 23-114N-62W	Gravel (auger sample)	5.26	4.56
		Random Samples		
Mg	NE SW SE 27-100N-63W	Nodules	4.9	9.2
Mh	SE NW 3-110N-59W	Nodules	8.31	35.0
Mi	NE SW 3-110N-59W	Nodules	6.01	29.5
Mj	NW NW 23-111N-59W	Gravel	2.75	35.6
Mk	NE SE 23-111N-59W	Pierre Shale	2.15	6.3
Ml	NW NW NE 11-110N-59W	Pierre Cuttings	1.18	3.1
Mm	NE NW 36-110N-59W	Large concretion	5.31	32.0
OM-86-002	SE NW 25-123N-66W	Dam site - Lower level Pierre	0.04	1.81
OM-86-003	SE NW 25-123N-66W	Dam site - Upper level Pierre	1.44	1.92
OM-86-004	SE NW 25-123N-66W	Dam site - Upper level nodules	22.5	3.70
OM-86-005A	NE NE 6-127N-65W	Dam site - Upper level Pierre	0.22	1.84
OM-86-017	SW NW 26-115N-62W	Interior of large concretion	0.02	7.90
OM-86-018	NW NW NW 35- 10N- 2E	Carlile Shale	0.0064	2.61
OM-86-019	NE SW 4- 14N- 3E	Pierre Shale	0.011	3.08
OM-86-020	SE NW 32- 5N-13E	Pierre Shale	0.011	4.08

SAMPLE NO.	LOCATION	TYPE SAMPLE	PERCENT MANGANESE	PERCENT IRON

Random Samples -- continued.

SAMPLE NO.	LOCATION	TYPE SAMPLE	MANGANESE	IRON
OM-86-021	SE SE 34- 9N- 2E	Graneros Shale	0.0042	2.15
OM-86-022	SE SW SW 9- 9N-11E	Hell Creek Shale	0.0056	1.95
OM-86-023	NE NE 15- 9N-11E	Hell Creek Shale	0.029	2.37
OM-86-024	NW SE 23- 99N-71W	Pierre Shale	0.033	3.13
OM-86-025A	SW SW 6- 17N- 9E	Hell Creek Shale	0.033	3.39
OM-86-025B	SW SW 6- 17N- 9E	Hell Creek Shale	0.032	3.61
OM-86-026	NE SE 15- 17N- 8E	Blackjack coaly seam	0.0024	5.44
OM-86-027	SW SW 34- 18N-10E	Thin coal seam	0.0064	2.60
OM-86-028	SW SW 7- 17N-30E	Pierre Shale	0.046	4.02
OM-86-029	SW NE 6- 10N- 3E	Pierre Nodules	0.122	26.4
OM-86-030	SW SW 15- 14N- 3E	Pierre Shale	0.024	3.58
OM-86-031	NW NW 22- 18N-15E	Ludlow Formation	0.02	3.80
OM-86-032	SE SE 7- 16N-29E	Pierre Shale	0.032	3.78
OM-86-033	SW SW 30- 3N-14E	Pierre Shale	0.023	3.75
OM-86-034	SW SW 19- 16N- 3E	Hell Creek Shale	1.54	1.75
OM-86-035A	NE SW 28- 14N- 3E	Pierre Shale	0.034	3.40
OM-86-035B	NE SW 28- 14N- 3E	Pierre Shale	0.038	3.88
OM-86-036	Center 8- 17N-13E	Scoria	0.051	3.25
OM-86-037	SW SW 1- 4S-17E	Interior Formation (Lower)	0.035	5.0
OM-86-038	SW SW 1- 4S-17E	Interior Formation (Lowest)	0.040	4.3
OM-86-039	SW SW 1- 4S-17E	Interior Formation (Higher)	0.0084	3.6
OM-86-040	SW SW 1- 4S-17E	Interior Formation (Highest)	0.0038	1.7
OM-86-041	SW SW 1- 4S-17E	Interior Formation (nodules)	0.429	39.2
OM-86-042	SE SW 10- 4S-17E	Interior Formation	0.011	4.2
OM-86-043	SE SW 10- 4S-17E	Interior Formation (Lower)	0.033	14.5
OM-86-044	NW SW 5- 16N-13E	Hell Creek Shale	0.012	2.9
OM-86-045A	NW SW 5- 16N-13E	Hell Creek nodules	1.96	33.0
OM-86-045B	NW SW 5- 16N-13E	Hell Creek nodules	1.18	29.0
OM-86-046	SE SW 25- 17N- 4E	Hell Creek Shale	0.056	3.0
OM-86-047	SE SW 25- 17N- 4E	Hell Creek nodules	1.20	39.0
OM-86-048	SE SE 36- 17N-19E	Hell Creek Shale (Upper)	0.018	2.0
OM-86-049	SE SE 36- 17N-19E	Hell Creek Shale (Lower)	0.025	2.3
OM-86-050	SW SW 21- 17N- 6E	Hell Creek Shale	0.019	3.3
OM-86-051	SW SW 21- 17N- 6E	Hell Creek nodules	0.98	28.0
OM-86-052	SE SW 12- 16N- 2E	Hell Creek Shale	0.034	3.50
OM-86-053	SE SW 12- 16N- 2E	Hell Creek nodules	0.93	24.5
OM-86-054	NE NW 8-126N-78W	Pierre Shale (Highest)	0.012	3.08
OM-86-055A	NE NW 8-126N-78W	Pierre Shale (Second Highest)	0.174	1.92
OM-86-055B	NE NW 8-126N-78W	Pierre Shale (Second Highest)	0.182	1.88

SAMPLE NO.	LOCATION	TYPE SAMPLE	PERCENT MANGANESE	PERCENT IRON
Random Samples -- continued.				
OM-86-056	NE NW 8-126N-78W	Pierre Shale (Middle)	0.012	3.04
OM-86-057	NE NW 8-126N-78W	Pierre Shale (Lowest)	0.014	3.56
OM-86-058 to OM-86-147	(Analyzed by Chemex Lab, see table 2)			
OM-86-148	Center 21-106N-73W	Pierre Shale (Lowest)	0.223	4.28
OM-86-149	Center 21-106N-73W	Pierre Shale	0.0562	3.47
OM-86-150	Center 21-106N-73W	Pierre Shale	0.102	3.17
OM-86-151	Center 21-106N-73W	Pierre Shale	0.402	3.42
OM-86-152	Center 21-106N-73W	Pierre Shale	0.159	3.69
OM-86-153	Center 21-106N-73W	Pierre Shale (Highest)	0.063	3.97
OM-86-154	SW SW 34- 5N-31E	Pierre Shale (Lowest)	0.170	2.72
OM-86-155A	SW SW 34- 5N-31E	Pierre Shale	0.436	2.73
OM-86-155B	SW SW 34- 5N-31E	Pierre Shale	0.192	2.69
OM-86-156	SW SW 34- 5N-31E	Pierre Shale	1.05	2.75
OM-86-157	SW SW 34- 5N-31E	Pierre Shale	0.054	2.73
OM-86-158	SW SW 34- 5N-31E	Pierre Shale	0.423	3.17
OM-86-159	SW SW 34- 5N-31E	Pierre Shale	0.499	3.22
OM-86-160	SW SW 34- 5N-31E	Pierre Shale	.371	3.05
OM-86-161	SW SW 34- 5N-31E	Pierre Shale	0.592	2.98
OM-86-162	SW SW 34- 5N-31E	Pierre Shale (Highest)	0.970	2.67
OM-86-173	NE NE 23- 93N-58W	Niobrara Formation (Lowest)	0.0214	3.00
OM-86-174	NE NE 23- 93N-58W	Niobrara Formation (Middle)	0.0100	3.82
OM-86-175A	NE NE 23- 93N-58W	Niobrara Formation	0.121	2.64
OM-86-175B	NE NE 23- 93N-58W	Niobrara Formation (Highest)	0.139	2.69
OM-86-176	Center 16- 93N-57W	Pierre Shale (Upper)	0.472	4.02
OM-86-177	Center 16- 93N-57W	Pierre Shale (Lower)	0.0414	4.54

Appendix B. Random-sample analyses by Chemex Labs., Inc., Sparks, Nevada.

SAMPLE DESCRIPTION	Mo ppm (ICP)	W ppm (ICP)	Zn ppm (ICP)	P ppm (ICP)	Pb ppm (ICP)	Bi ppm (ICP)	Cd ppm (ICP)	Co ppm (ICP)	Ni ppm (ICP)	Ba ppm (ICP)	FE % (ICP)	Mn ppm (ICP)	Cr ppm (ICP)	Mg % (ICP)	V ppm (ICP)	Al % (ICP)	Be ppm (ICP)	Ca % (ICP)	Cu ppm (ICP)	Ag ppm AAS	Ti % (ICP)	Sr ppm (ICP)	Na % (ICP)	K % (ICP)	Location	Formation
OM 86 058	6	< 10	31	2770	25	< 2	12.5	4	16	470	27.3	>10000	50	1.30	< 1	1.56	2.0	11.40	29	2.5	0.086	385	0.21	0.39	NE NW sec. 8-126N-78W	Pierre Nodule
OM 86 059	5	< 10	89	520	35	< 2	< 0.5	12	20	1470	3.49	135	73	0.96	135	6.76	2.0	1.40	24	0.5	0.351	265	0.95	1.38	NE NW sec. 8-126N-78W	Pierre Shale
OM 86 060	1	< 10	33	4350	110	< 2	7.5	5	17	480	19.40	>10000	46	1.18	< 1	1.72	2.5	17.50	20	2.5	0.094	520	0.25	0.42	NE NW sec. 8-126N-78W	Pierre Nodules
OM 86 061	4	< 10	80	440	25	< 2	< 0.5	19	46	590	4.14	980	77	0.98	80	6.41	2.0	0.98	25	1.0	0.351	265	1.08	1.21	SW SE sec. 13- 16N- 2E	Fox Hills Formation
OM 86 062	< 1	< 10	39	820	10	< 2	11.0	6	14	360	31.9	>10000	54	0.73	< 1	1.95	3.5	3.61	18	2.5	0.113	255	0.32	0.35	SW SE sec. 13- 16N- 2E	Fox Hills Nodule
OM 86 063	4	< 10	113	750	25	< 2	< 0.5	9	27	660	2.71	105	94	0.84	163	7.54	2.5	0.33	26	0.5	0.393	133	0.45	1.95	NE NE sec. 10- 9N- 2E	Graneros Shale
OM 86 064	< 1	< 10	48	1470	25	< 2	10.5	6	17	360	26.8	3280	57	2.04	44	2.35	3.0	6.64	19	2.0	0.132	320	0.14	0.52	NE NE sec. 10- 9N- 2E	Graneros Nodules
OM 86 065	< 1	< 10	36	880	5	< 2	12.0	3	11	400	35.1	2200	49	2.26	24	1.47	3.0	3.07	18	2.5	0.086	210	0.10	0.33	NE NE sec. 10- 9N- 2E	Graneros Nodules
OM 86 066A	4	< 10	100	450	25	< 2	< 0.5	10	24	610	2.15	73	105	0.79	147	8.39	3.0	0.33	36	0.5	0.376	96	0.35	1.83	NE NE sec. 6- 8N- 9E	Pierre Shale
OM 86 067	5	< 10	285	720	20	< 2	8.0	25	235	210	28.5	1590	25	0.95	< 1	6.11	9.0	1.29	13	2.5	0.148	45	0.06	0.24	NE NE sec. 6- 8N- 9E	Pierre Ledge
OM 86 068	3	< 10	84	540	25	< 2	< 0.5	7	14	630	2.55	57	110	0.89	150	8.92	3.0	0.83	38	0.5	0.397	167	0.40	1.99	NE NE sec. 6- 8N- 9E	Pierre Shale
OM 86 069	4	< 10	94	970	20	< 2	< 0.5	13	33	620	4.43	220	100	1.16	136	8.51	3.0	0.79	26	0.5	0.390	152	1.24	2.50	NE SW sec. 27- 2S-16E	Interior Shale
OM 86 070	5	< 10	107	1210	25	< 2	< 0.5	18	39	580	4.80	360	74	1.23	139	8.45	2.5	1.00	31	1.0	0.387	147	1.20	2.51	NE SW sec. 27- 2S-16E	Interior Shale
OM 86 071	5	< 10	102	740	20	< 2	< 0.5	18	33	670	5.09	385	88	1.21	144	7.95	3.0	0.58	24	0.5	0.365	151	1.26	2.43	NE SW sec. 27- 2S-16E	Interior Shale
OM 86 072	12	< 10	23	200	25	< 2	< 0.5	5	21	340	2.08	56	55	0.30	88	3.81	3.5	1.03	48	0.5	0.282	285	0.21	0.31	SW NW sec. 7- 17N-13E	Ludlow Coal
OM 86 073	6	< 10	100	590	25	< 2	< 0.5	14	27	480	3.22	141	78	1.02	108	7.41	2.5	0.88	32	0.5	0.341	182	0.51	1.56	SW NW sec. 7- 17N-13E	Ludlow Shale
OM 86 074	2	< 10	142	760	35	< 2	1.0	13	41	890	3.52	165	115	1.43	245	8.21	3.0	2.77	32	1.0	0.401	290	0.84	2.16	NE SE sec. 1- 10N- 2E	Pierre (upper)
OM 86 075A	4	< 10	118	750	25	< 2	< 0.5	12	32	740	2.96	157	99	1.19	205	7.01	2.5	5.39	26	1.0	0.338	330	0.66	1.75	NE SE sec. 1- 10N- 2E	Pierre (lower)
OM 86 076	5	< 10	116	680	35	< 2	< 0.5	18	40	950	4.44	310	88	1.33	144	7.76	2.5	2.16	31	0.5	0.357	315	0.97	2.37	NE NW sec. 7- 1N-14E	Pierre (lower)
OM 86 077	5	< 10	102	730	35	< 2	0.5	13	32	700	3.73	220	87	1.55	129	7.80	2.5	1.43	27	1.0	0.361	189	0.99	2.15	NE NW sec. 7- 1N-14E	Pierre Shale
OM 86 078	10	< 10	101	710	30	< 2	< 0.5	12	32	760	3.81	280	85	1.71	117	7.41	2.5	1.41	27	1.0	0.339	182	0.94	1.90	NE NW sec. 7- 1N-14E	Pierre Shale
OM 86 079	2	< 10	86	660	30	< 2	< 0.5	11	25	620	3.72	189	76	1.45	107	7.20	2.0	1.08	24	1.0	0.332	185	0.94	1.87	NE NW sec. 7- 1N-14E	Pierre (Highest)
OM 86 080	3	< 10	188	350	40	< 2	< 0.5	10	82	630	3.09	415	75	1.47	190	8.65	2.5	0.47	83	1.0	0.319	225	1.24	1.69	NE NE sec. 13-102N-73W	Pierre Oacoma
OM 86 081	< 1	< 10	440	1540	55	< 2	9.0	40	183	360	26.1	>10000	77	1.88	< 1	1.46	4.5	3.50	30	2.5	0.073	300	0.24	0.29	NE NE sec. 13-102N-73W	Pierre Nodule
OM 86 082	4	< 10	95	600	30	< 2	< 0.5	8	23	760	3.99	150	90	1.06	143	7.82	2.5	0.74	28	1.0	0.390	185	0.92	1.76	SE SW sec. 8- 17N-29E	Pierre Shale
OM 86 083	3	< 10	118	200	25	< 2	< 0.5	11	20	740	3.14	149	75	0.71	80	7.67	2.0	1.72	34	1.0	0.365	189	0.81	1.65	NW SW sec. 15- 9N-12E	Hell Creek Shale
OM 86 084	8	< 10	74	660	30	4	< 0.5	9	14	580	3.12	118	69	0.72	80	7.25	2.0	0.33	20	1.0	0.324	184	0.60	2.41	NE SE sec. 9- 17N-15E	Ludlow Formation
OM 86 085A	2	< 10	37	210	30	4	< 0.5	8	10	1540	1.40	195	34	0.64	57	4.81	1.5	1.59	12	0.5	0.247	240	1.05	1.24	NE NE sec. 25- 9N-12E	Fox Hills Formation
OM 86 086	< 1	< 10	126	570	45	4	1.0	16	36	870	5.34	535	84	1.08	166	8.12	3.0	1.70	35	0.5	0.336	345	0.53	1.61	NW SW sec. 16- 12N- 3E	Pierre Shale
OM 86 087	4	< 10	77	330	45	2	< 0.5	10	13	860	3.03	166	43	1.14	70	6.89	2.0	1.07	18	0.5	0.332	245	0.99	0.59	SE SW sec. 6- 4S-18E	Chadron Formation
OM 86 088	< 1	< 10	60	580	20	< 2	< 0.5	7	14	400	2.28	205	51	2.07	60	5.59	2.0	4.06	20	1.0	0.253	121	0.73	1.57	SW NW sec. 4- 6N-13E	Fox Hills Formation
OM 86 089	1	< 10	11	100	20	< 2	< 0.5	3	< 1	660	0.44	84	9	0.12	13	2.95	1.0	0.72	6	0.5	0.058	245	0.94	1.06	SW NE sec. 8-100N-73W	Valentine Formation
OM 86 090	2	< 10	52	180	30	< 2	< 0.5	6	9	620	1.81	260	30	0.67	36	5.81	2.5	1.20	15	0.5	0.270	240	1.09	1.69	NE SW sec. 24- 99N-71W	Pierre Shale
OM 86 091	4	< 10	89	150	25	< 2	< 0.5	11	18	440	3.91	98	82	0.88	94	7.86	2.0	1.60	32	0.5	0.373	225	0.36	1.18	NE NE sec. 29- 8N-13E	Fox Hills Formation
OM 86 092	4	< 10	91	410	25	< 2	< 0.5	15	33	770	3.33	174	72	1.53	80	8.98	1.5	1.19	21	0.5	0.375	245	1.17	1.50	NE NE sec. 21- 17N-17E	Ludlow Formation
OM 86 093	5	< 10	128	450	20	< 2	< 0.5	13	30	1080	4.47	161	93	1.27	190	9.61	3.0	0.54	38	0.5	0.388	136	0.66	2.27	SW SW sec. 10- 9N- 9E	Pierre Shale
OM 86 094	5	< 10	114	150	25	< 2	< 0.5	18	46	650	2.65	88	78	0.95	103	7.36	2.5	0.36	41	0.5	0.357	190	2.04	1.41	SE NE sec. 30- 17N-13E	Hell Creek Formation
OM 86 095A	5	< 10	107	480	15	< 2	< 0.5	11	22	620	3.83	111	88	1.28	142	7.93	2.5	1.46	33	1.0	0.363	255	0.76	1.77	SE SW sec. 12- 9N- 9E	Pierre Shale
OM 86 096	6	< 10	139	420	30	< 2	< 0.5	14	33	580	4.38	126	94	0.93	179	8.73	2.5	1.34	40	1.5	0.373	156	0.64	1.75	SE NW sec. 27- 9N- 7E	Pierre Shale
OM 86 097	3	< 10	127	1420	15	< 2	1.0	11	42	410	4.41	465	88	0.83	196	5.23	2.5	12.30	47	1.5	0.256	470	0.38	1.24	SE SW sec. 15- 99N-71W	Pierre Shale
OM 86 098	9	< 10	53	1410	5	< 2	10.5	6	23	350	29.6	8460	52	1.02	31	3.40	3.0	1.28	17	2.5	0.152	102	9,29	0.76	SW NW sec. 4- 6N-13E	Fox Hills Nodules
OM 86 099	2	< 10	93	1020	20	< 2	< 0.5	11	33	650	4.22	230	97	1.52	131	7.95	2.5	1.39	23	1.5	0.346	170	0.95	2.25	SW NW sec. 7- 3N-14E	Pierre Shale
OM 86 100	1	< 10	32	400	45	< 2	< 0.5	2	6	320	1.48	8410	30	0.66	3	3.12	1.5	20.1	15	2.0	0.142	153	0.56	0.85	SW NW sec. 24- 3N-18E	Fox Hills Formation
OM 86 101	< 1	< 10	74	410	25	< 2	< 0.5	8	13	670	3.37	610	38	1.24	39	7.66	2.0	1.33	30	1.0	0.386	235	1.28	2.26	SW NW sec. 24- 3S-18E	Brule Formation
OM 86 102	4	< 10	114	610	30	< 2	< 0.5	12	56	590	3.89	390	59	1.43	120	9.03	2.0	1.38	23	1.0	0.326	230	1.14	1.38	NW SE sec. 23- 16N-28E	Pierre Shale

Appendix B -- continued.

SAMPLE DESCRIPTION	Mo ppm (ICP)	W ppm (ICP)	Zn ppm (ICP)	P ppm (ICP)	Pb ppm (ICP)	Bi ppm (ICP)	Cd ppm (ICP)	Co ppm (ICP)	Ni ppm (ICP)	Ba ppm (ICP)	FE % (ICP)	Mn ppm (ICP)	Cr ppm (ICP)	Mg % (ICP)	V ppm (ICP)	Al % (ICP)	Be ppm (ICP)	Ca % (ICP)	Cu ppm (ICP)	Ag ppm AAS	Ti % (ICP)	Sr ppm (ICP)	Na % (ICP)	K % (ICP)	Location	Formation
OM 86 103	2	< 10	40	250	25	< 2	< 0.5	5	12	550	1.71	310	27	0.80	30	4.95	1.5	2.49	15	1.0	0.269	220	0.80	1.21	NE NE sec. 25- 9N-12E	Fox Hills Formation
OM 86 104	5	< 10	125	430	35	< 2	< 0.5	11	33	800	4.20	135	105	1.07	180	9.01	2.5	0.57	30	1.0	0.380	181	0.58	1.86	SW SW sec. 28- 5N-13E	Pierre Shale
OM 86 105A	< 1	< 10	136	740	30	< 2	< 0.5	19	69	760	3.52	2140	80	1.12	163	6.58	2.0	1.25	34	< 0.5	0.327	131	0.87	1.99	SW NE sec. 12- 17N-30E	Pierre Shale
OM 86 106	2	< 10	31	470	15	< 2	< 0.5	2	6	570	1.83	345	23	0.57	21	4.27	1.5	2.20	10	1.0	0.156	106	0.77	1.45	SE NE sec. 20- 7N-13E	Fox Hills Formation
OM 86 107	< 1	< 10	141	670	20	< 2	< 0.5	15	50	860	3.96	475	108	1.44	220	7.72	2.5	1.05	31	1.0	0.378	122	0.69	2.23	NW SE sec. 8- 11N- 3E	Pierre Shale
OM 86 108	< 1	< 10	65	970	5	< 2	< 0.5	5	28	550	34.7	4130	61	1.62	106	2.76	2.5	1.72	48	3.0	0.139	161	0.17	0.67	NW SE sec. 8- 11N- 3E	Pierre Nodules
OM 86 109	5	< 10	94	620	25	< 2	< 0.5	10	25	470	3.84	285	57	1.56	89	8.04	2.0	1.78	42	8.5	0.311	220	0.70	1.39	Center sec. 1- 1N-14E	Pierre (upper)
OM 86 110	< 1	< 10	100	550	35	< 2	< 0.5	10	27	590	3.58	275	64	1.66	101	7.70	2.5	1.69	58	2.0	0.311	345	0.70	1.44	Center sec. 1- 1N-14E	Pierre (lower)
OM 86 111	5	< 10	220	420	20	< 2	< 0.5	16	66	450	4.26	935	70	1.17	193	7.97	2.0	0.70	51	1.5	0.300	165	0.38	1.24	SE NE sec. 14- 99N-72W	Pierre Shale
OM 86 112	< 1	< 10	470	2560	5	< 2	14.0	72	565	480	36.4	>10000	78	0.99	< 1	3.21	6.0	0.68	71	3.0	0.125	129	0.13	0.54	SE NE sec. 14- 99N-72W	Pierre Nodules
OM 86 113	5	< 10	143	740	30	< 2	< 0.5	24	58	900	5.14	435	103	1.27	193	9.01	3.0	1.44	37	1.5	0.378	158	0.74	2.39	SE SW sec. 16- 1N-15E	Pierre Shale
OM 86 114	12	< 10	133	720	20	< 2	< 0.5	23	29	690	5.65	230	93	1.07	170	8.04	2.5	0.98	34	1.0	0.336	165	0.79	2.25	SE SW sec. 16- 1N-15E	Pierre Shale
OM 86 115A	2	< 10	189	1020	15	< 2	< 0.5	21	56	820	4.93	590	123	1.37	220	8.68	2.5	1.48	49	1.0	0.400	220	0.81	2.27	SE SW sec. 16- 1N-15E	Pierre Nodules
OM 86 116	3	< 10	121	450	20	< 2	< 0.5	20	65	760	3.99	395	101	1.12	122	8.56	2.0	0.58	52	1.5	0.453	171	2.06	1.96	SW NE sec. 19- 17N- 4E	Hell Creek Shale
OM 86 117	< 1	< 10	65	1350	5	< 2	4.0	5	50	540	42.8	>10000	68	0.75	< 1	2.35	4.0	0.51	37	3.0	0.141	310	0.29	0.52	SW NE sec. 19- 17N- 4E	Hell Creek Nodules
OM 86 118	13	< 10	139	880	25	< 2	< 0.5	28	53	680	5.23	580	93	1.05	160	8.32	2:5	0.73	40	1.0	0.348	194	0.72	2.06	Center sec. 1- 3N-14E	Pierre Shale
OM 86 119	< 1	< 10	92	560	20	< 2	< 0.5	9	23	540	3.34	215	54	1.23	99	7.56	2.5	1.24	28	1.0	0.346	200	0.72	2.13	SW NE sec. 7-100N-73W	Brule Formation
OM 86 120	3	< 10	118	640	25	< 2	< 0.5	13	40	920	4.41	345	94	1.19	147	8.41	2.5	1.42	35	< 0.5	0.367	220	0.74	1.84	SW NE sec. 10- 15N-26E	Pierre Shale
OM 86 121	5	< 10	116	520	30	< 2	< 0.5	12	19	880	4.62	124	99	1.05	158	8.58	2.0	1.23	36	1.0	0.383	215	0.77	1.80	SW SW sec. 8- 17N-29E	Pierre Shale
OM 86 122	4	< 10	188	390	40	< 2	< 0.5	24	149	550	3.01	1300	76	1.34	173	8.00	2.5	1.88	71	< 0.5	0.322	270	1.03	1.74	SW NE sec. 15- 99N-70W	Pierre Shale
OM 86 123	5	< 10	315	4660	30	16	4.5	34	162	1830	11.90	>10000	74	1.54	< 1	1.27	3.5	14.50	33	2.0	0.053	1130	0.29	0.28	SW NE sec. 15- 99N-70W	Pierre Nodules
OM 86 124	2	< 10	136	510	30	< 2	< 0.5	10	18	730	4.97	193	91	1.16	175	8.69	2.5	0.44	36	1.5	0.379	181	0.63	2.00	SE NE sec. 5- 1N-14E	Pierre Shale
OM 86 125A	2	< 10	139	690	20	< 2	< 0.5	14	40	820	4.41	250	103	1.52	182	8.87	2.5	1.14	38	1.0	0.417	220	0.83	2.27	SE NE sec. 5- 1N-14E	Pierre Shale
OM 86 126	4	< 10	66	198	20	< 2	< 0.5	15	28	550	2.31	198	68	1.06	84	7.72	2.5	2.19	31	< 0.5	0.398	205	0.92	1.55	NW NW sec. 5- 9N-12E	Hell Creek Shale
OM 86 127	< 1	< 10	110	710	15	< 2	9.0	2	9	410	44.0	>10000	52	1.04	< 1	2.14	4.0	1.18	10	3.5	0.101	128	0.13	0.45	NW NW sec. 5- 9N-12E	Hell Creek Nodules
OM 86 128	8	< 10	60	140	20	4	< 0.5	5	16	500	2.68	82	83	0.77	106	8.98	2.0	1.13	40	1.5	0.431	210	1.05	1.27	NE NE sec. 5- 16N-19E	Hell Creek (upper)
OM 86 129	5	< 10	88	240	25	< 2	< 0.5	13	37	630	2.66	100	84	0.79	104	8.11	2.5	0.82	44	1.0	0.412	230	1.27	1.92	NE NE sec. 5- 16N-19E	Hell Creek (middle)
OM 86 130	5	< 10	60	140	15	< 2	< 0.5	6	18	540	2.63	60	83	0.70	110	8.98	2.0	0.68	25	1.0	0.463	220	1.28	1.35	NE NE sec. 5- 16N-19E	Hell Creek (lower)
OM 86 131	8	< 10	88	970	10	< 2	1.5	18	53	1370	8.76	4720	57	0.87	68	5.28	2.5	3.10	30	2.0	0.281	275	1.07	1.39	NE NE sec. 14- 14N-24E	Gravel
OM 86 132	2	< 10	110	710	15	< 2	0.5	10	30	730	4.42	142	100	1.03	164	8.05	2.5	1.10	41	1.0	0.367	197	1.10	2.00	SE SW sec. 5- 6N-27E	Pierre Shale
OM 86 133	< 1	< 10	52	21400	5	< 2	7.0	11	46	790	26.9	>10000	60	1.09	< 1	1.38	5.0	8.48	20	3.0	0.073	745	0.43	0.32	NE SW sec. 16- 6N-29E	Pierre Nodule
OM 86 134	5	< 10	128	590	25	< 2	< 0.5	13	46	650	3.75	260	105	1.07	205	8.55	3.0	1.39	46	1.5	0.388	141	0.55	2.19	SW NE sec. 10- 14N-25E	Pierre Shale
OM 86 135	< 1	< 10	50	760	5	< 2	7.5	5	29	520	29.7	298	53	1.91	< 1	1,63	2,0	2,27	27	2.5	0.081	114	0.15	0.30	NE NE sec. 34- 7N-26E	Pierre Nodule
OM 86 136A	2	< 10	122	880	20	< 2	< 0.5	16	42	850	4.27	435	94	1.31	171	8.23	3.0	2.91	36	1.0	0.383	230	0.86	2.45	SW SW sec. 12- 10N-23E	Pierre Shale
OM 86 137	6	< 10	139	740	20	< 2	0.5	18	51	1000	5.63	2340	81	1.22	185	715	2.5	0.96	41	1.0	0.332	215	0.85	1.60	SE NE sec. 3- 8N-24E	Pierre Shale
OM 86 138	6	< 10	171	640	15	< 2	< 0.5	17	32	1390	5.22	187	88	1.14	255	7.60	2.5	0.58	43	1.0	0.355	300	0.77	1.68	NE NE sec. 34- 7N-26E	Pierre Shale
OM 86 139	7	< 10	111	1270	30	< 2	0.5	13	25	890	5.43	215	97	1.04	184	8.39	3.0	1.67	40	1.0	0.391	205	0.87	2.34	SW SW sec. 4- 14N-29E	Pierre Shale
OM 86 140	4	< 10	99	580	25	< 2	< 0.5	9	19	920	4.43	103	93	1.07	178	8.39	2.5	0.82	36	1.5	0.377	330	0.87	1.79	SW SW sec. 1- 6N-27E	Pierre Shale
OM 86 141	6	< 10	91	720	25	< 2	< 0.5	15	33	1080	3.90	630	75	1.18	120	8.10	3.0	1.65	29	1.0	0.380	280	1.36	2.10	NW NE sec. 24- 14N-23E	Pierre Shale
OM 86 142	4	< 10	107	990	25	< 2	< 0.5	10	21	890	4.26	137	105	1.19	146	7.99	2.5	1.35	37	1.0	0.361	300	1.32	2.05	SE SE sec. 12- 14N-24E	Pierre Shale
OM 86 143	3	< 10	149	560	15	< 2	< 0.5	13	32	1100	5.48	225	88	1,28	230	8.26	3.0	0.49	45	1.5	0.395	245	0.78	1.95	SW NE sec. 29- 9N-24E	Pierre Shale
OM 86 144	5	< 10	146	1180	25	< 2	< 0.5	14	33	1050	5.21	235	105	1.05	280	7.86	3.0	1.16	56	1.5	0.376	340	0.72	1.94	SW NW sec. 20- 9N-24E	Pierre Shale
OM 86 145A	3	< 10	117	680	25	< 2	< 0.5	13	43	710	3.80	370	87	1.26	174	7.41	3.0	2.19	36	1.0	0.353	240	1.58	1.92	NW NW sec. 20- 15N-26E	Pierre Shale
OM 86 146	< 1	< 10	81	5080	5	< 2	<0.5	6	46	480	36.8	7410	67	1.24	90	2.81	3.5	1.87	33	2.5	0.144	240	0.21	0.67	NW NE sec. 36- 15N-25E	Pierre Nodules
OM 86 147	5	< 10	70	430	25	< 2	< 0.5	10	47	650	4.19	1070	40	1.73	76	9.14	1.5	1.21	24	1.5	0.276	155	1.31	0.88	NE SW sec. 16- 6N-29E	Pierre Shale