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MANGANESE OCCURRENCES IN MANITOBA

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the summers of 1940-41. Because of the similarity of some Manitoba occurrences of manganese to those of the lower Missouri valley in South Dakota, reference is made to the work of Gries and Rothrock[1] and their report has been freely drawn upon.

Location of the Manganese Occurrences

Occurrences of manganese in Manitoba that have even a remote possibility of commercial application are all confined to areas underlain by rocks of Cretaceous age. In western Ontario, close to the Manitoba boundary, small nodular bog deposits of doubtful origin occur in areas underlain by Precambrian gneiss. So far no deposits of this type have been found in Precambrian areas in Manitoba.

Cretaceous rocks underlie a large part of western and southwestern Manitoba. Their approximate eastern limit is marked by the Manitoba escarpment which extends in a north-northwesterly direction from Pembina mountain to Porcupine mountain. The area under consideration in this report is delimited by the above defined extent of the Cretaceous beds, the only formations known at the present time to be manganiferous.

PHYSICAL FEATURES OF THE MANITOBA CRETACEOUS

The Cretaceous of Manitoba, where it overlaps on the underlying Palaeozoic rocks, presents a steep escarpment which has been

1. Gries, J.P. and Rothrock, E.P.: "Manganese Deposits of the Lower Missouri Valley in South Dakota"; South Dakota State Geol. Surv., Rep't of Investigations No. 38, 1941.

MANGANESE OCCURRENCES IN MANITOBA

INTRODUCTION

The occurrence of a small deposit of bog manganese near Roseisle, Manitoba has been known for many years. It is also known that "ironstone" nodules, which occur at certain horizons in the Cretaceous shales of Manitoba, are manganiferous. These occurrences, which are either very small or else low in grade, received little attention prior to the outbreak of the present war. The possibility of a materially reduced supply of manganese from foreign sources has recently focused attention on domestic occurrences of the metal. As a result, prospecting activities in Manitoba in the years 1940-41 have included a search for commercial deposits of manganese on the part of various prospectors and prospecting syndicates. A limited number of mining claims have been staked where occurrences of manganiferous material have been found.

The present report is intended as a preliminary summary describing the occurrence of manganese in Manitoba from the data, in many respects incomplete, available at this time. Stratigraphical information is largely derived from the work of Kirk[1] and from map 637A recently published by the Geological Survey of Canada. Descriptive information relative to the manganese occurrences is the result of examinations conducted by officers of the Manitoba Mines Branch in

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1. Kirk, S.R.: "Cretaceous Stratigraphy of the Manitoba Escarpment", Geol. Surv., Canada, Sum. Rept., 1929, pt. B, pp. 112-135.

eroded and dissected to form a series of hills. The more important of these hills are named Pembina mountain, Riding mountain, Duck mountain and Porcupine mountain, in order from south to north. These hills are separated by the wide valleys of the Assiniboine, Valley, and Swan rivers.

The Great Plains region, or second prairie level, stretches to the west of the escarpment. Pembina mountain rises to elevations of over 1,600 feet, while the more northerly hills of the escarpment have summit elevations in excess of 2,200 feet. From the foot of the escarpment, at elevations of 900 to 1,100 feet, the lake plain of Manitoba, or first prairie level, extends eastward.

Owing to the generally heavy drift-covering and to the dense growth of forest and other vegetation along the escarpment, good exposures of bedrock are relatively rare. Good sections of the Cretaceous rocks have, however, been cut by the many small streams descending the face of the escarpment, and from these it has been possible to work out the stratigraphical succession.

At places along steeper slopes of the escarpment, landsliding has displaced small blocks of the Cretaceous rocks below their normal elevation. Local deformation was also caused by glaciation by the ice-sheet which advanced from a northerly or northeasterly direction. Although deformation from this cause is normally slight, the beds are locally highly crumpled or even overthrust upon younger beds. Beds containing low grade material of possible economic interest should, therefore, be carefully examined to ascertain whether or not they have been displaced by either of these agents.

STRATIGRAPHY

The Cretaceous rocks in Manitoba are underlain by limestone and dolomite of Devonian age which outcrops to the east of the Manitoba escarpment. Devonian rocks are the youngest Palaeozoic rocks occurring in the Province. Drilling records indicate that, in a large part of the area underlain by Cretaceous rocks, beds of Jurassic age lie between the Cretaceous and the underlying Devonian beds. Outcrops of Jurassic beds are not known to occur. The only consolidated rocks known to overlie the Cretaceous occur in a small area at Turtle mountain. They are marine and continental shales and sandstones of Tertiary (Eocene) age.

The geological sketch-map of Manitoba, depicted in figure 1, indicates the area underlain by Cretaceous rocks.

The Cretaceous rocks are all of marine origin, chiefly shales with subordinate amounts of sandstone and limestone. The subdivision proposed by Kirk[1] in 1929 has, in the Riding Mountain section at least, been slightly modified through more recent work by officers of the Geological Survey of Canada, and the modified section is indicated in part in Map 637A (1941). Kirk's subdivision and the modified subdivision are given for comparison in the following table:

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1. Kirk, S.R.: op. cit., p. 114.

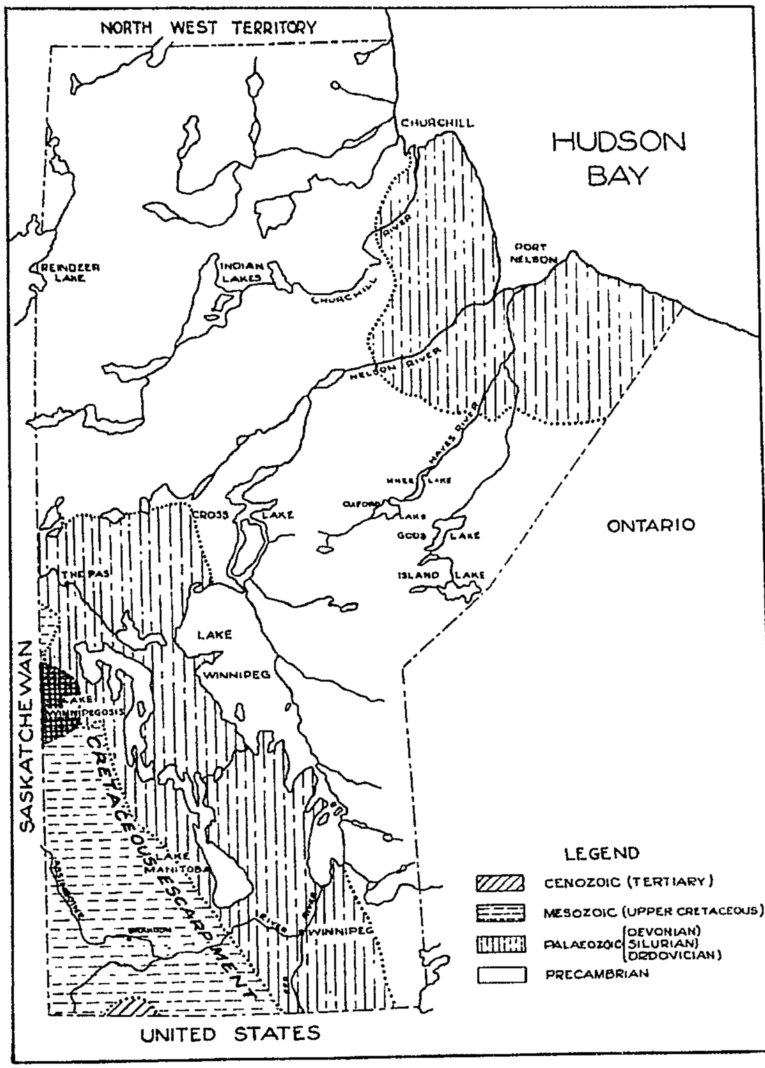

Figure 1. Geological sketch-map of Manitoba, showing location of Cretaceous escarpment. Porcupine Mountain area indicated by cross-hatching.

Table of Formations

	Pembina Mountain sec. (after Kirk)	Riding Mountain sec. (after Kirk)	Riding Mountain sec. (Map 637A)
Pierre	Odanah beds - 250 ft.	Odanah beds - 300 ft.	Odanah formation
	Riding Mountain beds 50-80 ft.	Riding Mountain beds 200 ft.	Riding Mountain formation
	Pembina beds - 80 ft.	Vermilion River beds 250-300 ft.	Vermilion River formation
Pierre or Niobrara?	Boyne beds - 140 ft.		
	Morden beds - 200 ft.		
Niobrara or Benton	Assiniboine beds - 70 ft.	Assiniboine beds 70 ft.	Favel formation
Benton	Keld beds - 90 ft.	Keld beds - 60-65 ft.	
	Ashville beds - 100-150 ft. (unexposed)	Ashville beds - 170 ft.	Ashville formation (Lower (?) and Upper Cretaceous)
	Basal beds - 90 ft. (unexposed)	Basal beds - 19-90 ft.	Lower Cretaceous (?)

Lower Cretaceous (?), Ashville and Favel Formations

Because these three formations are not known to be mangani-ferous and hence do not feature in the following discussion, they are grouped together and will be given only passing comment.

The Lower Cretaceous (?) beds, or the basal beds tentatively correlated with the Dakota by Kirk, consist largely of sand and sandstone, but include beds of more or less sandy clay and shale. Lignite occurs commonly in these beds, but only as disseminated fragments or thin lenses.

The rock of the Ashville formation is generally a dark grey, or almost black, shale, which is carbonaceous and essentially non-calcareous. Pyrite is present, while secondary growths of selenite crystals, and incrustations of yellow melanterite are abundant on lamination planes and joint fissures. Calcareous concretions and thin limestone beds occur locally in the shale.

The Favel formation includes the Keld and Assiniboine beds of Kirk's classification. The beds consist for the most part of calcareous, somewhat carbonaceous shale, mainly dark grey in colour. Bentonite occurs in the lower part of the section. Limestone beds, 6 feet or less in thickness, are common, particularly in the upper part of the section.

Vermilion River Formation

The Vermilion River shales are dark grey in colour and, typically, non-calcareous. As described by Kirk, they are tenacious and well jointed where washed clean by streams, but on exposed banks they weather into thin flakes which form an abundant talus and assume, when dry, a dull, silvery grey colour with a slightly pinkish cast. Pyrite is present and secondary development of selenite is strong. White bands of bentonitic clay up to 4 inches in thickness are numerous. These shales are indistinguishable lithologically from the Ashville shales.

Bands of calcareous shale from 1 foot to 2 feet in thickness are found in a 12-foot zone near the centre of the Vermilion River section. These shales are dark and more or less carbonaceous, but weather to a light grey colour with white specks showing on the lamination planes. They resemble the calcareous shales of the Favel formation.

Riding Mountain Formation

"The Riding Mountain beds differ rather markedly in appearance and properties from the Vermilion River beds. They consist of a rather light grey to greenish grey, non-calcareous shale in which nodules and irregular bands of ironstone are abundant. The shale is hard when dry and shows lamination, but is not markedly fissile. In this condition it tends to break into small, equidimensional particles, quite distinct from the thin flakes of the dark Vermilion River beds. It slakes readily in water and passes directly to a very tenacious and plastic clay. As a result of this property, exposed surfaces of the shale are almost invariably covered by clay from its disintegration. When dried the clay surface becomes hard and strongly mud-cracked. The plasticity of the material causes numerous clay slides where the Riding Mountain beds occur on the steeper slopes of the Manitoba hills. By its slumping over the Vermilion River beds the top of these beds has in some places been completely covered. Another feature of the Riding Mountain beds is the presence of a certain amount of fine sand, disseminated through the shale or clay. The amount varies in different places, but in some of the beds is sufficient to give to the rock, in its dry state, a slightly gritty feel.

"Although good sections of the Riding Mountain beds are somewhat rare, the presence of the group can generally be recognized by the distinctive topography and the character of the soil in areas which it immediately underlies. On it are developed rounded hills or buttes whose sides are generally almost bare of vegetation. Around these buttes dark brown, weathered fragments of ironstone are scattered on the surface of the ground, and, in dry weather, the latter assumes a hard, mud-cracked condition."[1]

Odanah Formation

"The Odanah shale is a relatively hard, brittle rock and is often referred to in the Province as "slate". Analyses have shown it to be highly siliceous. When moist the shale is of a dark greenish grey colour, but on drying turns to a light steel or slightly greenish grey and resembles parts of the underlying Riding Mountain beds. Unlike the latter, however, it does not disintegrate in water as can be seen by its abundance as gravel in many of the streams of the Manitoba escarpment. In parts the rock is fissile, but more commonly it is rather compact and breaks into sharp-edged splinters and slabs with a tendency to sub-conchoidal fracture. In natural and artificial cuts it is capable of holding steep or vertical faces, and it is everywhere traversed by numerous joints whose surfaces show black or reddish

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1. Kirk, S.R.. op. cit., pp. 124-5.

brown staining by iron oxide. Ironstone nodules occur in bands in the shale and in some exposures compact, ellipsoidal, grey limestone concretions are found. Thin beds of yellow, bentonitic clay varying up to 4 inches in thickness have been observed in the shale at many localities."[1]

Odanah shale constitutes the predominating bedrock seen in the southwestern part of Manitoba. Exposures are also numerous at and near the top of Riding mountain, but no beds definitely referable to the Odanah formation have been seen on Duck or Porcupine mountain, and the tops of the latter hills are underlain by shales of the Riding Mountain formation.

STRUCTURE OF THE MANITOBA CRETACEOUS

The Cretaceous beds of Manitoba are flat-lying and undisturbed except where superficially distorted by slumping or ice-shove. Kirk computes the strike of the beds to be between north 42 degrees west and north 48 degrees west, and the dip, towards the southwest, to be 8.6 to 9.3 feet a mile. He adds. "Based, as these figures are, on a single western location, they cannot be regarded as entirely satisfactory, but until further data are obtained they may be taken as a general indication of the attitude of the Cretaceous beds."[2]

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1. Kirk, S.R.: op. cit., p. 123.
2. Kirk, S.R.: op. cit., p. 132.

OCCURRENCE OF MANGANESE

The known manganese occurrences in Manitoba are of two distinct types: nodular deposits in shale, of Cretaceous age, and bog deposits of secondary origin and post-Glacial age.

Nodular Deposits

With few and minor exceptions, the occurrence of manganiferous nodules in the Cretaceous shales of Manitoba is confined to the upper part of the Vermilion River formation and to the Riding Mountain and Odanah formations. No information is available at present as to the manganese content of the ironstone nodules occurring in shales of the Vermilion River formation; the percentage of manganese, however, is presumably very low. Analyses of ironstone nodules found in Odanah shale on Riding Mountain show manganese content varying between 3 and 4 per cent. This grade is too low for the nodules to be regarded as a possible ore of manganese in themselves; the nodules are, however, the source of manganese which has been redeposited by springs to form small bog deposits in the area.

Ironstone nodules of considerably higher manganese content occur at one or more horizons in shale of the Riding Mountain formation. So far, the known occurrences of this type are confined to the Porcupine Mountain area.

The nodular deposits of Porcupine Mountain area have an interesting similarity in stratigraphical position, lithology and manganese content to those of the lower Missouri valley in South Dakota.

In the latter area manganiferous nodules occur in the Oacoma zone of the Sully shale member which is a subdivision of the South Dakota Pierre. The Pierre in Manitoba includes the upper part of the Vermilion River formation, the Riding Mountain formation and the Odanah formation. The stratigraphical position of the known manganiferous horizon or horizons in the Riding Mountain formation is, further, similar to the position of the Oacoma zone in the Pierre of South Dakota.

The lithology of the Oacoma zone is described in part as follows.

"The zone consists of gray shale, and is characterized by the presence of abundant black iron-manganese carbonate concretions and numerous thin bentonite beds.

"In the Chamberlain area, this zone forms the most conspicuous part of the Pierre outcrop. The shale weathers to gumbo which is less favorable to vegetation than the adjacent beds. As the outcrops are eroded, the iron-manganese concretions weather out into relief, and accumulate on the surface so that exposures appear nearly covered with the black fragments."[1]

This description might almost be applied to the Riding Mountain shale beds which have been described in somewhat greater detail earlier in this report. It might be mentioned that, although bentonite is not generally abundant in the Riding Mountain formation, it does

1. Gries, J.P., and Rothrock, E.P.: op. cit., p. 19.

occur in thin beds in the horizon or horizons which contain the greatest concentration of iron-manganese concretions. The slaking property of the shale is a marked feature of similarity in the occurrences at the two localities.

Ten measured sections of the Oacoma zone of South Dakota indicate that approximately 10 per cent of the volume of the deposits is composed of nodules. Preliminary tests made on two nodule occurrences in Porcupine Mountain area suggest that a similar proportion of nodules to shale may be expected in these deposits.

Analyses of a large number of nodule samples taken from the South Dakota deposits are reported to show average manganese contents ranging from 13 to 21.3 per cent. These values are averages of the manganese content of the nodules across the whole thickness of the deposit at different locations. To date, no exhaustive sampling of the Porcupine Mountain occurrences has been attempted. Analyses of preliminary samples of nodules have, however, given results ranging from 10.03 to 18.42 per cent of metallic manganese. The grade, therefore, is comparable with that of the South Dakota deposits, though probably somewhat lower.

One of the most important steps in the exploration of low-grade deposits of this nature is the delimiting of areas in which the manganiferous beds outcrop or in which covering by shale or drift is at a minimum. The South Dakota deposits outcrop along both sides of the valleys of Missouri river and its tributaries. Where the bluffs are steep, the outcrop areas are narrow, but in places where erosion has stripped the cover or where the surface gradient is gentle wide outcrops are available. Gries and Rothrock[1] make the following statement in this regard:

The outcrop of this zone can be followed along both bluffs of the Missouri and up its tributaries for a distance of several miles. It is known to underlie the uplands on both sides of the Missouri valley, also, at a depth of about two hundred feet. Judging from the location of the outcrops it is fairly safe to assume that it underlies about one-eighth of the area of the state. For the purposes of this report, however, only that part of the zone which outcrops is being considered, as it is the only part which can be profitably exploited under present conditions."

In Porcupine Mountain area and, indeed, in most parts of the Manitoba escarpment the underlying shales are covered by extensive deposits of variable thickness of soil and glacial drift. For this reason outcrops of shale are few and occur where small streams descend the escarpment and cut through the recent surface deposits or where landslides expose the shale on the steeper slopes. It is, therefore, not surprising that outcrops of manganiferous beds are scarce. Preliminary exploration should, accordingly, consist of test pitting or similar operations, supplemented by levelling, in an attempt to outline areas in which the cover above the manganese horizon is at a minimum.

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1. Gries, J.P. and Rothrock, E.P.: op. cit., p. 57.

Manganiferous beds that may have been displaced by landslide or ice-shove should not be considered in any estimation of tonnage, since such beds can be followed only a short distance before they terminate abruptly against non-manganiferous shale.

Figure 2 illustrates in a generalized way the mode of occurrence of manganiferous beds in Porcupine Mountain area. The effect of landslides on surface outcrops of such beds is depicted in figure 3.

Origin of the nodules

The following conclusion regarding the origin of nodules in the Oacoma zone of South Dakota is quoted by Gries and Rothrock[1]:

"Many geologic problems arise in the study of such concretion zones, but it will be sufficient to state here that the concretions appear to have developed in the sediments of a shallow sea shortly after burial. They are not related to processes of recent weathering that have produced the present surface but without doubt persist under the upland plains many miles east and west beyond the outcrop along the Missouri valley."

The striking similarity of the Porcupine Mountain deposits to those of South Dakota would suggest a similar origin. One feature of difference is the presence at one of the Porcupine Mountain occurrences of manganiferous nodules in the glacial clay immediately overlying the nodule-bearing shale. These are not nodules or fragments of nodules

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1. Gries, J.P. and Rothrock, E.P.: op. cit., p. 20.

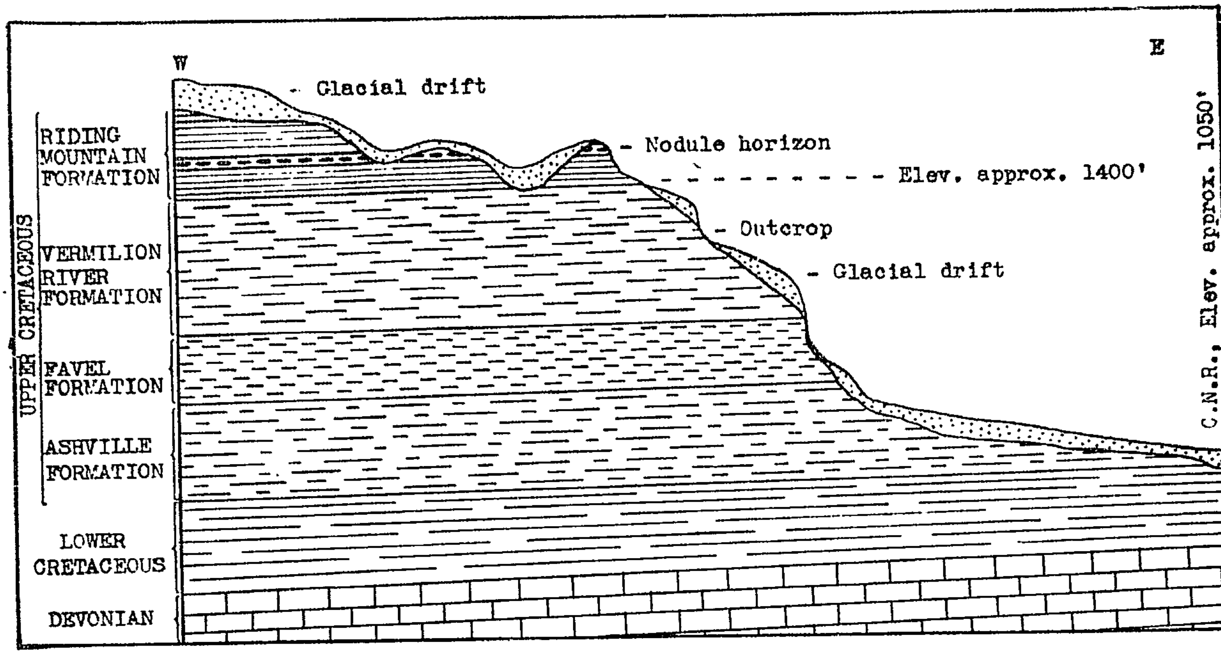

Figure 2. Generalized geological section through Porcupine Mountain showing probable mode of occurrence of manganiferous nodules. Vertical scale - 1 inch to 200 feet; horizontal scale - 1 inch to 1 mile.

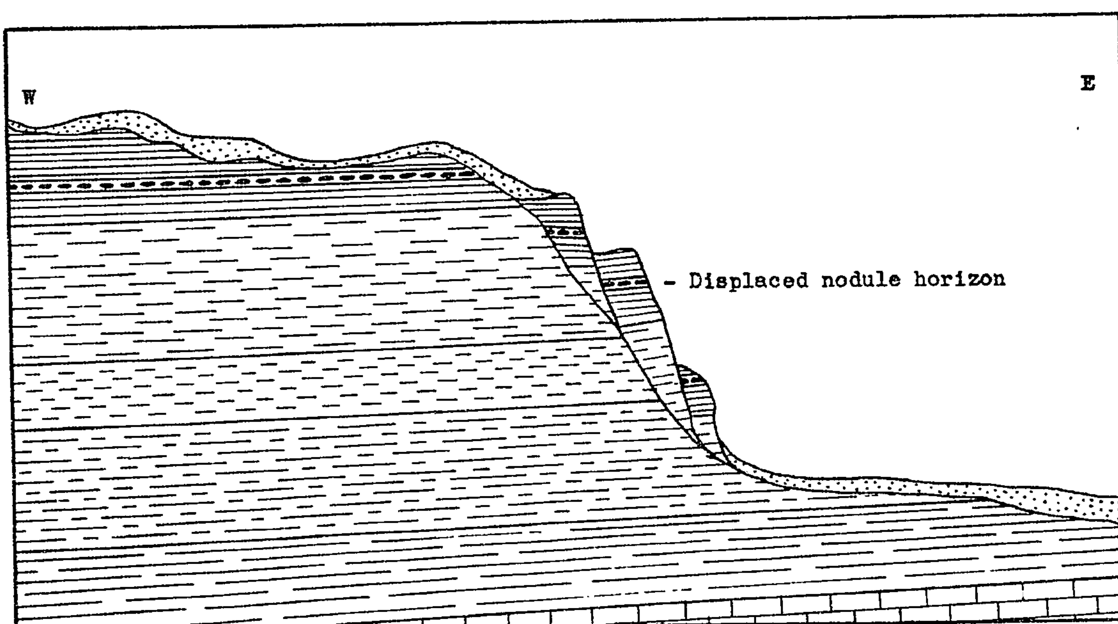

Figure 3. Section illustrating displacement of beds by landslides. Scale same as in figure 2.

derived from erosion of the shale beds, since they are small and spherical or cylindrical in shape as contrasted with the larger disc-shaped concretions found in the shale. Their apparent composition is, however, similar. These well-formed nodules occurring in the glacial clay are presumably of post-Glacial age. Their significance as regards the origin of nodules in the underlying shale requires further investigation before it can be properly evaluated. A suggestion is therefore made that the post-Glacial concretions have developed within the clay by the accretion of manganiferous material finely disseminated through till derived from the glacial erosion of beds which themselves had been manganiferous. In the meantime, exploration appears justified on the assumption that the nodule-bearing shale beds persist as a definite horizon or horizons over the Porcupine Mountain area.

Character of the nodules

The nodules of the South Dakota deposits, when fresh, are light grey or olive green in colour. They weather readily, however, through yellow and brown to a black or purplish colour. Those found in place, to date, in the Porcupine Mountain deposits are all of the black, oxidized variety. Some have in part a distinctly metallic appearance. Numerous light grey to brown, commonly septarian concretions have been found in the surface clay or scattered on the ground in the Porcupine Mountain area. The horizons from which they are derived, and their manganese content, are not known. Kirk mentions concretions of this type as commonly occurring throughout the Riding Mountain formation. Concentrations of light coloured nodules should, therefore, be tested wherever they are found in place in the Riding Mountain beds, since their manganese content may be equally as high as that of the black, oxidized variety.

The mineralogy of the nodules has not been determined. They apparently consist of mixed carbonates of calcium, magnesium, iron and manganese along with clayey, aluminous material and silica. On oxidation, variable amounts of iron and manganese oxides are probably developed.

Bog Deposits

Bog manganese has been found occurring as small deposits near Roseisle, Manitoba, in Riding Mountain area and, in traces, in Porcupine Mountain area. The manganese is derived by the leaching of manganiferous nodules in shale by ground water and is deposited in the form of manganese dioxide by springs issuing near the bases of hills. Soft surface material of this kind is readily removed or dissipated by glaciation, accordingly, the known deposits have all been formed since the retreat of the continental ice-sheet and, as a result, are extremely small. The largest known deposit has a surface area of approximately 1,000 square feet and a maximum thickness of 42 inches. The better grade material contains from 25 per cent to 50 per cent manganese. The principal impurities in the deposits are shale fragments, travertine, iron oxide and organic material.

DESCRIPTION OF DEPOSITS

Porcupine Mountain Area

Four groups of mining claims have been staked on exposures of manganiferous shale in Porcupine Mountain area. Two of these, known as the Wolf group and the Mafeking group, located to the west of the town of Mafeking, have not been examined by officers of the Manitoba Mines Branch. They lie within a large area in which the stratigraphical boundaries cannot be determined on account of the prevalence of landslides, and it is therefore possible that the manganiferous shale beds exposed do not represent material in place.

The two other groups of mining claims are known as the Victory group and the Birch River group and are controlled by Mr. F.L. Nelson of Mafeking, Manitoba.

Victory group

The four mining claims constituting the Victory group are located approximately 6 miles north-northwest of the town of Birch River and are traversed by Fishtown creek. The principal occurrence is an east-facing cut bank of the creek. The bank exposes shale of Riding Mountain age for an average height of approximately 30 feet and a length of 70 feet. The shale beds have been closely folded and crumpled by ice-shove, and at the south end of the exposure have been thrust from the north so that they locally rest on typical glacial material consisting of gravel and large boulders. The shale has the light grey colour and slaking properties typical of the Riding Mountain beds and contains a number of bentonite beds up to 4 inches in thickness. The upper 4 feet of the shale bank has coatings of yellowish green melanterite and contains clusters of tiny gypsum crystals. Disc-shaped iron-manganese concretions occur along bedding planes in the shale; some of these are as thick as 2 inches and extend for several feet along the bedding planes. The nodules are completely oxidized to a black colour and frequently have a metallic appearance. More than 10 per cent of the material of the beds is probably made up of nodules. Analyses of a limited number of nodule samples show manganese content ranging from 12.45 per cent to 18.42 per cent, and iron content from 9.0 per cent to 10.0 per cent.

Approximately 200 feet to the west of the shale exposure, and at an elevation estimated to be 10 feet above the top of the shale bank, a pit has been sunk to a depth of 12 feet in glacial boulder clay. Between the 4-foot horizon and the bottom, the clay contains small spherical or cylindrical nodules. Apart from their different shape, these nodules are identical in appearance and, reportedly, similar in composition to those found in the shale. To the west of the pit the surface slopes down steeply to an elevation slightly above creek level.

Birch River group

The Birch River group consists of five mining claims located on the north side of Birch river, 4 miles to the west of the town of Birch River.

The principal manganese occurrence is on a high ridge to the north of Birch river. here a land-slip exposes a 12-foot thickness of shale, which appears to be in place, for an explored length of approximately 600 feet. The shale is flat-lying but in other respects is similar to that exposed on the Victory group of mining claims. The iron-manganese nodules are distinctly smaller than those occurring at the other locality but are similar in shape and relative concentration. The proportion of nodules to shale is roughly estimated at 10 per cent. Preliminary samples of nodules indicate a manganese content slightly in excess of 10 per cent.

The shale is covered by 2 to 12 feet of overburden which consists of buff-coloured boulder clay. In the clay and 6 inches to 2 feet above the shale is a band of salmon coloured clay 6 to 16 inches in thickness. Samples of this clay have been reported to contain over 10 per cent of manganese. This could not be checked, however, by a sample taken by the Manitoba Mines Branch, which sample showed only traces of manganese on analysis.

Riding Mountain Area

Bog manganese deposits in Riding Mountain area have been described, in greater detail than in this report, in an article by

Spector[1], who examined them for the Manitoba Mines Branch during the summer of 1940. The known deposits are located near Mears on the southern flank of Riding Mountain, towards its west end. The largest known deposit is located in section 35, township 21, range 24 west of principal meridian. This deposit appears to contain approximately 100 tons of manganese ore of possible chemical grade.

Six smaller occurrences of a similar nature, but varying somewhat in grade, are found in the same area which lies in the valley of Birdtail river between Mears and a point 7 miles to the north.

Roseisle Deposit

This deposit was described by Wallace[2] in 1927 as follows:

"Four miles northwest of Roseisle, on the northeast quarter of Section 36, Tp. 6, Rge. 8 W., an occurrence of manganese has been discovered recently. It has been apparently deposited by springs issuing from the Pembina Hills in the form of hydrous oxides, probably manganite and psilomelane or wad. The manganese is found in the low swampy land at the base of the escarpment, partly overlain by one or two feet of soil and partly on the surface. Considerable proportions of limonite invariably accompany it. Insufficient work has been done to determine the economic possibilities of the deposit. An analysis of the best material showed:

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1. Spector, I.H.; "Manganese Deposits in the Riding Mountain Area, Manitoba", The Pre-Cambrian, July, 1941 (reprints available).
2. Wallace, R C.; "The Mineral Resources of Manitoba", Ind. Dev. Board of Manitoba, 1927, p. 37.

Mn - - - - - - - - - - - 26.96

Fe - - - - - - - - - - - 13.11 "

CONCLUSIONS

Of the two types of manganese deposits occurring in the Province the nodular occurrences in shale of Riding Mountain age have the more important economic possibilities. Their low grade is partly offset by the possibility of extensive deposits being found, and their importance depends on two principal factors:

1. The feasibility of outlining by exploration extensive areas underlain by nodule-bearing beds and covered by a minimum thickness of overburden (or possibly shale). The covering must be thin since, to be profitably exploited, such low-grade material must be readily and cheaply mined by large-scale methods.

2. The development of an economic process to concentrate the nodules and to beneficiate them to ferro- or other marketable grades. Specifications for ferro-grade ore call for a minimum of 48 per cent manganese and a maximum allowance of: iron, 7 per cent, silica, 8 per cent; phosphorus, 0.15 per cent; alumina, 6 per cent; zinc, 1 per cent, and low in copper, lead and barium. The ore should be in lump, sinter or briquette form. The nodules of Porcupine Mountain area are obviously much too low in manganese and too high in iron and other impurities to be marketable. The nodules of the South Dakota deposits which are apparently similar, both chemically and physically, to those occurring

at Porcupine mountain have been subjected to laboratory tests and several methods of beneficiation have been tried out with a certain degree of success. A pilot plant is now under construction at Chamberlain, South Dakota for the purpose of experimental commercial-scale production.

Gries and Rothrock[1], in the conclusion to their report, state that a very extensive deposit of low-grade manganese ore has been shown to exist in the lower Missouri valley in South Dakota; that, in spite of the low grade, and with expert mining and beneficiation along with good business management, the deposit could be made to produce manganese on a large scale. This conclusion is of interest with regard to the Manitoba occurrences in view of the similarity between the deposits at the two localities. Even assuming the as yet unproven large extent of the Manitoba occurrences, an equally attractive picture cannot justifiably be painted for their future. The Manitoba "ores" are lower in grade and mining and transportation costs would no doubt be higher than at the South Dakota locality. Nevertheless further investigation of the deposits is justified in order to determine their commercial possibilities which cannot be properly evaluated at the present time.

It would appear that the successful production of manganese from the manganiferous shale horizons in Manitoba would depend, among others, on the following conditions:

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1. Gries, J.P. and Rothrock, E.P., op. cit., p. 96.

(1) The blocking out of a grade of ore comparable or superior to the Chamberlain type of material.

(2) The obtaining of transportation and power facilities equally as favorable as those existing in the case of the South Dakota deposits.

(3) The delimiting of areas for mining operation where the amount of surface cover above the manganese zone would not be prohibitive, and

(4) The perfecting of a process of extraction capable of offering a reasonable degree of assurance of economic success.