# THE CAMBRIAN MANGANESE DEPOSITS OF SOUTHEASTERN NEWFOUNDLAND

by

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## Introduction

### Scope and basis of the report

During the 1951 field season a study was made of the Cambrian manganese deposits of southeastern Newfoundland in order to provide information on their thickness, distribution, grade, availability and estimated tonnage. This work was done under the supervision of R.D. Hutchinson of the Geological Survey of Canada.

### Historical Note

A.O. Hayes and G. vanIngen in 1911 recorded manganiferous rocks of supposedly Lower Cambrian age exposed at Manuels, Topsail, Brigus and other places while making a study of the general geology, stratigraphy and paleontology of the shores of Conception Bay in connection with the investigation of the iron ores of Great Bell Island. Undoubtedly these deposits had been investigated previously because N.C. Dale in 1912 reported the presence of old test pits at Brigus.

In 1910 a fee sample grant was recorded in the name of "Newfoundland Manganese Iron Ore Mines Ltd.", for a portion of the Kelligrews deposit. Extensive stripping was done on the property, an 80 foot drift was driven and the ore removed to a dump. Several test pits were sunk. An open cut and a prospect adit at Topsail were photographed by Dale in 1912.

N.C. Dale in 1913-14, carried out a mineralogical survey of the manganese deposits around Conception and Trinity bays.

In 1942 bulk samples from Manuels were collected by R. Wiseman of the Newfoundland Geological Survey. Mill tests on these samples were run by the Ore Dressing and Metallurgical Laboratories, Ottawa.

## Location and Accessibility

The known manganese deposits are located at Manuels, Topsail, Long Pond, Kelligrews, Chapel Cove and Brigus South Head on Conception Bay, at Normans Cove and Smith Point on Trinity Bay, and at Burin Bay Arm and near Ships Cove on Placentia Bay.

The exposures at Topsail, Manuels and Long Pond are ideally located, and are easily accessible by sea, road and railway. The Kelligrews deposit is situated alongside a secondary road and is only a few miles removed from the sea and railway. The above locations are outcrops of one large deposit, 4 miles long and 1,000 feet wide. At Chapel Cove and Brigus South Head the beds are exposed in the cliffs along the sea coast and are not far distant from secondary roads. However, the terrain at Brigus South Head would make road building expensive. The exposures at Smith Point, Ships Cove and Burin Bay Arm are accessible by sea and secondary roads. These localities are shown on the accompanying map.

## Acknowledgments

The writer is indebted to R.D. Hutchinson for information regarding the stratigraphy and paleontology of the region and to R.A. Bell who made X-ray and polished section studies of the various minerals associated with the manganese deposits.

## Geology

### General Summary

B.F. Howell, in his 1925 report gave a general summary of the geology of the area around Conception Bay; portions of it are quoted as follows:

"The (Avalon) peninsula is composed of a complex of Precambrian igneous and sedimentary rocks, with scattered remnants of a once widespread blanket of sediments of Cambrian, Lower Ordovician (and perhaps also Ozarkian) age clinging to it in the places where they have been protected from erosion. The Precambrian rocks include interbedded rhyolite and basalt flows, with corresponding breccias and tuffs, and volcanic dust beds, shales, sandstones, and conglomerates (the Harbour Main volcanics, total thickness unknown); thin bedded greenish-grey, dense slates, feldspathic sandstones, and conglomerates (named by Dr. Walcott the Conception slates; estimated to be about 3,000 feet thick); green and reddish slates (Dr. Walcotts "Torbay slates"; estimated thickness, 3,300 feet); dark brown and blackish slates (Dr. Walcott's "Momable slates"; estimated thickness 2,000 feet); reddish brown and green feldspathic sandstones and conglomerates, with intercalated shale beds (the "Signal Hill sandstones" of Jukes; estimated by Dr. Buddington to reach a thickness of 10,000 feet); reddish, greenish, and white sandstones and quartzites (Dr. Walcott's "Random terrane"; supposed to be 1,000 feet thick); and intrusives of gabbro, granodiorite, granite, granophyre, quartz syenite, aplite, rhyolite porphyry, and diabase. It is probable that the Harbour Main volcanics are the oldest members of this group; and that they are succeeded in age from oldest to youngest by the Conception, Torbay, and Momable slates, and the Signal Hill and Random sandstones; although the Conception slates may be in part contemporaneous with the Harbour Main volcanics. The Conception, Torbay, Momable, Signal Hill, and Random shales, sandstones, and conglomerates have been grouped together by Dr. Walcott in the "avalon series" (Walcott 1899, pp. 218-220; 19006). This sedimentary series has been referred by Dr. Walcott to the Algonkian, and Dr. Buddington has stated that the volcanic and intrusive igneous rocks were also possibly formed during that era.

Dr. Buddington has interpreted the beds of the Signal Hill formation as "dominantly subaerial fluviatile deposits," formed "in a subaerial climate"; those of the Momable as "well-decomposed marine sediments with traces of organic life"; and those of the Conception, as deposits composed of "materials derived from rocks resembling the Harbour Main volcanics, swept into the sea in a comparatively fresh, unaltered condition".

The Cambrian and overlying Ordovician (and perhaps Ozarkian) beds are shales and sandstones, with a few limestones and limy shales in the Cambrian. They probably aggregate some 10,000 feet in thickness (vanIngen, 1914a) and are not known to be divided by any angular unconformities. They are cut by dykes of basalt at some localities. The pre-Paradoxides beds of the Cambrian are conglomerates and sandstones, red and greenish shales (often with many nodules of impure limestone), and thin reddish and greyish limestones; some of them are manganiferous. They include the "Etcheminian" and "Hanfordian" series of Professor vanIngen's 1914 table. So far as the author is aware, these "Etcheminian" and "Hanfordian" sediments are the only ones of Paleozoic age that are known to have been laid down directly upon Precambrian rocks in the region about Manuels. Wherever the contacts between these Cambrian and Precambrian rocks are known, they appear to be either unconformities or disconformities. The Paradoxides beds (Professor vanIngen's Manuels series) are grey, brown, and black shales, with thin beds of limestone and limy nodular shale. The beds that overlie the Paradoxides beds along the southeastern shore of Conception Bay, most or all of which belong in Professor vanIngen's Elliot Cove series, are"grey and black shales with cone-in-cone concretions and thin-bedded sandstones" (vanIngen, 1914b). Some of these beds are of

Upper Cambrian age and some may be Ozarkian or earliest Ordovician. The three islands that lie out in the middle of Conception Bay (Bell, Little Bell, and Kellys islands) are composed of beds which have been referred to the Lower Ordovician - the Bell Island and Wabana series of Professor vanIngen's 1914 classification. They are light and dark coloured shales and sandstones, with several beds of primary hematitic iron ore. Beds probably referable to Professor vanIngen's Clarenville series, which belongs stratigraphically between the Elliot Cove and Bell Island series, presumably underlie Conception Bay between the islands and the mainland. No angular unconformity is known to exist anywhere within this great stratigraphic section.

The main structural features of the Avalon Peninsula are a series of folds, and faults, whose axes lie in a general NNE-SSW direction. The Precambrian rocks were folded before the deposition of the Lower Cambrian sediments upon them. Later the Precambrian, Cambrian, and Ordovician rocks were folded, faulted and tilted. The masses of Cambrian and Ordovician sediments that were folded or faulted by these movements into situations where they were protected from erosion are the ones that have been preserved until the present day. One of these favored masses underlies much of Conception Bay in such a way that a few small patches along the western and southern sides of the bay and a narrow strip along the eastern shore are the only parts of the mass that project above sea level. It is in the narrow strip along the eastern shore that the exposures at Manuels are situated."

Table of Formations (Murray's succession)

| ERA | PERIOD | ROCK SERIES | THICKNESS | CHARACTER |
|---|---|---|---|---|
| Cenozoic | Quaternary | Pleistocene (Glacial) | 0-50'± | Boulder clay, sand boulders |
| | Tertiary (Absent) | | | Absent - Represented by erosion & Tertiary earth movements |
| Mesozoic | (Absent) | | | Absent - Represented by erosion & Mesozoic earth movements. |
| Paleozoic | Ordovician | Wabana and overlying strata | 3000'± | Pyrite beds, Scotia (Middle) & Upper beds of Iron Ore, Shale&sandstone. |
| | | Bell Island and underlying strata | 6000'± | Shale and Sandstone Dominion (Lower) bed at top. |
| | Cambrian | Upper Cambrian<br>Middle Cambrian<br>Lower Cambrian | 1000'± | Sandstones, shales, limestones and conglomerate. |
| Precambrian | Keweenawan and older | Avalonian Series<br>Blackhead<br>Signal Hill<br>St. John's Slates<br>(Named also Momable slates) | 15,000'± | Dark grey sandstone and slates. Red conglomerate and sandstone. Greyish red sandstone, grey fine grained quartzite sandstones |
| | | Torbay | | Dark greenish grey quartzitic sandstones and slates. Green and reddish brown and dark grey slates |
| | | ~Unconformity ~~~~ | | |
| | | Conception Slates | 10,000'± | Flint-like sediments. Dark grey sandstones. Grey purple sediments composed partly of volcanic ashes and coarse fragmental rocks at base. |
| | | Avondale volcanics (Harbour Main) | ? | Complex of green schists with basalt and rhyolite lava flows, and volcanic breccia with basalt and granitic intrusions. Volcanic breccia may be the same as at the base of conception slates |

Howell's Paleozoic Classification

| | | | |
|---|---|---|---|
| Lower Ordovician | All the early Paleozoic beds that are known to occur above the Elliot Cove beds about conception and Trinity bays. *Bryograptus* occurs in lower beds. | | |
| Possibly Ozarkian | Beds with *Orusia lenticularis* and other fossils | | |
| CAMBRIAN IN THE RESTRICTED SENSE IN WHICH THAT TERM IS USED IN AMERICA TO-DAY. | Upper Cambrian in a restricted sense. | Unnamed beds. | *Agnostus pisiformis* obesus, *Olenus* and other Fossils |
| | | Unnamed beds. | *Agnostus pisiformis*. |
| | Age unknown | Unnamed beds. | Small Fauna of unidentified forms. Possibly a *Paradoxides Farchhammeri* Fauna. |
| | "Newfoundland" beds of all parts of southeastern Newfoundland. Represented about Conception Bay by the "Manuels" Paradoxides beds. | Kelligrews Brook Formation. *Paradoxides davidis* zone | Beds 93-125 of Howell |
| | | Long Pond Formation. *Paradoxides hicksi* zone | Beds 36-92 of Howell |
| | | Chamberlins Brook Formation *Paradoxides bennetti* zone | Beds 1-35 Howell |
| | Age Unknown | Unnamed Formation | Manganiferous beds |
| | Exact age Unknown | Unnamed beds (catadoxides zone) | Beds with *Catadoxides magnificus* and other fossils |
| | Exact age Unknown | Protolenus zone | Beds with *Protolenus* and other Fossils |
| | Lower Cambrian in a restricted sense | Callavia zone, and possibly pre-Callavia beds. | Beds with *Callavia broggeri* and other fossils. Some of the beds of this division may be of pre-Callavian age; they appear to contain no trilobites but hold a "*coleoloides*". |

## Manganese Deposits

### General Summary

Proof of the sedimentary origin of the manganese deposits is their occurrence at the same stratigraphic horizon, the base of the Middle Cambrian, at widely separated points on Conception, Trinity and Placentia bays. At each deposit the manganese was found to occur in the base of the Paradoxides bennetti zone (R.D. Hutchinson, 1951), usually in green or red shales. At Manuels it is 13.7 feet; at Kelligrews it is about the same; at Topsail 2.5 feet; at Long Pond 15 feet; at Chapel Cove 3-5 feet; at Brigus 15 feet; at Smith Point 3-5 feet and at Burin Bay Arm the manganese zone is represented by a thin bed of nodules. The manganese is contained in thin jasper - like green and brown bands, in nodular beds, and in argillaceous and calcareous beds.

In 1942, J.D. Bateman, Bureau of Geology and Topography, Ottawa, reported as follows on thin sections and polished sections prepared from the deposits at Manuels: "Examinations of one section of material from each of the four samples submitted by the Bureau of Mines failed to disclose any pertinent information on the mineral association. This is because it was not possible to resolve the minerals under the microscope owing to the extreme fineness of grain of most of the material. The samples were then investigated by microchemical methods and staining procedure, and the information gained in this way is correlated with the geological and chemical work of Dale. The results of this investigation indicate that most of the manganese occurs as a carbonate associated with a complex carbonate group in red and green argillaceous carbonate rocks. The manganiferous carbonates are finely disseminated throughout the rocks and are also concentrated in (a) carbonate nodules, (b) pale green

cherty lenticules and (c) red iron oxide laminae. These manganese-rich structures are not easily amenable to mechanical methods of concentration, but most of the manganese content of the specimens is soluble in acids without difficulty."

N.C. Dale gave a summary of the genesis of the manganese in his 1915 report. His opinions are as follows:

"Ultimate source of the manganese was the manganese-bearing silicates of Precambrian igneous and metamorphic rocks east and west of the Cambrian Sea.

Solution of manganese-bearing silicates and conversion of the manganese into soluble bicarbonate; under favorable conditions oxides of manganese resulted from the oxidation of the bicarbonate of manganese.

Transportation of the manganese chiefly as the bicarbonate and to a less extent as suspended particles of oxides by Precambrian drainage systems to Cambrian basins.

Concentration of the salts of manganese chiefly as the bicarbonate in the sea-water immediately overlying the deposited muds.

Precipitation of manganese carbonate from solution through liberation of $CO_2$ from the bicarbonate,or of the oxide.

Clastic origin of some manganese - While the main contribution of the manganese came from the Precambrian drainage area in solution undoubtedly the deposited muds supplied a minor portion."

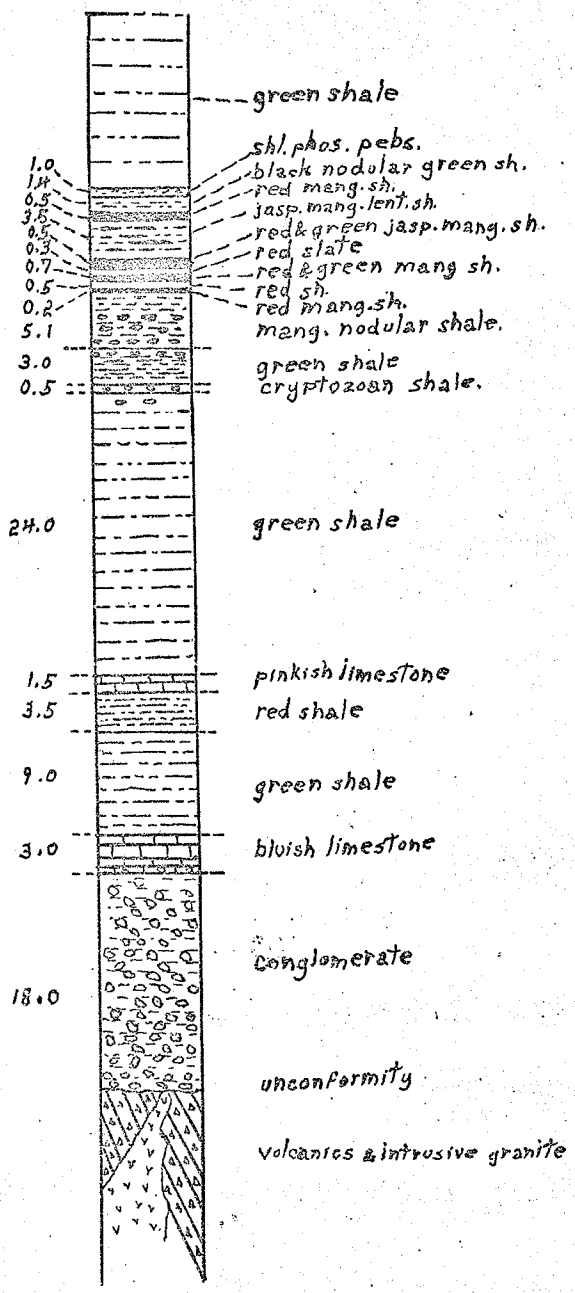
Descriptions of Localities

Manuels.

At Manuels the manganiferous zone is 13.7 feet thick and consists essentially of green and red argillaceous carbonate rocks containing manganese carbonate, and with hematite, barite, and tricalcium phosphate as accessories. Manganese is contained

Figure 2

# Manuels River




Columnar section showing the details of the manganese zone.

After Dale.

in thin jasper-like green and brown bands, in nodular beds, and in argillaceous and calcareous beds that are interbedded with green and red shales of lower Middle Cambrian age. The stratigraphic relations are shown in Fig. 2.

This bedded deposit has been traced from Topsail Head to Duffs, along the east side of Conception Bay. It outcrops along the highway cuts, rivers and brooks and along the shore in some places. The strike of the beds is N 82E and the dip is 10°N, under Conception Bay. The extent of this deposit along the south east shore of Conception Bay is approximately 5 miles by 1000 feet with an average thickness of 5 feet.

Assay reports show values of 10.73% Mn over a 7'8" width, 11.55% over a 5'8" width and 18.50% Mn over a 2' width at Manuels. Topsail.

The manganese at Topsail, 4 miles east of Manuels occurs interbedded in steep northerly dipping (50°to 78°) Cambrian strata consisting of shales limestones and sandstones. The manganese is found in several beds of which only one measuring 1.4 feet in thickness seems to be of sufficient importance to warrent consideration. The manganese carbonate and oxide presents a brown colour and has a vitreous lustre. Although the manganese is part of the same bedded deposit as that at Manuels, the character and structure of the manganese at Topsail differ from that of Manuels and the section shows some lithologic variations.

The rocks of the section are very much disturbed with rapid changes in the dip of the beds. The structural changes in these beds are no doubt due to the great fault, the plane of which passes about 300 feet east from the manganese zone with a strike of N 13°E and a vertical dip. The fault lies between the Precambrian and

Lower Cambrian and the beds immediately adjacent are considerably disturbed and so to a lesser extent are those farther away.

The generalized section as worked out by vanIngen and Hayes in 1912 is as follows:

| | |
|---|---|
| Brown shales with manganese at base | Open cut |
| Brown shales with limestone at base | |
| Heavy limestone | |
| | Ft. |
| Shaly limestone | 6.0 |
| Brown sandstone with limestone nodules | 3.0 |
| Fine and coarse sandstone with small limestone nodules | 6.0 |
| Much sheared brown shale with limestone nodules and manganese at base | 4.0 |
| Mouth of tunnel and rotten zone | .15-0 |
| Coarse sandstone | .6-0 |
| Shear zone | 0.3 to 0.5 |
| Precambrian | 25.0 |

A more detailed study of the manganese zone at the top of the section is given below.

| | Ft. |
|---|---|
| Green shale, badly broken | |
| Banded, concentric and nodular shale | 1.0 |
| Green shale, badly sheared | 0.5 |
| Manganese oxide - carbonate ore | 1.4 |
| Broken nodular green shale with manganese stain | 0.7 |
| Calcareous manganiferous shale | 0.3 |
| Hard nodular olive green shale, badly weathered and sheared, with manganese stain. | |

High grade grab samples from the 1.4' bed of manganese oxide-carbonate ore assayed 35.73% Mn.

Long Pond

Manganese beds are exposed in a low cliff at Long Pond, about 2½ miles southwest of Manuels and west of the railroad. The manganese occurs as nodular and banded layers interbedded with shales. These occurrences are similar to those exposed at Manuels and are part of the same bedded deposit.

Kelligrews

The Cambrian manganese deposit outcrops at Kelligrews about 4 miles west of the Manuels and one mile south of the highway through Kelligrews. The deposit is traversed by a secondary motor road.

This section is almost similar to that at Manuels. Diamond drill results obtained in 1942 show the unoxidized manganese deposits to be very uniform quantitatively. The manganese at depth is reported to be in the carbonate form with only visible traces of $MnO_2$.

Assay reports show values of 7.41% Mn over 11' width, 11.6% Mn over a 9'2" width, 16.1% Mn over a 4'1" width, and 15.31% Mn and 19.78% Mn from grab samples.

Assay reports from 2 diamond drill holes show values of 8.6% Mn over a 9'6" width, 13.7% Mn over a 3' width, and 13.3% over a 3' width.

The high values obtained from the channel samples are undoubtly due to the high degree of oxide concentration of the exposed portions of the deposits.

Chapel Cove

The manganese at Chapel Cove is of inconsiderable amount and occurs in a very much faulted series of limestones and shales. The manganese occurs as 3 narrow nodular bands within a 15 foot thickness in green shale. The beds strike N25$^{o}$E and dip 50$^{o}$E.

Brigus

At Brigus South Head on the west shore of Conception Bay, manganese is found to a great extent in the oxidized state in several beds at the waters edge in the shales at the base of the Middle Cambrian. The Lower and Middle Cambrian shales and limestones make up the sharp hog back ridge overlooking the entrance to the harbour. The beds strike N30°E and dip 45°E into Conception Bay.

The best manganese measures a total of 4'6" in a manganiferous zone of 15'. Surface weathering has altered the manganese carbonate to psilomelane but some specimens still show the original jaspery carbonate quite similar to the types at Manuels. The beds exposed above sea level at Brigus are the erosional remnants of a more widespread manganese deposit and are now separated into two parts, #1 375' x 200' and along strike about 800' #2 which is 300' x 75'.

The generalized section as worked out by vanIngen and Hayes in 1912 is as follows:

| | Ft. |
|---|---|
| Green shales, end of needles | 50.0 |
| Paradoxides zone, green shales | 1.0 |
| Green shales | 75.0 |
| Manganese zone (4.5' best) | 15.0 |
| Red shales, thin band | 3.0 |
| Green shale | 60.0 |
| Red shale | 210.0 |
| Red shaly limestone | 11.6 |
| Red shale | 28.0 |
| Limestone, heavy white at base, nodular and red above, Holmid broggeri and other trilobites | 30.0 |
| Red shale | 5.0 |
| Limestone, very shaly | 12.0 |

| | Ft. |
|---|---|
| Red shale | 32.0 |
| Limestone with Cryptozoon | 30.0 |
| Red shale with local sandstone and conglomerate | 50.0 |
| Unconformity | |
| Precambrian shale and ash beds. | |

Assay reports show values of 32.86% Mn for grab samples of high grade carbonate-oxides, 7.34% Mn over a 5'6" width which included much green shale, and 9.89% Mn over a similar width in exposure #2, Normana Cove, Trinity Bay.

Three narrow bands of nodular manganese carbonate and oxide outcrop along the cliff at Normans Cove. The manganese is of inconsiderable amount but serves to show that the manganese horizon is widespread and continuous wherever Cambrian strata occur in southeastern Newfoundland. Paradoxides bennetti was found in the shale between two manganiferous beds and consequently shows these deposits to be at the base of the Middle Cambrian.

Smith Sound, Trinity Bay

The manganese zone at Broad Cove, Smith Sound is associated with red and green nodular shales and limestones. The bed measures 3'6" and is faulted with a down throw of 15' on the west side. Dale described the bed as a manganiferous, dolomitic, ferruginous shale. The bed is somewhat massive and nodular though the nodules are very irregular as compared with those at Manuels; irregular crystalline areas form the nodular portions while the matrix is made up of more argillaceous matter.

A section of the Cambrian from the dike down to the top of the Smith Point Limestone is given below.

| | Ft. |
|---|---|
| Dike | 3.0 |
| Bright red fissile shale with thin green seams and patches | 97.0 |
| Manganese limestone (manganiferous dolomitic shale) | 3.5 |
| Bright red fissile shale | 78.0 |
| Greyish green fissile shale | 28.0 |
| Bright purplish shale alternating with brighter shale | 97.0 |
| Green gritty shale | 33.0 |
| Grey band of fine grain siliceous limestone full of pyrite and some brachiopods and trilobites | 0.5 |
| Gritty green shale, brachiopods and trilobites | 62.0 |
| Heavy green siliceous conglomeratic manganiferous | 2.5 |
| Purple shale | 10.0 |
| Green shale | 10.0 |
| Red shale | 47.0 |

Smith Point Limestone

Assay reports show a value of 7.98% Mn over the 3.5' bed of manganiferous limestone.

Burin Bay Arm, Placentia Bay

On the west side of Burin Bay Arm, north of the mouth of Salmonier Brook, a bed of pink limestone 3' thick contains pyrite and black phosophatic nodules. Green manganiferous shale overlies the limestone. The manganese occurs as a thin nodular horizon and is of stratigraphic importance only. A manganiferous nodule gave an assay value of 12.79% Mn.

Lawn Harbour, Placentia Bay

West of Lawn Harbour about 2000 feet north of Black Head, two manganiferous zones are interbedded with red and green shales and sandstones. These two zones of green and brown manganiferous shale, siliceous and locally pyritized, are separated by 15 feet of red and green argillaceous sandstone. The upper manganiferous zone is 6 feet thick and the lower manganiferous zone is 20 feet thick.

These and other manganiferous beds on Placentia Bay were not examined during the 1951 field season. However it appears quite evident from descriptions in the literature that the Placentia Bay manganese deposits are quite similar in mineralogic character and stratigraphic position to those in Conception and Trinity bays. The basin into which the manganiferous muds were deposited to form the present manganese beds of the Middle Cambrian undoubtedly extended to or covered Placentia Bay and Trinity Bay.

Sampling and Analysis

Channel and grab samples were collected at the various localities where manganiferous beds were examined and the thicknesses of these beds were measured. In each case the samples were assayed for manganese and carbonate content. These assay results have been compared with and are supplemented by data from Dale's 1915 report and Wiseman's 1942 report. Detailed investigations were confined to the deposits at Conception Bay, namely Manuels, Kelligrews and Brigus, because these showed the best possibilities for economic exploitation.

At Brigus South Head, samples were taken at various distances in from the surface of the rock in order to determine the effect of surface weathering on the mineralogy of the deposit. It is of

economic importance to know whether the manganese occurs predominantly as oxides or as a carbonate beyond the zone of surface weathering.

Samples were taken at: 1. the weathered surface, 2. about a foot in from the surface where the effects of weathering appeared slight and 3. about ½ foot in from an old 5 foot test pit. The following results were obtained:

| | Mn% | $CO_2$% |
|---|---|---|
| 1. | 26.62 | 1.24 |
| 2. | 6.80 | 8.52 |
| 3. | 2.74 | 7.90 |

Although the above figures do not give an accurate measurement of the manganese content of the beds, they do indicate a trend towards an increase in carbonate content away from the weathered surface.

A channel sample was taken across the weathered surface of the best 2 foot manganiferous zone at Manuels. Surface weathering has altered the carbonate to oxide as shown by the assay results.

Manuels. Weathered cross section - 2 feet; 18.50% Mn; $CO_2$%-Nil.

Wiseman's samples across this zone assayed 17.69% Mn and 17.26% Mn.

In further support of the idea that the manganese deposits are richer at the weathered surface due to oxidation of the manganese carbonate, the following evidence has been taken from Wiseman's 1942 report on the Kelligrews deposit.

High-grade grab samples: 1. 35.21% Mn; 2. 43.83% Mn.

Test pit channel samples giving percentages of Mn over various widths:

| | | |
|---|---|---|
| 1. | 110" | 11.0% Mn |
| 2. | 49" | 16.1% Mn |
| 3. | 41" | 17.4% Mn |

Drill-hole samples from the high-grade zone are as follows:

| | | |
|---|---|---|
| D.D. Hole No. 2 | 1. 9.5' | 8.6% Mn |
| | 2. 3.0' | 13.7% Mn |
| D.D. Hole No. 3 | 1. 11.0' | 7.41% Mn |
| | 2. 3.0' | 13.33% Mn |

Wiseman states: "The high values obtained from the grab samples and channel samples from test pit No. 1 are undoubtedly due to the high degree of oxide concentration of the exposed portions of the deposits.

The result of Diamond Drill Holes Nos. 2 and 3 show the unoxidized ore to be very uniform quantitatively ---------- The manganese at this depth is in the carbonate form with only visible traces of $MnO_2$. This carbonate occurrence would tend to make flotation concentration more difficult if the gangue is comprised of limestone."

Wiseman chip sampled 15'8" across the different bands in the manganiferous zone at Manuels. The assay results show the Mn% in each lithologic unit, and may be used as a general guide for the large deposit on the south-east shore of Conception Bay. However, the fact must be kept in mind that these samples were taken in the zone of surface weathering.

| Sample No. | Width in Inches | Assay, Mn% | Remarks |
|---|---|---|---|
| 1. | 22" | 3.6 | Nodular phosphate bed, broken shale |
| 2. | 5" | 4.4 | Massive, very hard bed. |
| 3. | 18" | 4.22 | Red and green hard shales |
| 4. | 24" | 8.32 | Few large nodules, some pink and others green centers |
| 5. | 20" | 17.69 | More massive - slightly nodular with rhombohedral jointing. |

| Sample No. | Width in Inches | Assay, Mn% | Remarks |
|---|---|---|---|
| 6. | 20" | 17.26 | Duplicate of #5, but taken about 15 ft. further up river |
| 7. | 26" | 9.82 | Upper 2" band high in $MnO_2$. Bottom section is red shale but not nodular. Highly fractured and split. |
| 8. | 24" | 8.34 | Nodular shale |
| 9. | 22" | 6.76 | Nodular shale. |
| 10. | 7" | 4.39 | of which top 5" are duplicate of bottom 5" of #9. Very few nodules, and last 2" show no trace of manganese. |

An inspection of the analyses of the chip samples shows values of Mn to increase from about 3% in sample #1 to 17.7% in #5, then decrease to practically zero in #10.

Four bulk samples for milling tests were taken on the basis of the results obtained from the chip samples. The bulk samples were channel samples taken across the beds of the deposit where it outcrops on the south side of the Manuels River valley.

Bulk Sample No. 1 - 481 pounds - a channel, 1 foot, 11 inches long, taken across the manganese beds from the uppermost section of the deposit.

Bulk Sample No. 2 - 1134 pounds - the next 4 foot, 8 inch section of the beds.

Bulk Sample No. 3 - 1063 pounds - bottom 5 foot section of the bed.

Bulk Sample No. 4 - 226 pounds - consisted of the section of bulk sample no. 2 and the uppermost 14 inch section of bulk sample no. 3.

The samples were crushed, ground and sampled by standard methods. Analysis showed the following

| | Bulk Sample | | | |
|---|---|---|---|---|
| | No. 1 | No. 2 | No. 3 | No. 4 |
| Manganese % | 5.68 | 10.69 | 9.27 | 10.35 |
| Iron % | 9.26 | 5.67 | 5.21 | 5.37 |
| CaO(acid soluble) % | 3.09 | 2.96 | 2.50 | 2.81 |
| MgO ( " " ) % | 1.84 | 1.22 | 1.16 | 1.19 |
| Phosphorous % | 0.09 | 0.07 | 0.10 | 0.06 |
| Sulphur % | 0.36 | 0.13 | 0.12 | 0.10 |

Dr. J.D. Bateman of the Bureau of Geology and Topography, Ottawa, pointed out that most of the manganese occurs as a carbonate associated with a complex carbonate group in red and green argillaceous carbonate rocks.

Dale made polished sections and thin sections of the manganese nodules at Manuels and reported as follows:

"The nodules are discoidal in shape and vary in diameter from 1/6 inch to 1½ inch, with an average of about 1 inch and a thickness ranging from 1/8 to 1/2 inch. The longer diameters of the nodules lie in the plane of the bed. Where the nodules are very numerous or crowded they are found intergrown with or overlapping each other. Specimens ground and polished often show a lemniscate formed by two nodules. In color they are for the most part green, but may have greenish, white, or pink central cores. Cross sections of the nodules reveal a distinct zonal arrangement with spherical central cores surrounded by concentric shells conforming to the shape of the nodule. The grain of the nodules is usually exceedingly fine, impalpable or crystalline. The pinkish cores are usually crystalline and respond to the HCl test quite readily, indicating some carbonate mineral. By analysis the green nodules are found to consist essentially of rhodochrosite, while the pinkish crystalline mineral occupying the centers of the nodules or occurring as intercalated

lenses or nodules in the nodular bed is found to be essentially a manganiferous calcite.

Further macroscopical examination of the nodules shows the presence of barite blades within the central portions of the nodules or disseminated throughout the nodule or its shaly matrix. The characteristics which determined the barite are its c and m cleavage, its hardness of 2 and its diaphanuty. Its optical properties confirm it microscopically. Pyrite is found sometimes completely surrounding central cores as irregular and continuous grains. The surfaces of the nodules usually are covered with minute pink or reddish disseminated grains which upon microscopic examination are found to be hematitic spherules.

Thin sections of these nodules, on the whole, are not satisfactory for microscopical work because of the almost impalpable fineness of the grain. However, some of the larger features may be of interest and importance. The structure is nodular and concentric and some of the concentric shells are oolitic. In all the thin sections of nodules the most conspicuous feature is the zonal arrangement of crystalline and indeterminable portions. The crystalline parts usually occupy the centers of the nodules while the impalpable or indeterminable areas are arranged around the centers. However some of the cores consist of indeterminable material. The zones are sometimes marked off from each other by more or less sharp contacts as brought out by a difference in shade of color or by an apparent difference in grain. The exterior zones merge imperceptibility into the shale, a fact which has some genetic significance."

Dale gave the analyses of the green and pink nodules as follows:

| Green Nodules | |
|---|---|
| $SiO_2$ | 10.31 |
| $Fc_2O_3$ | 7.35 |
| $Al_2O_3$ | 3.68 |
| MnO | 31.76 |
| CaO | 10.46 |
| MgO | 1.80 |
| $BaSO_4$ | 6.43 |
| $H_2O$ | 2.85 |
| $CO_2$ | 25.31 |
| | 99.96 |

| Recalculation | |
|---|---|
| $MnCO_3$ | 39.56 |
| MnO | 7.30 |
| $CaCO_3$ | 18.61 |
| $MgCO_3$ | 3.79 |
| $SiO_2$ | 5.94 |
| $BaSO_4$ | 6.29 |
| $H_2O$ | 1.51 |
| $Fe_2O_3$ | 7.35 |
| $2H_2O-Al_2O_3-2SiO_2$ | 9.17 |
| | 99.52 |

| Pink Nodules | |
|---|---|
| $SiO_2$ | 5.14 |
| $Fe_2O_3$ | 1.40 |
| $Al_2O_3$ | 1.64 |
| MnO | 20.49 |
| CaO | 32.92 |
| MgO | .01 |
| $H_2O$ | 1.65 |
| $CO_2$ | 36.77 |
| | 100.02 |

| Recalculation | |
|---|---|
| $CaCO_3$ | 58.05 |
| $MnCO_3$ | 29.32 |
| MnO | 2.34 |
| $SiO_2$ | 3.78 |
| $Fe_2O_3$ | 1.40 |
| $H_2O$ | 1.06 |
| $2H_2O-Al_2O_3-2SiO_2$ | 4.07 |
| | 100.02 |

The main manganese-bearing bed at Manuels measuring .7 of a foot in thickness is of much more than usual interest in that the manganese occurs as primary carbonates and oxides in the form of this jasper-like trends of green and light chocolate brown color, and as lenticles, and nodules. Interlaminated with the jaspery bands are reddish bands with manganese essentially in the form of an oxide and a carbonate. The green bands are very similar chemically

to the green nodules. The reddish band is essentially a manganiferous shale.

R.A. Bell, a graduate student at the University of Wisconsin made X-ray and polished section studies of samples from the various manganese deposits.

The polished surface of a high-grade ore sample from a surface exposure at Brigus contained oxides and hydrous oxides of manganese with some carbonate. The bulk seemed to be pyrolusite. The polished surface of a weathered nodule showed essentially the same minerals as the high-grade ore sample.

X-ray studies failed to differentiate the various manganese minerals as the bulk of the X radiation was obsorbed by the manganese. The absorption edge of Mn is 1.90 angstrome, therefore the target required would have to give off X radiations with a wave length greater than 1.90 angstroms, such as Mn targets or Cr targets. However, these are not available. The only available targets are Mo. -0.71, Cu. -1.54, Co. -1.79, and Fe. -1.94. The Fe target was tried but the wavelength of 1.94 was too close to the absorption edge of Mn -1.90, therefore the bulk of the x-radiation was absorbed.

Orange-yellow material from weathered nodules was identified as $Ca_3 (PO_4)_2$ or possibly a calcium aluminum phosphate. Dale reports tri-calcium phosphate as a conspicuous accessory of the manganese deposits of Newfoundland.

A bed of red crystals with a white matrix was found underlying the manganese beds at Brigus. This bed does not exceed $\frac{1}{4}$ of an inch in thickness. The red mineral was found to be barite.

Reserves

Manganiferous beds are found in varying thicknesses, usually in the nodular form, wherever Middle Cambrian beds occur in southeastern Newfoundland. However, in most places the beds are not thick enough to warrant economic consideration. The deposits that show promise are, Manuels, Kelligrews, Long Pond, Brigus and possibly Broad Cove on Smith Sound.

Manuels, Kelligrews and Long Pond are part of one large deposit extending from Topsail four miles along the coast of Conception Bay to beyond the Kelligrews. This deposit extends over 1,000 feet inland from the bay and dips under the bay at an angle of $10^{\circ}$. The extent and thickness of the manganese beds under Conception Bay could only be guessed at. However, along the southeastern shore a more reasonable estimate of the tunnage can be made. This estimate of the tonnage of the deposit is based on certain assumptions.

1. That the mode of occurrence (oxide or carbonate) does not change.
2. That the thickness and grade are constant.
3. The distances are rough estimates, yet are conservative over which the manganese bands have been located.

This gives an estimated tonnage of 10,000,000 tons of ore 4 miles long 1,000 feet wide and 5 feet thick.

$$\frac{20{,}000 \times 1000 \times 5}{10} = 10{,}000{,}000 \text{ tons estimate.}$$

At Brigus South Head the manganese beds dip into the sea at a $45^{\circ}$ angle. The extent of these beds under Conception Bay is not known except that stratigraphically they are the continuation of the deposits on the south east side of Conception Bay. The tonnage of the manganese beds exposed along the cliffs at Brigus is negligable and amounts to roughly 50,000 tons.

The tonnage of potential manganese ore underlying Conception Bay is undoubtedly enormous. However, the stratigraphic section thickens rapidly and at Bell Island, one mile out in the bays the manganese beds are overlain by an estimated 10,000 feet of Ordovician sediments.

At Broad Cove on Smith Sound, Trinity Bay, a 3.5' bed of manganiferous dolomitic ferruginous shale assayed at roughly 8% Mn. The beds dip $20^{\circ}$W and strike roughly N-S. The manganiferous bed has a potential length of 5 miles or more along the surface strike. Since no exploratory work has been done on the outlining of the manganiferous bed in the Smith Sound area it would be difficult to estimate the tonnage of this deposit. However it must compare favourably in size with the deposit on the southeast shore of Conception Bay. The grade is considerably lower. At Broad Cove the 3.5' zone runs 8% / h whereas the highest grade zone of similar width at Conception Bay runs 13% - 17% Mn.

## Recommendations and Conclusions

Most of the manganese occurs as a carbonate associated with a complex carbonate group in red and green argillaceous carbonate rocks. These complex carbonates are solid solutions of $MnCO_3$ with $FeCO_3$ on one hand and with $CaCO_3$ on the other. The carbonates are finely disseminated throughout the red and green shales, but the manganese is limited to a definite horizon that varies from place to place. Within this horizon there are local concentrations of manganese in (a) carbonate nodules, (b) pale green cherty lenticles and (c) red iron oxide laminae. The local concentration as well as the dissemination of manganese carbonates is to be considered a primary occurrence.

The results of a reconnaissance survey of the manganese deposits of southeastern Newfoundland show that those along the southeast shore of Conception Bay, that is at Manuels, Long Pond and Kelligrews, are the most worthy of economic consideration. These are really part of large deposit estimated at 10,000,000 tons, averaging about 12% Mn over a 5 foot width. Since these manganiferous beds extend under Conception Bay with a dip of 10% N., the tonnage of potential manganese ore underlying Conception Bay must be enormous. Nevertheless, mining operations under Conception Bay would be limited by depth, at Bell Island the manganese beds are overlain by an estimated 10,000 feet of Ordovician sediments.

The results of mill tests run in 1942 show that the ore is not amenable to flotation concentration; the grade of the concentrate is low, analysing about 25% Mn, and recovery is poor. The manganese at depth is in the carbonate form with only visible traces of $MnO_2$. It is associated with a complex carbonate group. This mode of mineral association will account for the low grade concentrates and low recoveries obtained.

It therefore is apparent that this manganese deposit cannot be exploited by any known means of concentration short of chemical treatment. However in the case of national emergency where cost would be of secondary importance, these deposits could supply a vital need.

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