New Brunswick / Nouveau Brunswick

Natural Resources
Lands, Minerals and Petroleum Division

Manganese

Mineral Commodity Profile No. 1

Manganese (Mn) is a hard, brittle, greyish white metal—the second most abundant heavy metal and the twelfth most common element in Earth's crust.

Manganese rarely exists in its pure, elemental state but instead combines with other elements in nearly 300 different minerals. Mn is extracted from several economically important oxide minerals. These include pyrolusite (manganese dioxide), psilomelane (a hydrous barium manganese oxide), manganite (a hydrated manganese oxide) and wad (manganese oxides of varied compositions).

Uses

Manganese is among the world's most widely used metals, ranking fourth after iron, aluminium and copper. Thousands of everyday metallic items require some percentage of manganese in their manufacture.

The double-billing of manganese as an industrial mineral comes from its non-metallurgical application in such diverse products as fertilizers, glass, perfumes, bricks and water purification systems.

- Pyrolusite (MnO_2) has been used for centuries in glass-making. When mixed with molten silica, MnO_2 causes iron impurities to oxidize from the ferrous to the ferric state, removing greenish tints from the melt.
- The thin metal used in making aluminium beverage cans contains about 1% Mn to prevent metal corrosion.
- Manganese in dry-cell batteries helps to reduce production of waste matter. The generation of electricity causes hydrogen gas to accumulate on battery electrodes. MnO_2 acts as a depolarizing agent, reacting with the hydrogen to form oxygen and water. Without MnO_2 the electrodes would become coated with waste, shortening battery life.

More than 90% of the world's mined manganese ends up in steel products. On average, 1 t of steel contains about 7.5 kg of manganese. Manganese serves two functions in steel-making: additive and alloy.

- Manganese added to the primary melt binds excess oxygen and sulphur generated during the early stages of smelting iron ore. The resultant slag floats on top of the molten steel for easy removal.
- As an alloying element, manganese increases the strength of steel, making it less brittle, easier to form, and more resistant to shock, abrasion and corrosion.

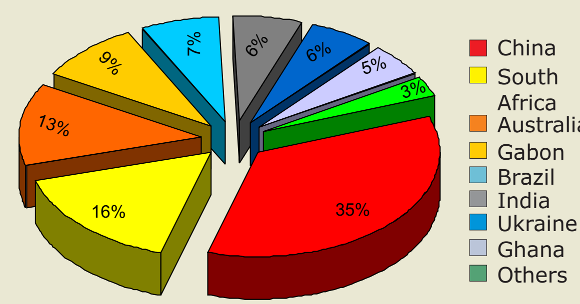
The world's second-largest market for manganese is dry-cell battery production. Global battery sales are estimated at $50 billion annually and are growing steadily (Buchmann 2004). The demand for manganese in battery manufacture is anticipated to increase accordingly.

World Production and Reserves

Global production of manganese ore reached 33.7 Mt in 2006. The major suppliers—China, South Africa, Australia, Brazil and Gabon—provided 80% of the international market (International Manganese Institute [IMI] 2006).

Worldwide reserves of manganese ore containing >35% Mn were estimated at 440 Mt in 2006 (U.S. Geological Survey 2007). Ukraine, India and Australia account for about 70% of the reserves. The remainder occurs in Brazil, China, Gabon, South Africa, and Mexico.

Global Manganese Ore Production
(Total = 33.7 Mt)



2006 figures (from IMI 2006)

Canada and the United States presently import 100% of their manganese requirements. In January 1987 the United States redesignated manganese as a strategic metal essential for the economy and national security. Manganese is now being stockpiled to safeguard against future shortages.

In the past, both countries supported small mines of low- to medium-grade manganese ore. More recently, sizeable manganese deposits have been delineated, including ones in New Brunswick. However, the profitable extraction and processing of these ores remains a significant challenge.

The problems are twofold. First, the manganese in some deposits is not economically recoverable using available separation procedures. Second, metallurgists have not yet developed cost-effective ways to concentrate the lower grade manganese ores of Canada and the United States into the high-grade material required for steel applications.

Manganese Exploration and Mining in New Brunswick

Manganese ore was first noted in New Brunswick during the 1820s. As the world steel industry expanded after 1860, small manganese mines opened in the province to satisfy emerging markets in western Europe and the eastern United States. The most noteworthy of the early New Brunswick operations occurred at Markhamville, Dawson Settlement, Jordan Mountain and Gowland Mountain (Fig. 1). They produced ore sporadically until the early 1900s.

Today, these deposits would be regarded as too small and/or too low grade for economic consideration. However, in the mid-19th-century, their proximity to major steel mills gave them an advantage over the world's larger but more remote manganese deposits at a time when transportation logistics were formidable.

During World Wars I and II, the designation of manganese as a strategic metal for armament manufacture stimulated some of New Brunswick's former manganese mines to be reactivated. None remained open beyond 1946.

Manganese came of age in 1839 when metallurgists introduced it as a component in crucible steel.

As the world steel industry evolved, manganese became an essential element in iron and steel manufacture, particularly as ferromanganese in the Bessemer method of steel production.

Modern metallurgists have yet to discover an effective substitute for manganese in converting iron ore to steel. Without this versatile metal, the steel industry would grind to a halt.

Draining water from a wad manganese deposit at Dawson Settlement, south-eastern New Brunswick, c. 1898. *Bailey 1899*

Manganese processing facility at Dawson Settlement, where wad manganese was dried and compressed into briquettes, c. 1899. *Courtesy of John Whitmore, Hillsborough, NB*

The strategic status of manganese continued into the 1950s as steel mills shifted from weapon-making to postwar reconstruction. By then, the global steel industry was consuming huge tonnages of metallurgical-grade manganese. Worldwide manganese demand had far surpassed the capacity of localized deposits such as those in southeastern New Brunswick.

The 1950s also saw the discovery of rich base-metal deposits in the now-famous Bathurst Mining Camp, northeastern New Brunswick. The discovery sparked a surge in claim-staking around Bathurst and revitalized exploration for metals—including manganese—elsewhere in the province.

At the height of this activity, exploration companies seeking manganese in New Brunswick focused on exploring the long-recognized but little-investigated iron–manganese deposits near Woodstock in western New Brunswick (Fig. 1). These deposits contain low- to medium-grade ore but occur in stratabound formations covering many square kilometres.

Considerable investigation took place during the 1950s and early 1960s to better define and quantify the manganese resources around Woodstock. Metallurgists tested various methods of economically processing the lower grade ore to meet steel industry specifications.

Although upgrading techniques were developed, beneficiation costs exceeded the price of imported material. Manganese exploration in the region consequently dwindled after the mid-1960s. Since then, exploratory interest in New Brunswick manganese has been limited to the mapping, sampling and testing of ores from Woodstock, Dawson Settlement and North Renous (Fig. 1).

Manganese deposits in New Brunswick, the rest of Canada, and the United States currently remain non-productive. However, worldwide metal prices continue to climb, and manganese once again is a designated strategic commodity. Research is ongoing in the United States and elsewhere to devise innovative ways of efficiently processing manganese ores such as those in the large, lower grade deposits near Woodstock.

Geology of New Brunswick Manganese Deposits

New Brunswick's manganese occurrences can be divided into two broad types according to whether manganese mineralization is primary or secondary. The two divisions are further categorized on the basis of regional and localized geological setting. The main categories are shown here, using selected examples.

Steeply dipping manganiferous shale of the Smyrna Mills Formation, west of Richmond Corner near Woodstock, western New Brunswick.

Primary Manganese Deposits

Manganese mineralization in primary manganese deposits develops syngenetically with deposition of the host rocks. Significant deposits of this type in New Brunswick occur in two geological settings.

1, **Silurian sedimentary rocks**: manganese mineralization resulted from oxidization of manganese in ambient seawater during the deposition of sediments in marine basins.

2. **Ordovician volcanogenic–sedimentary rocks**: manganese mineralization was derived largely from hydrothermal fluids associated with submarine volcanism.

1. Sedimentary Deposits

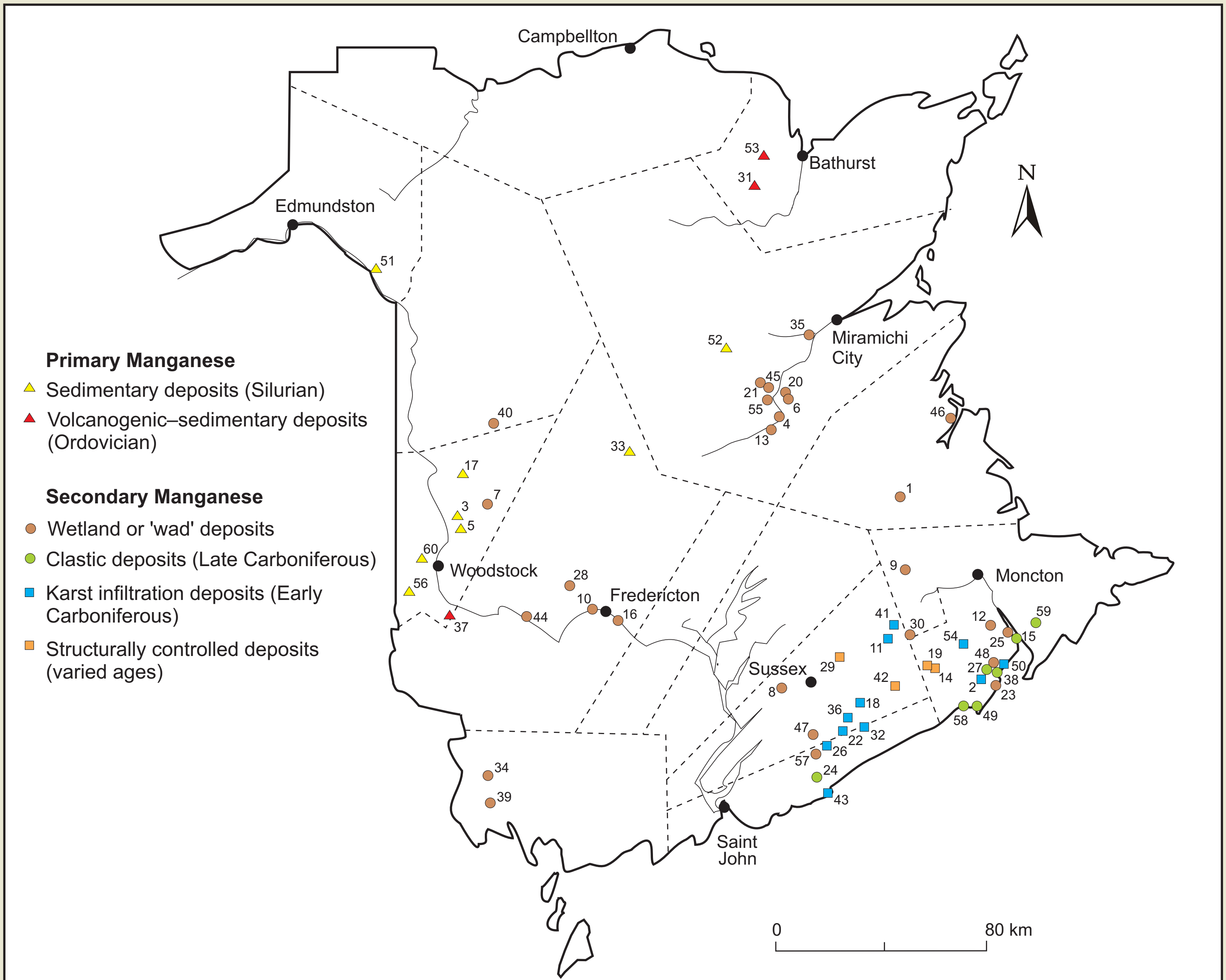
New Brunswick's largest and most extensive known manganese resources occur in Silurian sedimentary rocks near Woodstock (Fig. 1, 2). These stratified ferromanganiferous deposits are associated with red and grey, siliciclastic to calcareous siltstone and shale of the Smyrna Mills Formation (Perham Group).

Deformed quartz vein in folded shale of the Smyrna Formation, same site as above. Hammer is 30 cm long.

Manganese content in the rocks is interpreted to have been deposited from seawater in an oxygen-rich environment. Following deposition and lithification, the manganese-bearing horizons underwent structural thickening due to repeated folding and faulting. The associated remobilization of manganese by migrating fluids also led to the redeposition and concentration of manganese in fracture zones.

The ferromanganiferous horizons near Woodstock lie along a 10 km stretch between Richmond Corner and Jacksonville, reaching from west to northwest of Woodstock. These horizons, which include the Plymouth, North and South Hartford, Moody Hill, Iron Ore Hill, and Sharpe Family deposits (Fig. 2 inset), hold some of the largest known manganese reserves in North America.

One report estimated that manganese resources near Woodstock contain nearly 200 Mt of iron–manganese ore. However, the ore averages only 9% Mn and 13% Fe (Sidwell 1957). Research efforts have yet to develop economically viable techniques of upgrading the fine-grained, complex ore to meet current market specifications.



1. Adamsville Bog Station (743)
2. Albert (646)
3. Ashland
4. Upper Blackville (316)
5. Becaguimec River
6. Blackville
7. Brummagen Brook (188)
8. Bull Moose Hill
9. Canaan River (319)
10. Currie Mountain
11. Davis Farm (761)
12. Dawson Settlement (707)
13. Doaktown
14. Douglas Mountain
15. Edgett's Landing
16. Fredericton
17. Glassville (191)
18. Glebe Mine (690)
19. Gowland Mountain (643)
20. Grey Rapids (747)
21. Grainfield (317)
22. Hammondvale (689)
23. Harvey
24. Henry Lake (680)
25. Hillsborough
26. Hillsdale
27. Hopewell
28. Jones Forks (220)
29. Jordan Mountain (763)
30. Kays Farm
31. Little River No. 2 (500)
32. Londonderry
33. Lower Birch Island (172)
34. Lynnfield
35. McKays Brook
36. Markhamville (691)
37. Meductic (538)
38. Memel (712)
39. Moores Mills
40. North Branch
41. Petitcodiac
42. Pollett Lake (type inferred)
43. Quaco Head (2)
44. Queensbury
45. North Renous (286)
46. Richibucto
47. Salt Springs
48. Saw Mill Creek
49. Salisbury Bay
50. Shepody Mountain (721)
51. St. Leonard (10)
52. Stewart (592)
53. Tetagouche Falls (49)
54. Turtle Creek (719)
55. Underhill Bog (318)
56. Union Corner (281)
57. Upham
58. Waterside (645)
59. Woodhurst (702)
60. Woodstock area (270–275; see Fig. 2 inset)

Figure 1. Location of selected New Brunswick manganese deposits. Numbers in brackets refer to the Unique Record Number in the New Brunswick Department of Natural Resources (NBDNR) Mineral Occurrence Database (NBDNR 2008a).

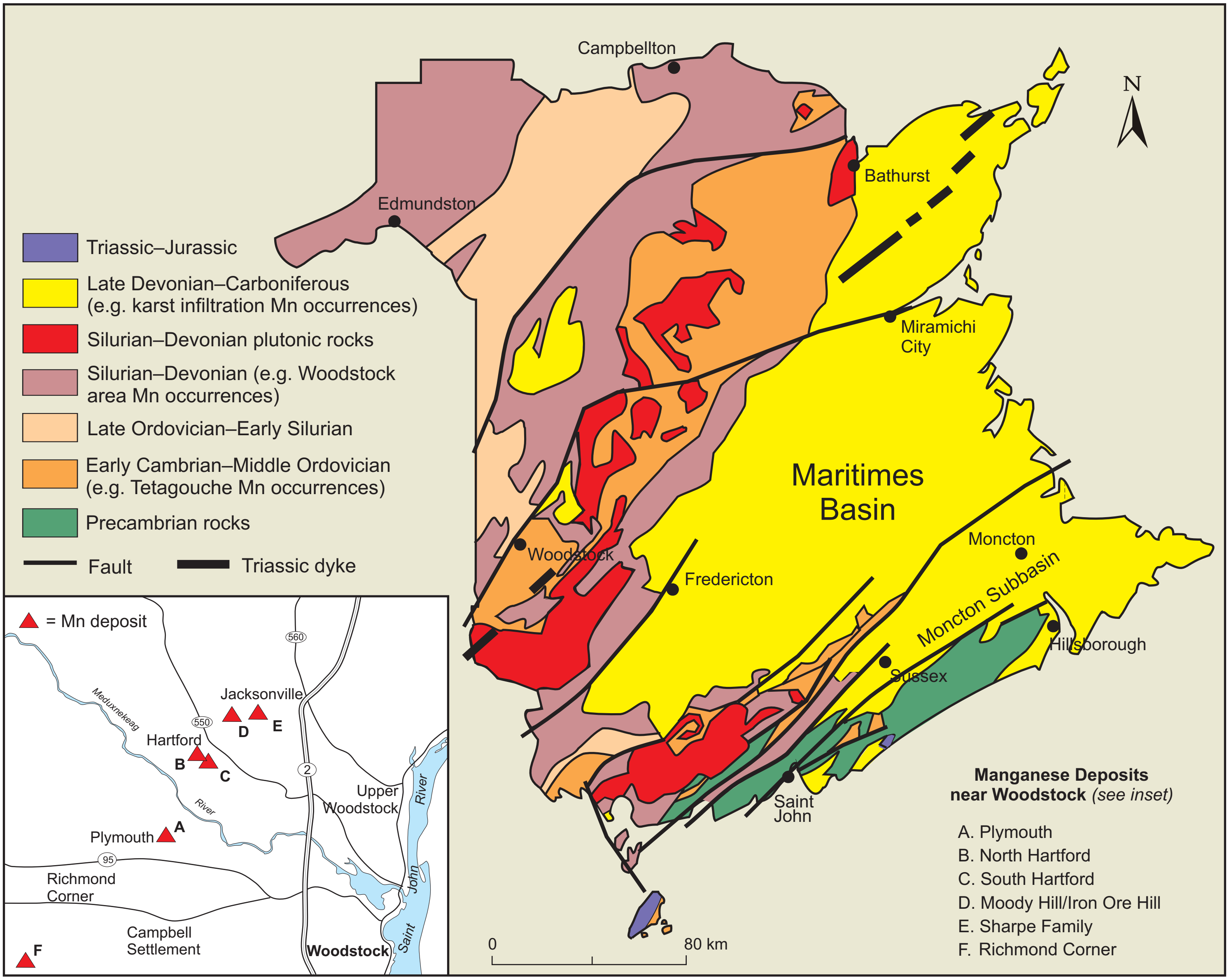


Figure 2. Simplified geology map of New Brunswick, showing the geological setting of selected manganese deposits. The inset map shows manganese deposits in the Woodstock area of western New Brunswick.

2. Volcanogenic–Sedimentary Deposits

Shale and associated chert beds containing hydrothermal iron–manganese oxides are interstratified with volcanic rocks of the Ordovician Tetagouche Group over large areas of the Bathurst Mining Camp in northeastern New Brunswick. At some sites, such as Tetagouche Falls near Bathurst (Fig. 1), manganese grades have been enriched by secondary processes that concentrated manganese in veins, vugs and concretions; and as a matrix in breccia zones.

The Tetagouche Falls deposit was mined briefly in the 1840s but yielded little ore. Analyses in Sidwell (1957) indicate that the occurrence consists mainly of low-grade (<4% Mn) material. However, the deposit's localized zones of high-grade ore (>58% Mn) could encourage manganese exploration elsewhere in the district.

Manganese-bearing strata of the Tetagouche Group, Tetagouche Falls.

Secondary Manganese Deposits

Secondary manganese mineralization takes place when circulating fluids remobilize the manganese from its initial deposition site in the host rock and redeposit it elsewhere. The fluids may comprise one or more of the following: 1) hydrothermal fluids of magmatic origin, 2) hydrothermal fluids of metamorphic origin such as heated pore water, groundwater, or brine, or 3) non-hydrothermal (unheated) groundwater.

As warm manganese-rich fluids circulate and migrate up through bedrock, changes in temperature, pressure and available oxygen cause the manganese to precipitate out of solution as manganese oxides, manganese carbonates or (less commonly) other mineral forms. Depending on sedimentological, compositional and structural characteristics of the new depositional environment, secondary manganese deposits may be concentrated in fractures, vugs and cavities, or pores spaces.

Secondary deposits can also form when groundwater emerges from rock as a spring into a surficial, wetland environment. Manganese precipitates out as the groundwater moves from a reducing environment in the rock to an oxidizing one in the wetland.

The most historically and/or economically significant secondary manganese occurrences in New Brunswick are

1. structurally controlled deposits in veins, fractures and fault gouge,

2. karst infiltration deposits in Early Carboniferous limestone, and

3. wetland or 'wad' deposits in fens and related wetland environments.

1. Structurally Controlled Deposits

Structurally controlled manganiferous occurrences in New Brunswick typically appear in epithermal or mesothermal veins, rarely forming stratabound deposits. They have been reported in a range of sedimentary and intrusive rock types of varied ages.

The deposits are interpreted to have formed when manganese-bearing hydrothermal fluids migrated up from depth through structural features in the bedrock. Once reaching higher levels, manganese minerals precipitated out of solution to form veins and coatings along fractures or fault surfaces, and in breccia zones.

Deposits of this type in New Brunswick may contain zones of higher grade ore (up to 50% Mn), but generally they have low tonnages and lack lateral continuity.

Localized concentrations of secondary manganese also appear in clastic rocks of the Late Carboniferous Cumberland and Pictou groups. The rocks consist of siltstone, sandstone and conglomerate, and are found throughout the Maritimes Basin in New Brunswick (Fig. 2).

As heated pore water and groundwater migrated through the clastic rocks, the fluids dissolved and remobilized ions from manganese-bearing minerals. The manganese later precipitated out of solution in pore spaces, on fracture surfaces, and along bedding planes. Other manganese occurrences in these rocks may have resulted from the scavenging and recycling of older manganese-enriched lithologies.

Occurrences of this type in New Brunswick have no economic value. However, they can produce locally elevated manganese levels in groundwater in areas underlain by Maritimes Basin strata.

Examples of this deposit type include the former Gowland Mountain and Jordan Mountain mines in southeastern New Brunswick (Fig. 2). At Gowland Mountain, a fault breccia composed of felsic rock fragments cemented by manganese oxides occurs in contact with Neoproterozoic intrusions of the Point Wolfe Granite. Mineralization at Jordan Mountain consists mainly of manganite–pyrolusite lenses and stringers cementing conglomerate of the Late Carboniferous Hillsborough Formation.

Gowland Mountain manganese mine site, autumn 1941.

2. Karst Infiltration Deposits

In southeastern New Brunswick, historically important manganese deposits occur in algal limestone of the Early Carboniferous Gays River Formation (Windsor Group), mainly along the southern margin of the Moncton Subbasin (Fig. 2).

Gays River limestone typically features areas of palaeokarst that locally contains deposits of secondary manganese ore. Deposit formation is interpreted as the result of manganese-bearing hydrothermal brines and related solutions circulating through peripheral sections of Early Carboniferous evaporite subbasins.

Pyrolusite in algal limestone of the Gays River Formation at the former Glebe mine, southeastern New Brunswick.

Manganese deposits in the Gays River Formation are also locally hosted in algal limestone and related rocks, where the ore appears as fillings in cavities and vugs, and in veinlets and stockwork. Mineralization consists of psilomelane, pyrolusite, manganite, huasmannite and bruanite.

Secondary manganese deposits of this type in New Brunswick are small and discontinuous. However, they hold pockets of high-grade ore that can exceed 90% MnO_2 (Bailey 1899). During the middle to late 1800s, Gays River deposits accounted for much of New Brunswick's manganese production, which came mainly from the Markhamville and Glebe mines near Sussex (Fig. 1).

3. Wetland or 'Wad' Deposits

Many of New Brunswick's manganese deposits occur in wetlands known as fens. Fens form at the base of a slope where the water table intersects the land surface to create a mineral spring. They generally support such vegetation as sedge, rushes and light forest cover.

Wetland or 'wad' deposits can develop where groundwater enriched in iron and manganese percolates through rock, then emerges as a spring within the confines of a fen. A chemical reaction involving decaying vegetation, bacterial processes, and groundwater causes the manganese to precipitate out as a mixture of manganese oxides and hydroxides (Hanson 1932).

Wad deposits can reach 3 m thick. They fan outward from the spring, generally thicken downslope, and terminate abruptly at the distal end.

Wad manganese deposits in New Brunswick typically overlie manganese-bearing Late Carboniferous clastic sedimentary rocks of the Cumberland and Pictou groups (see sidebar on p. 6). The deposits seldom contain more than several hundred tonnes of ore. In most instances, they are too small, scattered and low grade for economic consideration.

New Brunswick's largest deposit of wad manganese lies at Dawson Settlement west of Hillsborough (Fig. 1, 2) and was mined intermittently from 1893 to 1930. About 3550 t of ore were treated for ferromanganese production and brick manufacture. Reserve estimates for a 3.8 ha area of the deposit were about 42 700 t of crude wet manganese ore averaging 6.97% Mn; early resource estimates for dry ignited ore were 9000 t averaging 35% Mn (Uglow 1920; Hanson 1932).

Wad deposit in a fen at Dawson Settlement, showing black manganese oxides and orange limonite.

Summary

New Brunswick's manganese occurrences can be placed in two broad categories, based on whether the deposits are 1) primary: they developed syngenetically with deposition of the host rocks, or 2) secondary: they contain manganese that was remobilized from its original deposition site by circulating fluids and was redeposited elsewhere in the geological environment.

Primary manganese deposits in New Brunswick occur mainly in Silurian sedimentary rocks and Ordovician volcanogenic–sedimentary rocks. Secondary manganese deposits are found in rocks of varied types and ages. The most significant occurrences are 1) structurally controlled deposits, 2) karst infiltration deposits, and 3) wetland or wad deposits.

The wad manganese deposits occur in wetlands and contain small quantities of mainly low-grade ore, some of which has been mined. Manganese extraction from such sites today would be economically and environmentally unfeasible, given current government standards of resource development.

The karst infiltration and structurally controlled types of manganese deposits hold more historic interest than economic merit. They contain low-grade to higher grade manganese ores but lack the tonnages to justify development.

Primary manganese deposits associated with stratified, ferromanganiferous sedimentary rocks of the Smyrna Mills Formation near Woodstock offer the best exploration potential of all known New Brunswick manganese occurrences. However, further research is needed to develop cost-effective processing technologies for upgrading the ore to meet current specifications of the steel industry.

Canada and the United States currently import 100% of their manganese requirements, and manganese remains one of the top four strategic metals in the United States. Moreover, the price of manganese has risen sharply since 2005. As metallurgical techniques are improved, and as manganese prices continue to escalate, the large, lower grade deposits near Woodstock may warrant fresh exploration and development interest.

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For More Information

For more information on manganese and other New Brunswick mineral commodities, please see the NBDNR Mineral Occurrence Database (NBDNR 2008a) and Industrial Mineral Database (NBDNR 2008b), or contact:

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Recommended citation: Webb, T.C. 2008. Manganese. New Brunswick Department of Natural Resources; Minerals, Policy and Planning Division, Mineral Commodity Profile No. 1, 8 p.