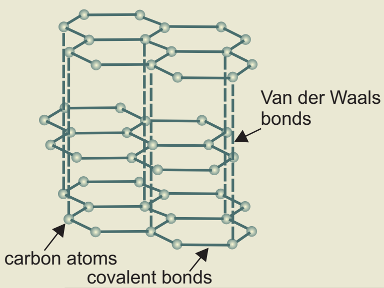
Graphite

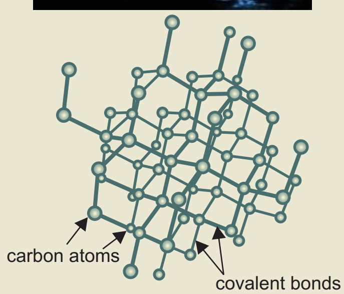
Mineral Commodity Profile No. 3

New Brunswick / Nouveau Brunswick
Natural Resources
Lands, Minerals and Petroleum Division

Graphite is one of two naturally occurring minerals comprised solely of the element carbon (C), the other being diamond. Although both graphite and diamond have the same chemical composition, they differ greatly in their internal arrangement of carbon atoms. A diamond crystal contains an exceptionally strong tetrahedral framework of carbon atoms, making it one of the hardest substances on earth. In contrast, graphite is formed of stacked, loosely bound layers composed of interconnected hexagonal rings of carbon atoms making it one of the softest materials known; yet its linked ring structure can be used as a source of strength (Perkins 2002). These fundamental structural differences reflect the lower temperature and pressure conditions under which graphite formed compared to diamond.

Although graphite and diamond share the same carbon (C) chemistry, differences in how their carbon atoms are arranged imparts several contrasting properties.



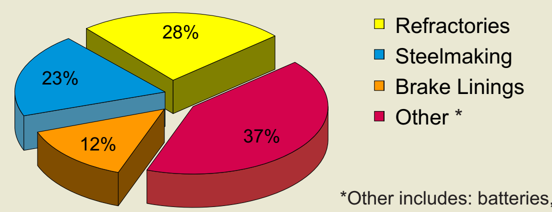


Graphite	Diamond
soft	hard
dirty to touch	clean to touch
good electrical conductor	non-electrical conductor
lubricant	abrasive
opaque	transparent
Value: hundreds of dollars per tonne	Value: millions of dollars per tonne

Physical Properties and Uses

Graphite has the distinction of being the only non-metallic substance that is an efficient conductor of electricity. Its high thermal and electrical conductivity, soft and greasy texture (low frictional resistance), and structural strength are among its most appealing physical properties. From pencils to steelmaking, graphite's versatile properties make it suitable for a variety of everyday and industrial applications. In 2006, the United States Geological Survey (USGS) reported US consumption of natural graphite in the order of 40 700 tonnes valued at $36 million (Olson 2009a). Graphite's inert behaviour toward most chemicals and high melting point (3927°C) make it an ideal material for use in: the steel manufacturing process (it is added to molten steel to raise carbon content to meet various hardness quality standards), refractory linings in electric furnaces, containment vessels for carrying molten steel throughout manufacturing plants, and casting ware to create a shaped end-product. In addition, graphite is used as a foundry dressing, which assists in separating a cast object from its mould following the cooling of hot metal. The automotive industry uses graphite extensively in the manufacture of brake linings and shoes. Graphite is an effective lubricant over a wide range of temperatures and can be applied in the form of a dry powder or as a colloidal mixture in water or oil. Other uses include electrodes in batteries, brushes for electric motors, and moderators in nuclear reactors. Graphite is used in the production of carbon fibre which strengthens components of items like musical instruments and lightweight sporting equipment (i.e., golf clubs, fishing rods, bicycles, and tennis rackets). Graphite is also one of the key components in the outer temperature protective system (i.e., heat protective tiles) of a space shuttle (Dunn 2007).

End Uses of Graphite in the United States (2008)



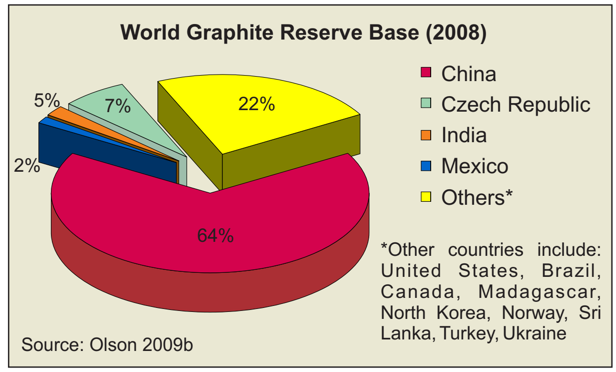
*Other includes: batteries, stoppers, sleeves, nozzles, lubricants, pencils

Source: Olson 2009b

Following its 16th century discovery in England, graphite became popular as a writing implement because of the fact that it would leave a dark, resilient mark on most materials. Its soft, greasy texture combined with its brittleness made it difficult to hold. The humble pencil would eventually satisfy this handling dilemma. The early pencil consisted of sticks of graphite wrapped in string. Hollowed-out wooden sticks eventually replaced the string...the wooden-cased pencil had been invented.

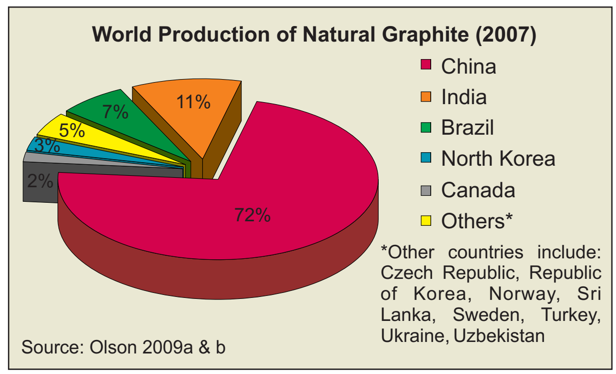
Graphite Types: Origin and Mode of Occurrence

Sedimentary rocks rich in decayed organic matter and limestone and dolomite made of carbonate (CO_3) compounds, serve as potential carbon sources for graphite. Graphite deposits are formed when carbonaceous rocks undergo various chemical and structural transformations via metamorphism (elevated temperatures and pressures).



Graphite deposits are typically grouped into three main textural types: 1) amorphous, 2) crystalline, and 3) flake. Amorphous graphite, as the name suggests, has essentially no crystalline structure, consisting of particles so small that it maintains an earthy appearance. The amount of graphite present in amorphous deposits depends on the amount of carbonaceous (organic) material in the host rock. Amorphous material is typically represented by fine-grained graphite disseminations and aggregates in mildly metamorphosed carbonaceous and carbonate-bearing sedimentary rocks (i.e., slate, shale, limestone, and dolomite). Amorphous deposits typically contain up to 60% graphite.

Flake graphite comprises separate, flat, plate-like crystals (flakes) with irregular to perfect hexagonal edges. It occurs as disseminations in strongly metamorphosed rocks such as marble, gneiss, and schist.



Crystalline graphite deposits tend to be fairly pure often reflecting carbon contents in excess of 90%. Crystalline graphite occurs as massive accumulations of flat, plate-like crystals with angular, rounded, or irregular edges in well-defined veins. Vein graphite is produced by the mixing of methane (CH_4)-rich and carbon dioxide (CO_2)-rich fluids which react to form water (H_2O) and carbon (C). The C-O-H gas-fluid mixture transports carbon throughout fractured rock to favourable locations where it precipitates as veins of massive graphite. Vein deposits are commonly situated adjacent to contacts between hydrothermally altered limestone and plutonic rocks emplaced as high-temperature silica-rich melts.

World Resources and Production

In 2004, the USGS reported that 86% of the world's graphite resources consisted of amorphous material with almost all other resources represented by flake (Taylor 2006). Sri Lanka is the only country with crystalline resources. According to preliminary USGS statistics, the world's natural graphite resource base stood at 220 million tonnes in 2008 (Olson 2009b). USGS data indicates world production of natural graphite was just over 1.1 million tonnes for the same year with nearly 95% of global supply sourced in just five countries. China is by far the most dominant force in the world's graphite supply industry, accounting for 72% (800 000 t) of world production, followed by India (130 000 t), Brazil (76 200 t), North Korea (30 000 t), and Canada (28 000 t) (Olson 2009a & b). In 2006, Canadian production originated from a mine and processing facility in the Province of Québec (Dumont 2008). Other known deposits from Québec, Ontario, and British Columbia are reportedly in various stages of exploration and development.

Reflective of strong demand from a metal-using economy in United States and an expanding domestic consumption in the Chinese steel industry (Taylor 2006) the outlook for graphite was positive. It was predicted that China would become a temporary net importer of graphite, a situation that would revive exploration and development opportunities for natural graphite throughout the world, particularly in North America. The current economic slowdown is perpetuating the negative trend that has plagued the global graphite market over most of the last decade. Consumption of graphite can be expected to decrease as production of steel and automobiles declines. On the positive side, an expected growth in production of batteries in hybrid vehicles could lead to a rise in demand for graphite over the next five to seven years (Merchant Research & Consulting, Ltd. 2007).

Graphite in New Brunswick

The early days

Although not currently produced in New Brunswick, graphite has, from time to time, sparked interest in the exploration and development community, particularly in the Saint John area. Evidence of exploration and development interest is recorded in descriptions of several former 19th century mining ventures that operated in the eastern part of the city. Some graphite was produced from two small deposits at Marble Cove-Split Rock (near The Reversing Falls) and Botsford. An entertaining and informative account of these past enterprises is presented by Gwen Martin in her book, 'Gesner's Dream: The trials and triumphs of early mining in New Brunswick' (Martin 2003; pp. 65–67 and 168–69).

With the support of several prominent members of the city's business community, the first of three reported graphite mines in the Marble Cove-Split Rock area was established in 1850 by the Saint John Mining Company. Under the direction of an imported British mine captain, local miners extracted and dispatched several hundred tons of hand-picked ore during the mine's first year of operation. Production continued until 1860. Following the death of a key company official, the operation was abandoned. Under the direction of American entrepreneurs, two other graphite mining ventures in the Split Rock area emerged. These operations were short-lived, catapulting into the historical record by 1873. Old workings of these former enterprises are still visible at low tide on the north bank of the Saint John River, a few hundred metres downstream of the Reversing Falls Visitor Information Centre. Another graphite mine, the Botsford Mine, also known as the Mayes Mine, was established around 1880. It occupied property a few hundred metres north of the former Marble Cove–Split Rock operation(s). Until the late 1880s, the Botsford Mine was considered Canada's most productive graphite mine. For nearly a decade, up to 10 tons of hand-picked ore was extracted and processed on a daily basis. Severe flooding forced an end to operations in 1889. Another mine, very near the Botsford operation, opened in 1891 under the name St. John Plumbago Company. Despite having established American markets for its product, trade restrictions and other obstacles resulted in permanent closure in 1908. This failed enterprise was the last attempt to mine graphite in New Brunswick (Martin 2003).

Amorphous graphite at Marble Cove-Split Rock in Saint John, N.B.

Amorphous graphite at Mill Creek, N.B.

The Golden Grove graphite prospect

The most extensive and best studied graphite deposit in New Brunswick is situated approximately 24 km northeast of Saint John, near Golden Grove. In general, the deposit consists of a steeply dipping graphitic zone hosted in Neoproterozoic carbonates (limestone and dolomite) and quartzite of the Ashburn Formation. Ashburn strata at this location occur as a roof pendant within mafic (gabbro) to felsic (diorite, granodiorite) plutonic rocks of the Golden Grove Intrusive Suite. The Golden Grove deposit has been known for over 70 years; however, there are no records of work for the property until it was visited by Provincial Geologist, W.J. Wright in 1937. The main graphite

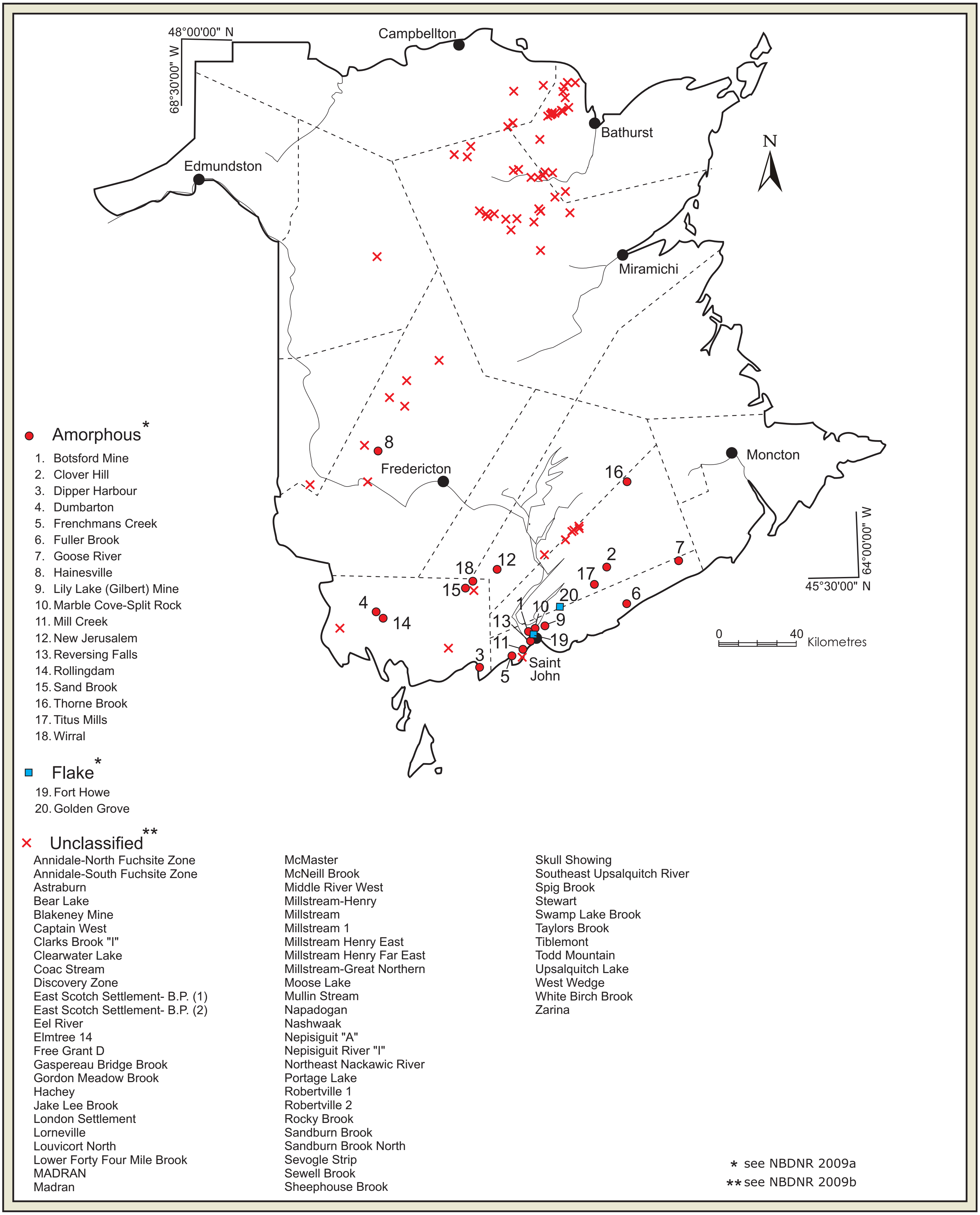


Figure1. Location of selected New Brunswick graphite occurrences.

showing at Golden Grove, visible in a 14-foot [4.3 m] deep shaft, was described by Wright as a near-vertical "lead [vein] of graphite" up to 53 inches [1.3 m] wide, found associated with dark grey crystalline limestone very near its contact with intrusive granitic rock (Wright 1939). A sample representing roughly two-thirds of "better looking [vein] material" assayed at 31.74% graphite. Considering that most graphite ore worked in Canada at that time ranged between 10 and 15%, significant interest was shown in the Golden Grove deposit.

Another sample from a former ore dump adjacent the shaft assayed 37.31% carbon. The textural properties of the graphite were examined and it was concluded that the graphite existed as "thin, ragged flakes" and any attempt to establish a marketable concentrate would most likely result in a very low recoveries of a very fine graphitic dust (Wright 1939).

No further interest was shown in the property until it was acquired 42 years later by Glenvet Resources Ltd. In 1982, Glenvet prepared a detailed geologic map of the property, undertook various geophysical investigations, dug several trenches, and conducted metallurgical testing of sampled material. Initial metallurgical test results were quite encouraging, suggesting an acceptable graphite product could be produced from the deposit (Anderle 1987; Tremblay and Riddell 1987).

A follow-up 22-hole drilling and trenching program to investigate the deposit at depth confirmed the existence of two main graphite zones with a total indicated geological reserve of 24 535 tonnes of 22.37% graphitic carbon (Tremblay and Riddell 1987). It was subsequently concluded that such a reserve was inadequate to support a commercial viable operation at that time. Additional work on the deposit was recommended but no further work was undertaken. Little interest has been shown in the deposit since 1987.

Other occurrences

Amorphous graphite occurrences in southern New Brunswick are locally associated with carbonaceous shales of the Ordovician Kendall

Flake graphite at Golden Grove near Saint John, N.B.

Mountain Formation and similar rocks of the Silurian Burtts Corner and Digdeguash formations. A few occurrences are reported in Early to Late Carboniferous carbonaceous sedimentary rocks, particularly from areas near prominent thrust faults.

Several minor graphite occurrences are noted in areas of northern New Brunswick. The Miramichi and the northern part of the Tobique-Chaleur geologic terranes display favourable geologic settings for graphite as an accessory to various forms of sulphide mineralization.

Summary

Graphite occurrences recorded in New Brunswick range from amorphous- to flake-type, reflecting the thermal effects of low- to high-grade metamorphism on organic-rich, carbonaceous sedimentary and carbonate rocks. On a regional scale, favoured geologic settings for the formation of graphite are areas where potential carbon-source rocks are found at or very near the fractured perimeter of plutonic rocks. Graphite is found as an accessory mineral locally in suitable host rocks near major regional fault systems. With one or two exceptions, most of these reported graphite occurrences must be considered limited in size and value in light of present industry standards and end-uses. Favourable geologic settings in some areas of New Brunswick suggest possibilities for extending the resource base of amorphous graphite with limited potential for higher quality flake material.

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For More Information

For more information on graphite and other New Brunswick mineral commodities, please see the NBDNR Mineral Occurrence Database (NBDNR 2009a) and Industrial Mineral Database (NBDNR 2009b), or contact:

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