New Nouveau Brunswick
Natural Resources
Lands, Minerals and Petroleum

Tungsten

Mineral Commodity Profile No. 7

Tungsten (W), from the Swedish *tung* (heavy) and Danish *sten* (stone), is a hard, ductile steel grey to greyish white metal. It has the highest melting point of all the non-alloyed metals, and is the densest metal used for everyday purposes. It also has the lowest vapour pressure and the highest tensile strength of all the non-alloyed metals at high temperatures. Tungsten is typically found in tungstate minerals that contain varying proportions of tungsten, iron, manganese, and calcium combined with oxygen; the most common ones are wolframite ($(Fe,Mn)WO_4$) and scheelite ($CaWO_4$) (International Tungsten Industry Association 2005).

Uses

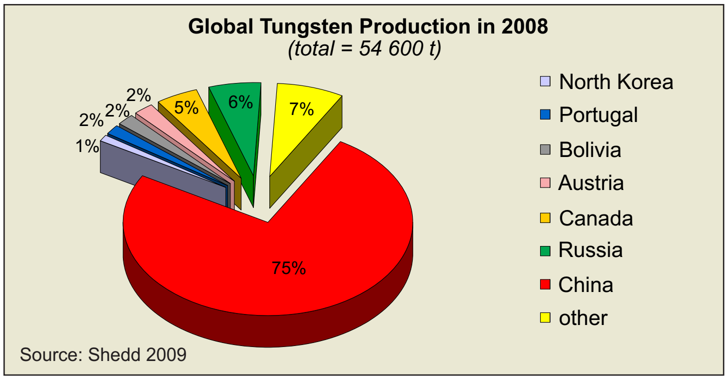
The pure form of tungsten, as well as its compounds and alloys, are used in the production of hardmetals (tungsten carbide), specialist steels, and in chemical applications. It is estimated that hardmetals utilize 60% of global tungsten production. Since hardmetals and specialist steels have high strength, hardness, heat tolerance, and wear and corrosive resistance, they are used to make cutting tools for mining and machining metals; stamping dies and hot rollers in steel mills; and turbine blades, rocket nozzles, space vehicle re-entry shields, exhaust gas assemblies, industrial furnaces, armour-piercing ammunition, and bearings. Other tungsten alloys are used in radiation shielding, high voltage switches, electrodes, and circuit breakers. The high melting point, conductivity, and ductility of pure metallic tungsten make it suitable for the production of incandescent light bulb filaments, x-ray and cathode-ray tubes heating elements, and electric circuit connections. Pure tungsten has a similar density to gold and can therefore be used in jewelry as an alternative to gold or platinum. It is ideal for making rings that will resist scratching, are hypoallergenic, and will not need polishing. In the chemical industry it is used in ceramic glazes and enamels, white pigments in paint, fireproofing of textiles, and in the production of semiconductor circuits (International Tungsten Industry Association 2005; Pitfield and Brown 2011).

The name tungsten is derived from both the Swedish *tung* and Danish *sten* meaning "*heavy stone*".

An American man named Irving Langmuir patented the tungsten filament lamp in 1916. This incandescent lamp used tungsten rather than carbon or other metals as a filament inside the light bulb. Soon after their invention, tungsten filament lamps completely replaced the inefficient and fragile carbon filament lamps.

World Production and Reserves

Global tungsten resources are estimated to be seven million tonnes. Tungsten is currently being produced in 20 countries with China ranking first in the world in terms of ore reserves and production. Canada, Russia, and Bolivia also have significant reserves and are major tungsten producers. In 2009, tungsten production totalled approximately 62 000 tonnes of metal. During the past several years, China has become the world's largest tungsten consumer because of rapid industrialization; therefore, export of the metal is now limited (Shedd 2009; Pitfield and Brown 2011).



Global Tungsten Production in 2008
(total = 54 600 t)

Source: Shedd 2009

Genesis of Tungsten Deposits

Tungsten mineralization is typically derived from granitic plutons found in a variety of tectonic environments including continental collision zones, continental rifts, and volcanic arcs along continental margins. Ages of these granites vary greatly, but in Canada, most are relatively young (geologically speaking) having been formed during Late Paleozoic to Cenozoic time. Generally, these granites are emplaced at moderate to high crustal levels in an environment that permits brittle fracturing and freer migration of metal-bearing fluids into surrounding country rocks (Kirkham and Sinclair 1996).

Tungsten is a highly incompatible element in evolved, silica-rich, granitic (72–77% SiO_2) magmas, and consequently, is progressively enriched in the hydrothermal fluid released from the cooling magma as it rises higher into the earth's crust. The circulating, metal-rich fluid becomes concentrated in the apices or in irregularities along the margins of the granite pluton as it crystallizes into a solid mass. Once the fluid pressure in the rising pluton exceeds the load pressure of the overlying country rocks, the tungsten (along with other metals such as tin and molybdenum) is deposited from these fluids in a variety of ways depending on the local geological conditions. Resulting styles of mineralization include stockworks and disseminations within a pluton (endogranitic-type deposits); massive quartz veins or stockworks that extend into the surrounding country rocks (vein-type deposits); and disseminations and stockworks in calcareous sedimentary horizons (skarn-type deposits) that act as chemical traps within the surrounding country rocks. Most of the tungsten is derived from within the granitic magma, but in some cases, a portion of the metal may have been leached from the surrounding country rocks as well. Such tungsten deposits generated from granitic sources can all be categorized as porphyry systems in the broader scheme of mineral deposit classifications (Strong 1985; Kirkham and Sinclair 1996).

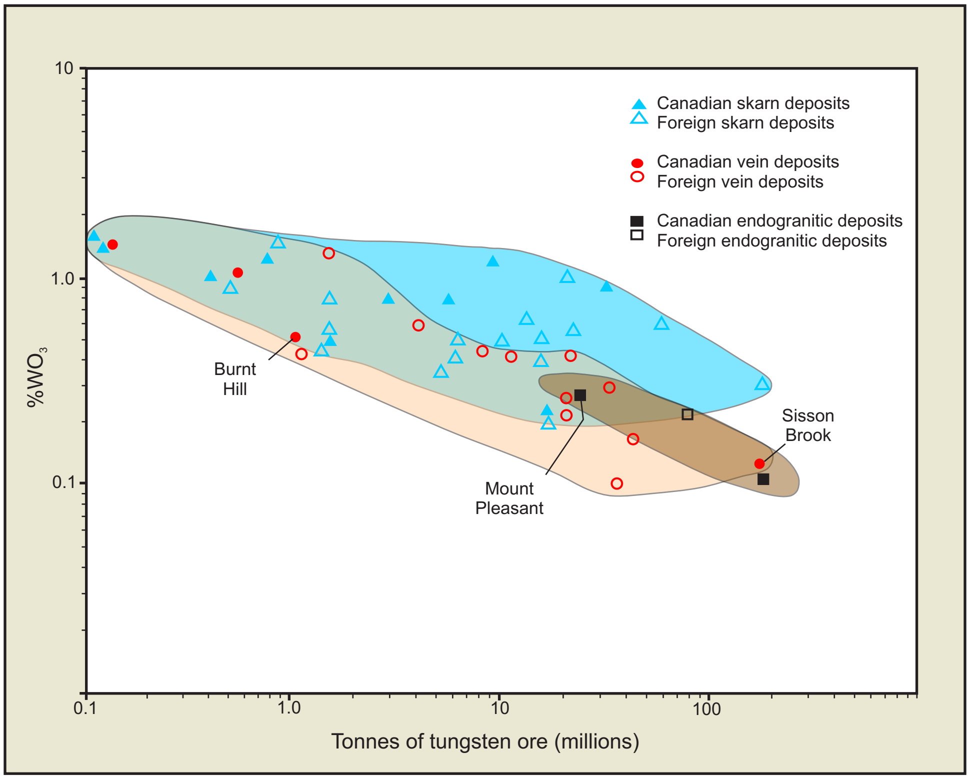


Figure 1. Grades and tonnages of Canadian and foreign tungsten deposits.

Among many other considerations such as location, depth of ore body below surface, and market and metal prices, basic factors that determine the economic viability of a specific tungsten deposit are its grade (% of metal) and tonnage In general, small tonnage deposits need to be of higher grade than those of large tonnage in order to become a mine. Although tonnages and grades vary widely, some general trends are evident among the different types of tungsten deposits in Canada and elsewhere (Fig. 1). Vein- and skarn-types are about equally represented in smaller tonnage deposits (i.e., those with less than a few million tonnes of ore), but the skarn-type tend to be richer in tungsten as the size of the deposit increases to the 100 million tonne range. The relatively few endogranitic-type deposits with tungsten as the primary ore metal tend to have sizable tonnages at low to moderate grades. Porphyry molybdenum and porphyry copper deposits, the latter of which are associated with silica-poor plutons (60–72% SiO_2), contain only very low-grade tungsten mineralization and are not plotted on the diagram.

History of Tungsten Discoveries in New Brunswick

In 1868, Dr. Charles Robb, a geologist with the Geological Survey of Canada, discovered molybdenite mineralization in quartz veins in the Burnthill Brook area of central New Brunswick, and later in 1910, Samuel Freeze discovered wolframite in the same area. Acadia Tungsten Mines Ltd. was formed in 1911, a road was built, a shaft was sunk, and some concentrate was sold to the imperial Munitions Board in 1915. Burnt Hill Tungsten Mines Ltd., formed in 1952, constructed an adit and new plant at the mine site, and sold about 22 000 kg of concentrate averaging about 69% WO_3 before ceasing production in 1956. Burnt Hill Tungsten and Metallurgical Ltd. sunk a new shaft in 1969. From 1972–80, Miramichi Lumber Company Ltd. conducted extensive surface drilling, underground bulk sampling, and constructed an on-site pilot plant. Currently, joint-venture partners Noront Resources Ltd. and Cadillac Ventures Inc. hold the property (Martin 2003; Puritch et al. 2009).

The Mount Pleasant deposit was discovered by Geochemical Associates in 1954 as a result of a regional geochemical survey. Mount Pleasant Mines Ltd. outlined significant tin mineralization in the North Zone in 1960 and developed an adit between 1962-65. In 1969, Sullico Mines Ltd. discovered tungsten-molybdenum mineralization in the Fire Tower Zone about a kilometre south of the North Zone. After acquiring the property in 1977 Billiton Canada Ltd. (Fig. 2) produced about 2000 tonnes of high-grade ore (70% WO_3) from the Fire Tower Zone between 1983-85, after which mining operations ceased due to low metal prices. Further exploration work was carried out by Lac Minerals Ltd. in 1985 and by Piskahegan Resources Ltd. in 1993. Adex Mining Inc. acquired ownership in 1995 and has since conducted definition drilling programs and metallurgical studies on the ore bodies (McCutcheon et al. 2010; New Brunswick Department of Natural Resources 2010).

Texasgulf Inc. discovered tungsten-molybdenum mineralization at Sisson Brook in west-central New Brunswick in 1979. The extent of the deposit was further delineated by Kidd Creek Mines Ltd. in 1981. Since 2004, Geodex Minerals Ltd. has carried out geological, geochemical, and geophysical surveys and an extensive drilling program on the deposit (Fyffe et al. 2009, 2010). Northcliff Exploration Ltd. acquired controlling interest in the property in 2010 and is currently conducting a feasibility study on the deposit.

The Lake George antimony deposit in southwestern New Brunswick (Fig. 3) was discovered by a Saint John prospector-lumber surveyor named John Henneberry in 1861 (Martin 2003). However, it was not until over a century later in the early 1980s that tungsten mineralization was found at Lake George during a drilling program by Consolidated Durham Mines and Resources Ltd. while exploring for additional antimony resources (Seal et al. 1985, 1987). Apocan Inc. has owned the property since 1990.

Mex Exploration Ltd. discovered base-metal sulfides in the Wildcat Brook area of southwestern New Brunswick (Fig. 3) in 1980, and subsequently found significant tungsten and molybdenum mineralization while following up on regional geochemical surveys. Annapolis Valley Goldfields Inc. acquired the property in 2005 after finding additional, heavily mineralized, molybdenum-bearing boulders in the area. Together with Golden Kamala Resources Inc., they continue to explore for additional tungsten, molybdenum, base-metal sulfides, and indium.

Figure 2. Aerial view of the Mount Pleasant mine site.

Indications of possible tungsten mineralization near Foster Lake in southwestern New Brunswick were first noticed during a geochemical sampling survey by Shell Canada Resources Ltd. in 1981. Later, regional surveys conducted by the federal and provincial governments verified the presence of geochemical anomalies in the area. Following up on these, prospector David Stevens staked claims over the anomalies in 2001 and discovered numerous scheelite-bearing boulders (Martin 2008). In 2008, Stevens discovered scheelite mineralization at Flume Ridge in southwestern New Brunswick (Fig. 3) while following up on regional geochemical and geophysical surveys of the area (Thorne 2009).

Types of Tungsten Deposits in New Brunswick

The distribution of tungsten deposits and occurrences in New Brunswick reveals a close spatial relationship to granitic plutons of Devonian age (Fig. 3). Currently, those at Sisson Brook and Mount Pleasant are considered to have economically viable reserves of tungsten and associated metals. The Burnthill deposit contains tungsten mineralization at relatively high grades but only a limited tonnage has been delineated to date. Several other prospects, including those at Wildcat Brook, Lake George, Flume Ridge, and Foster Lake, show potential for significant tungsten concentrations. The following classification scheme is based on the local style of tungsten mineralization that characterizes each deposit.

Vein-type Mineralization

The Sisson Brook vein-type deposit (Fig. 3) occurs along the eastern margin of an extensive belt of Late Silurian to Early Devonian plutonic rocks emplaced into a belt of Cambrian to Ordovician sedimentary and volcanic rocks in central New Brunswick about 60 km north of Fredericton (Nast and William-Jones 1991; Fyffe et al. 2008, 2009, 2010). The tungsten-molybdenum-copper (W-Mo-Cu) mineralization is

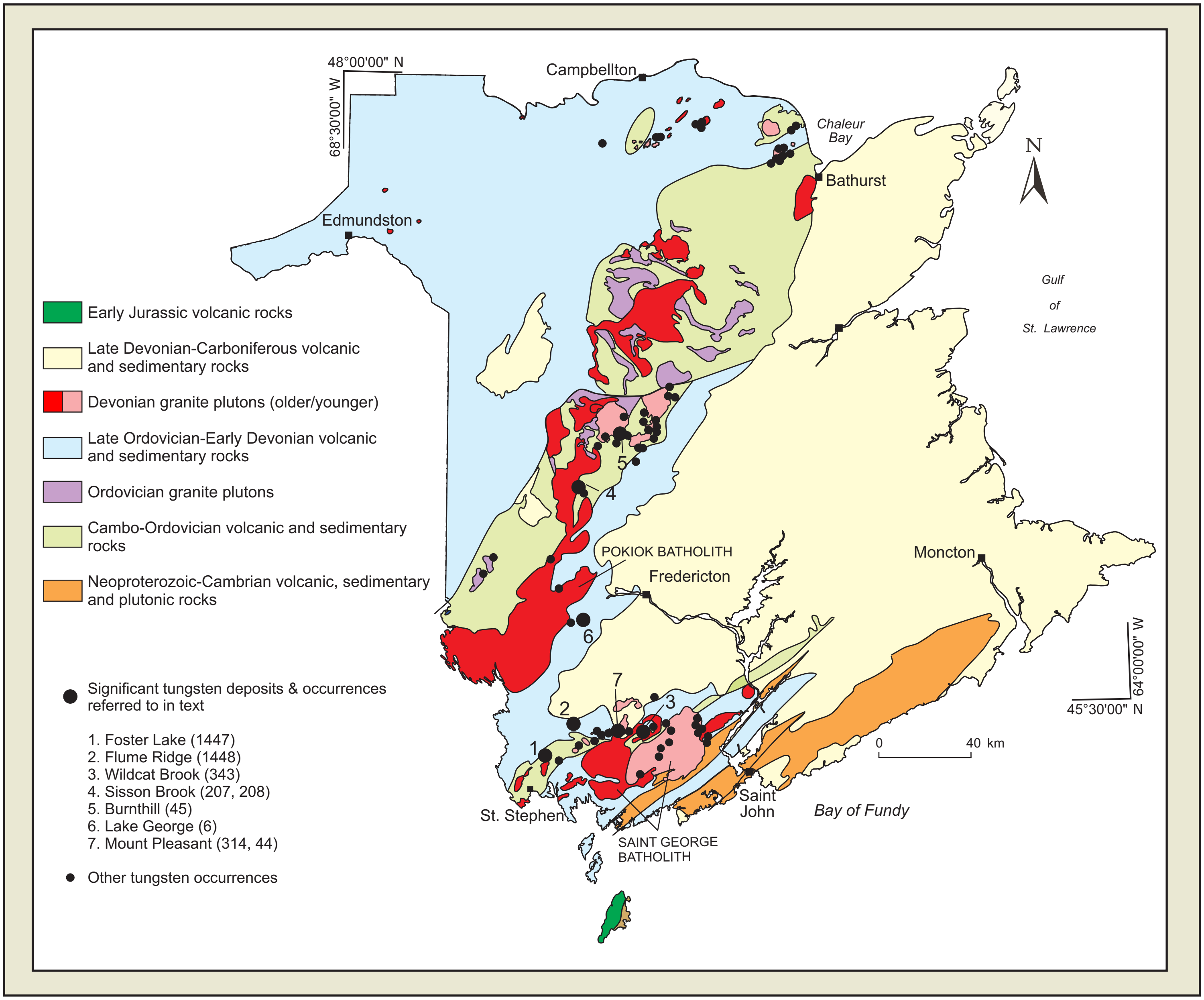


Figure 3. Distribution of tungsten deposits and occurrences in New Brunswick. The numbers in brackets refer to the Unique Record Number in the New Brunswick Department of Natural Resources Mineral Occurrence Database (NBDNR 2010).

interpreted to be related to a large, buried, younger (Middle to Late Devonian) granitic intrusion at depth beneath the deposit (Fyffe et al. 2008). The main zone of mineralization is hosted by sheared and silicified gabbroic rocks of the Early Devonian Howard Peak pluton and associated granitic veins that likely represent offshoots of the Early Devonian Nashwaak pluton exposed farther to the west. A system of mineralized stockwork veins and veinlets define a pod-shaped deposit that has been traced along strike for 1100 m with a maximum thickness of about 400 m. Scheelite and molybdenite are the predominant ore minerals with the deposition of the former being at least partly controlled by the calcium-rich nature of the gabbroic host rocks (Nast and William-Jones 1991). The main deposit is estimated to contain measured resources of 28.8 million tonnes grading 0.097% WO$_3$ and 0.034% Mo, indicated resources of 148.6 million tonnes grading 0.094% WO$_3$ and 0.030% Mo, and inferred resources of 69.0 million tonnes grading 0.086% WO$_3$ and 0.033% Mo at a cut-off grade of 0.100 WO$_3$ equivalent (WO$_3$ eq. = WO$_3$% + 2.02 Mo%) (Cullen and Harrington 2009). Wolframite and chalcopyrite mineralization occur in a highly silicified shear zone within an interbedded sequence of volcanic and sedimentary rocks to the north of the main mineralized zone. This near-vertical shear zone is a few tens of metres in thickness, strikes north-south, and has been traced along strike for about 950 m. The tungsten-bearing quartz veins in the shear zone range in width from about 0.5 to 3 cm, and contain an estimated resource of 6.8 million tonnes of 0.21% WO$_3$ and 0.35% Cu (Fyffe et al. 2010).

Several high-level, silica-rich Middle Devonian granitic plutons are known to have generated numerous occurrences of tungsten-tin-molybdenum (W-Sn-Mo) mineralization in the Burnthill area, located about 25 km northeast of the Sisson Brook deposit (Taylor et al. 1987; Fyffe et al. 2010).

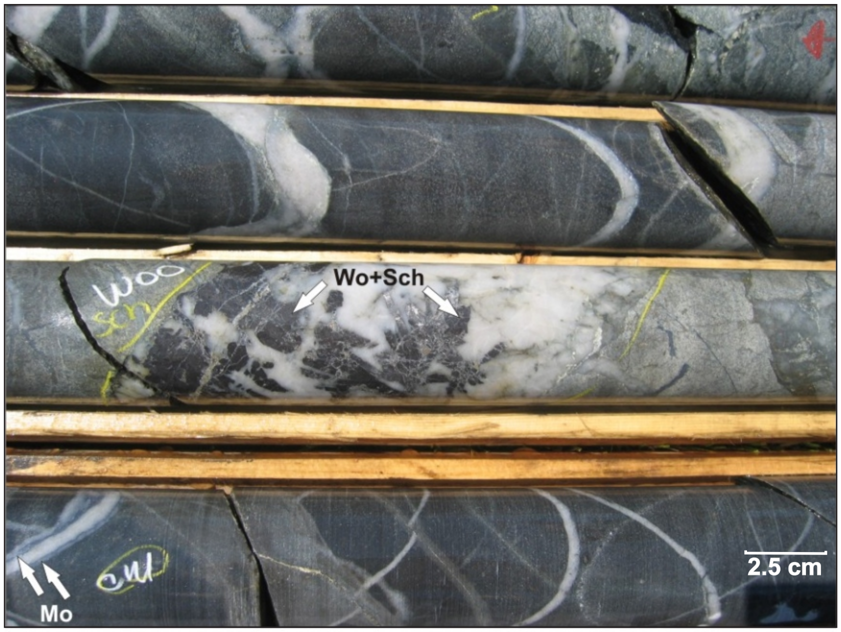


Figure 4. Wolframite (Wo), scheelite (Sch), and molybdenite (Mo) in quartz vein from the Wildcat Brook prospect.

The largest of these, the Burnthill deposit (Fig. 3), consists of numerous greisen-bordered, quartz veins with wolframite being the main tungsten-bearing mineral accompanied by variable proportions of molybdenite, scheelite, cassiterite, bismuthinite, base-metal sulphides, beryl, topaz, and fluorite. The quartz veins are steeply dipping, mostly southeast-trending, and range in width from a few centimetres to several metres. Mineralized veins cross-cutting a buried apical portion of the Burnthill pluton contain Mo-Sn whereas veins in the quartzose sedimentary country rocks above the pluton contain W-Mo-Sn. The mineralizating fluids are interpreted to be sourced directly from the Burnthill pluton (MacLellan and Taylor 1989; MacLellan et al. 1990). The W-Mo-Sn-bearing veins, concentrated in the sedimentary rocks above the apical part of the pluton, cover an area about 335 m long by 152 m wide and to a depth of 285 m. Open pit resources at Burnthill are estimated as indicated resources of 245 000 tonnes grading 0.530% WO_3, 0.012% MoS_2, and 0.012% SnO_2 and inferred resources of 38 000 tonnes grading 0.413% WO_3, 0.008% MoS_2, and 0.008% SnO_2 at a cut-off grade of 0.10% WO_3. Underground resources are estimated as indicated resources of 216 000 tonnes grading 0.440% WO_3, 0.011% MoS_2, and 0.007% SnO_2 and inferred resources of 552 000 tonnes grading 0.543% WO_3, 0.009% MoS_2, and 0.013% SnO_2 at a cut-off grade of 0.25% WO_3 (Puritch et al. 2009).

Endogranitic-type Mineralization in New Brunswick

The Mount Pleasant endogranitic-type, tin-tungsten-molybdenum deposit is associated with subvolcanic, silica-rich granitic plutons emplaced into the Late Devonian Mount Pleasant Caldera (Fig. 3), located along the northern flank of the Saint George Batholith in southeastern New Brunswick (McCutcheon et al. 1997, 2010). The apical parts of the subvolcanic plutons exhibit comb-quartz textures indicative of substantial hydrothermal fluid activity. The tungsten-molybdenum orebodies are concentrated in the Fire Tower Zone and are hosted by hydrothermal granite breccias that are altered to a quartz-topaz-sericite-fluorite greisen. Ore bodies are commonly ovoid and extend up to a few hundred metres in both their horizontal and vertical dimensions. The mineralization occurs as disseminated grains and rare coarse crystals of wolframite and molybdenite in fractures and in stockworks of quartz veinlets. Cross-cutting, chlorite-rich veins contain cassiterite, stannite, and base-metal sulphides (Kooiman et al. 1986). The Fire Tower Zone is estimated to contain indicated resources of 13 489 000 tonnes grading 0.33% WO_3 and 0.21% MoS_2 and inferred resources of 841 700 tonnes grading 0.26% WO_3 and 0.20% MoS_2 at a cut-off grade of 0.30% WO_3 equivalent (WO_3 eq. = WO_3% + 1.5 MoS_2%) (Dunbar et al. 2008).

The Wildcat Brook tungsten-molybdenum prospect in southwestern New Brunswick (Fig. 3) occurs within a roof pendant of Ordovician and Silurian sedimentary rocks surrounded by Early Devonian granitic rocks of the Saint George Batholith (McLeod 1991). The mineralization is hosted by both sedimentary country rocks and granitic dykes so exhibits features transitional between endogranitic- and vein-type deposits. The tungsten occurs as wolframite that is associated with greisen veins and stockworks of quartz veins and veinlets within the sedimentary rocks (Fig. 4). Hydrothermal breccia zones in the sedimentary rocks contain base-metal sulphides. Abundant porphyritic granite dykes, containing comb-quartz textures similar to those at Mount Pleasant, host disseminated molybdenum mineralization. Since the surrounding Early Devonian granitic rocks of the Saint George Batholith are not the highly evolved types that would produce such mineralization, the most likely source for the hydrothermal fluids is the porphyritic granite dykes likely derived from a younger (Late Devonian), more evolved granite pluton at depth (Thorne 2009).

Skarn-type Mineralization in New Brunswick

Skarn-type tungsten occurrences found in New Brunswick are similar to the vein-and endogranitic-types described above in that they are known or inferred to be generated from granitic plutons. However, unlike the latter types, the related plutons are not all as highly evolved (i.e., as silica-rich) in composition. Tungsten-molybdenum-antimony-gold mineralization at the Lake George mine in southeastern New Brunswick (Fig. 3) is associated with a buried Early Devonian granodioritic pluton (62–68 % SiO_2) that was emplaced into Silurian sedimentary rocks along the southeastern margin of the large Pokiok Batholith (Morrissy and Ruitenberg 1980; Scratch et al. 1984; Seal et al. 1985, 1987; Lentz et al. 2002; Yang et al. 2002). Both the apical part of the Lake George pluton, buried at a depth of 350 m, and the contact-metamorphosed, calcareous sedimentary rocks above the intrusion host the tungsten mineralization. Scheelite, along with molybdenite, accompanied by typical skarn-type (garnet, diopside, hornblende, clinozoisite, calcite) alteration assemblages (Dawson 1996), occurs as a stockwork of quartz veinlets and disseminations in the sedimentary rocks up to 750 m from the apex of the pluton. The scheelite-molybdenite mineralization at Lake George is considered to be the earliest in a protracted history of hydrothermal events related to the emplacement of the Lake George pluton, including the generation of antimony- and gold-bearing mineralization in the mine area.

Trenches excavated by Geodex Minerals Ltd. at Flume Ridge in southeastern New Brunswick (Fig. 3) revealed that scheelite mineralization occurs within Silurian calcareous sedimentary rocks in at least three generations of quartz veins and as disseminations (Thorne 2009). Despite the fact that plutonic rocks have not been found in the vicinity of the property to date, the presence of the tungsten-mineralized quartz-feldspar-muscovite-bearing veins, local intense alteration of the country rocks, and positive aeromagnetic anomalies on the property suggest such granitic source rocks could exist at depth. The veins and disseminations of scheelite in this environment suggest the possibility of a large, low-grade, skarn-type mineralizing system in the Flume Ridge area.

Tungsten skarn-type mineralization at Foster Lake occurs as scheelite in quartz veinlets, with or without carbonate and tourmaline, and as isolated grains along fractures and breccia zones mostly along contacts of the Foster Lake gabbroic pluton and the surrounding Ordovician sedimentary rocks (Fig. 3). Scheelite also occurs as disseminations within bands of skarn in the sedimentary country rocks and in pegmatitic granite boulders (Fig. 5). Drilling by Geodex Minerals Ltd. in 2007 intersected narrow zones of tungsten mineralization at depth (Martin 2008). The source of the mineralizing fluid has not been identified, but it may have been derived from the nearby Early Devonian Tower Hill granitic pluton (Thorne 2009).

Summary

Tungsten is a valuable mineral commodity that has been delineated in a variety of geological settings throughout New Brunswick (Fig. 3). It is evident that the younger, more highly evolved Middle to Late Devonian granites are capable of generating economically viable, vein- and endogranitic-type tungsten deposits. The older, less evolved, Early Devonian granitic plutons are also capable of generating significant concentration of tungsten, mainly as skarn-type mineralization.

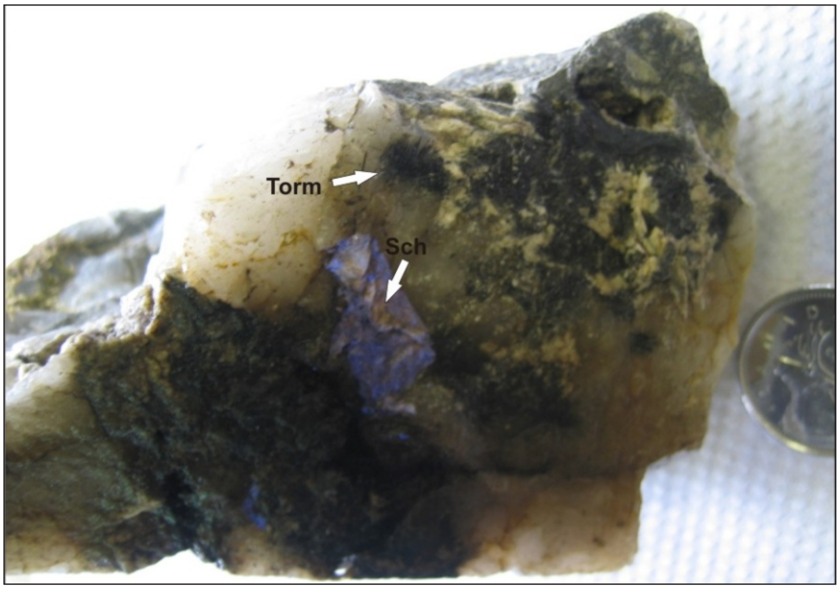


Figure 5. Scheelite (Sch) in tourmaline (Torm)-bearing pegmatite from the Foster Lake prospect. Note the coin for scale.

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For More Information

For more information on tungsten and other New Brunswick mineral commodities, please see the NBDNR Mineral Occurrence Database (NBDNR 2010) or contact:

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