

Gold (Au) is a rare, bright yellow metal with a high relative density of 19.3. It is soft, malleable, resistant to corrosion, and a good conductor of heat and electricity. Because of these properties, gold is a highly valued and sought-after commodity. Along with silver and platinum, gold is classified as a precious metal, distinct from the more common base metals such as copper, lead, and zinc. Gold does not readily react with other elements but can combine with tellurium, bismuth, antimony, and selenium to form some relatively rare minerals. Gold also forms a natural alloy with silver known as electrum but is more common in its native or pure state. Native gold can also occur as microscopic inclusions in sulphide minerals such as arsenopyrite, pyrite, stibnite, chalcopyrite, sphalerite, and galena (Gold Metallurgy 2011).

Uses

Its scarcity, inertness, high density, and ease of minting has made gold the world's main monetary standard (coinage) since historical times. By far the most common use of gold is for jewellery but it is also used in art, dentistry, electronics, medals, and in the aerospace industry.

World Production

Gold deposits are mined in several countries, and in 2009, global production of gold was on the order of 2,450 tonnes. China, the United States, Australia, South Africa, and Russia are the top producers followed by Peru, Indonesia, Canada, and Uzbekistan (USGS 2011). In Canada, approximately 90% of the gold production comes from underground and open-pit gold mines whereas the remainder is produced as a



A specimen, from the Hollinger Mine in Timmins, Ontario, Canada, of native gold in a quartz matrix.

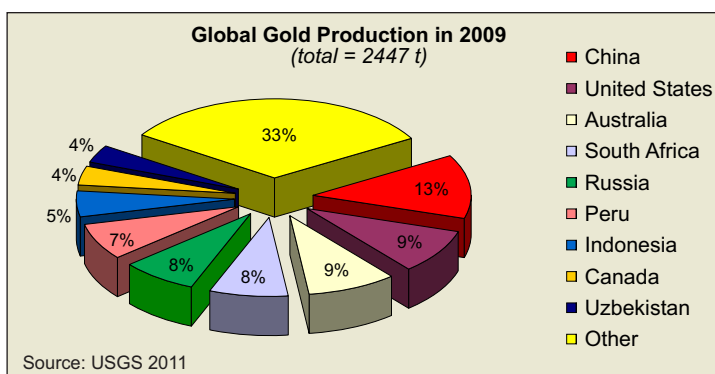
by-product from base-metal and placer mining operations (Natural Resources Canada 2011a). The provinces of Ontario, Quebec, and British Columbia account for the majority of Canada's gold production with reported outputs of 52.4 t (55%), 27.8 t (29%), and 7.8 t (8%), respectively in 2009. The Prairie and Atlantic Provinces together with the Yukon produced 8 t, accounting for the remaining 8% (Natural Resources Canada 2011b).



First produced by the Royal Canadian Mint in 1979, the Canadian Gold Maple Leaf Coin, which has a metallic composition of 99.99% gold, is the 24 Karat gold bullion coin of Canada. By law, the gold used to make the coins must be mined in Canada.

Gold Mining in New Brunswick

The main source of gold in New Brunswick has been as a by-product from the smelting of base-metal sulphide deposits including Brunswick, Caribou, and Murray Brook mines in the northern part of the province. About 200 kg of gold was recovered from Brunswick (5 on Fig. 1) base-metal concentrate in 2009 (Natural Resources Canada 2011c). From 1982 to 1983, about 250 kg of gold and 3300 kg of silver were produced from enriched gossan at Caribou Mine (3 on Fig. 1) The gold and silver were recovered using a heap-leach process and then melted together and poured into doré bars (Cavalero 1993). Between 1989 to 1992, NovaGold Resources Inc. recovered about 1400 kg of gold



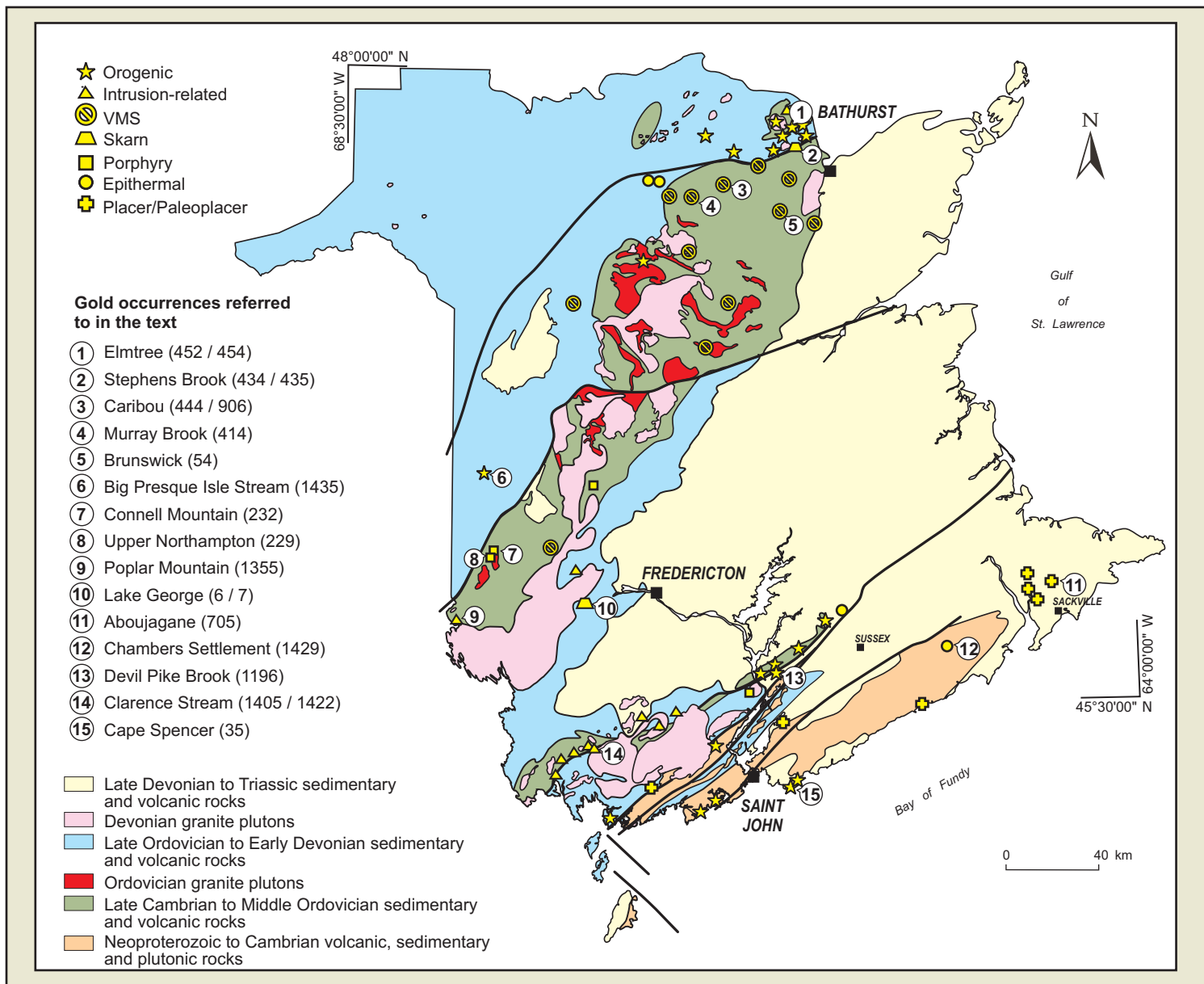


Figure 1. Geological map showing the distribution of various gold deposit types in New Brunswick. The numbers in brackets refer to the Unique Record Number in the New Brunswick Department of Natural Resources Mineral Occurrence Database (NBDNR 2011).

and 10 000 kg of silver from gossan at the base-metal Murray Brook Mine (4 on Fig. 1) (El Nino Ventures Inc., press release, May 11, 2011).

In 1986, the first doré bar was poured at the Cape Spencer Mine (15 on Fig. 1), located along the Fundy Bay coastline near Saint John, making it the first primary gold producer in New Brunswick. Operated by Gordex Minerals Ltd. until 1988, the mine produced approximately 150 000 grams of gold using a process similar to that at the Caribou Mine (NBDNR 2011). Currently, no primary gold is being mined in New Brunswick but exploration work at the Clarence Stream (14 on Fig. 1) and Elmtree (1 on Fig. 1) deposits continues to improve the economic viability of these two potential gold producers.

New Brunswick Gold Deposits

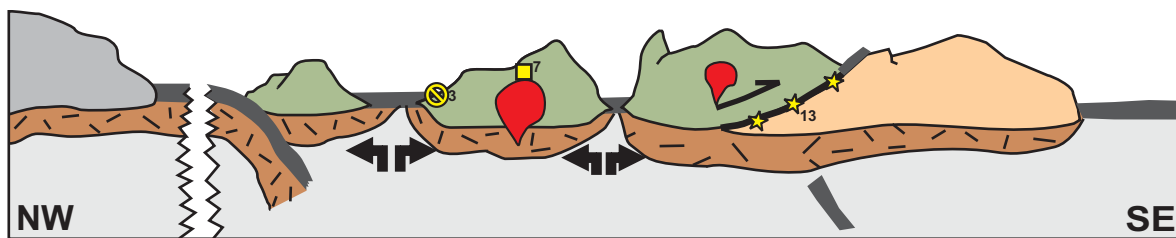
The diversity of geological environments throughout New Brunswick accounts for the many types of gold deposits

present in the Province. Many deposits were formed at different times throughout the formation and subsequent erosion of the Appalachian Orogen. Documented deposit types include: (1) orogenic, (2) intrusion-related, (3) gold-rich volcanogenic massive sulphide, (4) skarn, (5) porphyry, (6) epithermal, and (7) placer/paleoplacer deposits and smaller occurrences. Distribution of the most significant deposits in New Brunswick is shown in Fig. 1. The majority of these are focussed along large fault structures (some of which are major tectonic boundaries), and/or situated close to granitic plutons, exceptions being the volcanic massive sulphide and placer/paleoplacer types (Fig. 2). It is possible that other deposit types (i.e., iron oxide-copper-gold; abbreviated IOCG) are present; however, further geological investigations will be required to properly categorize them.

Orogenic Gold

The orogenic class of gold deposits is by far the most common deposit type found in New Brunswick. These deposits are

Early Paleozoic



Middle Paleozoic



Late Paleozoic



- | | | | |
|----------------------|-----------------|-------------------------|---------------------|
| ★ Orogenic | ▲ Skarn | ⊕ Placer/Paleoplacer | ▲ Intrusion-related |
| 1. Elmtree | 10. Lake George | 11. Aboujagane | 9. Poplar Mountain |
| 13. Devil Pike Brook | | | 14. Clarence Stream |
| 15. Cape Spencer | | | |
| ■ Porphyry | ⊙ VMS | ● Epithermal | |
| 7. Connell Mountain | 3. Caribou | 12. Chambers Settlement | |

Figure 2. Schematic tectonic model of New Brunswick gold deposit types.

typically situated along major faults where the gold has been mobilized and precipitated from fluids generated during deformational processes at relatively deep crustal depths. The variable styles of mineralization observed in these deposits are highly dependent on the pressure and temperatures at which gold deposition takes place. Styles of mineralization include stockworks, breccias, sheeted veins, quartz-carbonate veins, and as disseminations in host rocks (Groves and Phillips 1987, Goldfarb et al. 2005).

Orogenic gold systems throughout New Brunswick span several time periods that coincide with the various stages of tectonic activity related to the development of the Appalachian Mountain chain. Examples include the Devil Pike, Cape Spencer, and Elmtree gold deposits. The mineralization at the Devil Pike deposit (13 on Fig. 1) in south-central New Brunswick is hosted by a set of deformed en echelon 1–3 m wide quartz-carbonate veins that cross-cut Cambrian mafic volcanic rocks at an oblique angle to local structural features. Gold grades of up to 200 g/t have been reported in grab samples from mineralized bedrock exposed in trenches (PGE Resources Corp. 1993). Native gold is associated with pyrite, chalcopyrite, and tetrahedrite within alteration



Mineralized quartz-carbonate vein at the Devil Pike Brook occurrence.

halos characterized by carbonatization, silicification, chloritization, and hematitization (Lafontaine 2007).

At the Cape Spencer deposit (15 on Fig. 1) the mineralization is localized within a Carboniferous to early Permian fold-thrust belt situated along the northern coastal region of the Bay of Fundy (Watters 1993). Two styles of mineralization are recognized at Cape Spencer: (1) lower grade gold with pyrite in illite-altered, Neoproterozoic granitic rocks and possible Cambrian sedimentary rocks; and (2) higher grade gold in quartz veins associated with hematite and/or chalcopryrite (up to 27 g/t gold over 1.08 m). The gold is generally found as microscopic grains along the margins of pyrite, enclosed within pyrite, and also along fractures within pyrite (Stirling 1987, Watters 1993). The Cape Spencer deposit contains an estimated mineral resource of 937 200 tonnes grading 1.85 g/t gold (O'Sullivan 2006).

The Elmtree deposit (1 on Fig. 1) is structurally controlled by an easterly trending fault zone (Schwarz et al. 2007). Host rocks consist of strongly deformed Ordovician gabbroic dykes that intrude Ordovician sedimentary rocks. The highest gold grades are associated with sulphide-rich zones peripheral to areas of intense silicification and quartz veining within the gabbro (Ruitenbergh et al. 1989). The gold occurs as free grains (<10 µm) commonly attached to pyrrhotite that occupies fractures in pyrite, arsenopyrite, and pyrrhotite; and as tiny inclusions in arsenopyrite (Harris 1986). The Elmtree deposit contains an estimated mineral resource of 1.12 million tonnes grading 2.4 g/t gold (Castle Resources, press release, July 21, 2010).

Gold mineralization along the Trans Canada Highway, near Big Presque Isle Stream (6 on Fig. 1), may represent an example of a relatively high-level orogenic gold system. The mineralization consists of disseminated sulphides (arsenopyrite, pyrite, chalcopryrite), commonly bordering quartz-carbonate veins hosted by a mafic dyke swarm cross-cutting Late Ordovician calcareous shale. The dykes are concentrated in the vicinity of a major fault that likely played a major role in controlling the emplacement of the dykes and subsequent mineralizing fluids. Altered mafic grab samples from the area contain 3.8 g/t gold over 7 m (Stratabound Minerals Corp., press release, April 9, 2007) and 6.31 g/t gold over 4.8 m (Stratabound Minerals Corp., press release, May 2, 2007). The timing and source of this mineralization is yet to be established.

Intrusion-Related Gold

Intrusion-related gold (IRG) deposits are genetically related to syn- to post-collisional granitic plutons. The gold-bearing hydrothermal fluids tend to be elevated in granophile elements such as tungsten, molybdenum, antimony, tin, bismuth, and arsenic, and low in base metals and sulphur in contrast to gold-rich porphyry copper deposits (e.g., Thompson et al. 1999). Gold in these deposits is typically associated with arsenopyrite, pyrrhotite, and pyrite. Mineralization styles are variable and largely dependent on the depth at which the mineralizing event occurs and proximity to the pluton. Endogranitic deposits formed at shallow crustal levels are associated with stocks, sills, and dykes with the gold mineralization occurring in stockworks, breccias, and veins; those formed at deeper levels occur as sheeted veins, greisens, and disseminations. Exogranitic vein deposits formed in the surrounding country rocks are generally controlled by structural features that vary in style from brittle to ductile depending on the temperature and pressure conditions existing at the time of the mineralizing event.

In southwestern New Brunswick, IRG systems are associated with Late Silurian to Early Devonian post-orogenic granitic intrusions. Typically, mineralization is fault-controlled and has a gold-arsenic-antimony association. The best example of this type of deposit in New Brunswick is the Main Zone of the Clarence Stream gold deposit (14 on Fig. 1), where a direct granite-gold genetic relationship has been established (Thorne et al. 2008). Mineralization comprising several subzones is concentrated along a brittle-ductile shear zone that parallels the northern margin of an Early Devonian pluton (Fig. 2). Gold mineralization occurs within quartz veins and as disseminations within Silurian sedimentary and gabbroic host rocks, and within granitic pegmatite-aplite dykes that grade laterally into auriferous quartz veins. Native gold, gold-stibnite intergrowths, and aurostibite associated with berthierite, pyrrhotite, and arsenopyrite comprise the bulk of the gold mineralization. Only minor amounts



The first doré bar poured at the first primary gold producer in New Brunswick - the Cape Spencer Gold Mine, operated by Gordex Minerals Ltd.

of gold are bound within the crystal lattice of zoned arsenopyrite crystals. Geochemical, geochronological, and isotopic investigations provide supporting evidence for a magmatic source for the mineralizing fluids, more specifically the fluids related to the cooling of the nearby granitic pluton (Thorne et al. 2002, Thorne and McLeod 2003, Thorne et al. 2008). The various subzones that comprise the Main Zone contain an estimated mineral resource of 1 627 000 tonnes grading 6.48 g/t gold (Portage Minerals Inc., press release, April 18, 2011).

The Poplar Mountain gold deposit (9 on Fig. 1), located in west-central New Brunswick, is hosted mainly by a massive, porphyritic felsic volcanic dome emplaced into a sequence of felsic volcanoclastic rocks and breccia, and overlying massive to subordinate fragmental mafic volcanic rocks. The age of these volcanic and volcanoclastic rocks are known only to be no older than Middle Ordovician and no younger than Early Devonian on the basis of radiometric dating. The gold mineralization is associated with arsenopyrite that occurs as disseminations in the volcanic host rocks, in stockworks, and in narrow quartz-carbonate-sericite veins. Minor sphalerite and stibnite are present in some of the veins. Radiometric dating of sericite from a vein suggests an Early Devonian age for the mineralizing event (Chi et al. 2008). Fluid-inclusion studies indicate that the hydrothermal fluids were generated at relatively high pressure and may have been derived from a buried granitic pluton (Chi et al. 2008). The Poplar Mountain deposit contains an estimated mineral resource of 11 640 000 tonnes grading 0.96 g/t gold (Portage Minerals Inc., press release, April 26, 2011).

Gold-Rich Volcanogenic Massive Sulphide

Volcanogenic massive sulphide (VMS) deposits are accumulations of sulphide minerals precipitated onto an ancient ocean floor from a subaqueous volcanic centre. Reactions between seawater and metal-bearing fluids from the associated hydrothermal systems precipitate metallic minerals rich in copper, lead, and zinc as well as bismuth, antimony, cadmium, silver, and gold. Two mineralization styles are common: (1) massive sulphide lenses underlain by a feeder system of (2) vein-type sulphide mineralization, referred to as the stringer or stockwork zone. Pyrite is the most common sulphide present but sphalerite, galena, and chalcopyrite are also abundant.

Numerous VMS deposits are located in the northern part of New Brunswick (Fig. 2) within Middle Ordovician volcanic and sedimentary sequences that comprise the Bathurst Mining Camp. The Bathurst Camp contains some 30 massive sulphide deposits with defined tonnages, and approximately 60 other occurrences (McCutcheon et al. 1997). Many of these contain significant quantities of gold (0.85 g/t gold on average) largely as microscopic inclusions within pyrite and arsenopyrite (McClenaghan et al. 2003). The giant Brunswick Mine (5 on Fig. 1) is by far the largest VMS deposit (230 Mt) in



the Bathurst Camp and is the largest underground base-metal operation in the world. The deposit contains an average grade of 0.67 g/t gold (Martin 2006), and is recovered as a by-product from smelting of the base-metal concentrate. The Caribou VMS deposit (3 on Fig. 1) contains the highest average gold grade in the Bathurst Camp at 1.72 g/t (Goodfellow and McCutcheon 2003) with values locally exceeding 6 g/t (McClenaghan et al. 2003). An enriched gossan cap overlying the Caribou ore body contained gold at a grade of 6 g/t and silver at a grade of 250 g/t (Cavalero 1993). The Murray Brook VMS deposit (4 on Fig. 1) contains among the lowest average gold grades in the Bathurst Camp at 0.16 g/t (Goodfellow and McCutcheon 2003). Precious metal reserves in the gossan at Murray Brook were estimated at 1 700 000 t grading 1.51 g/t Au and 46.3 g/t Ag (Gardiner 1989).

Gold Skarn

“Skarn” refers to a metamorphic rock containing the minerals garnet and pyroxene. These high-temperature minerals commonly form in carbonate-rich bedrock surrounding plutons emplaced at considerable depth in the earth’s crust. Skarns may also form along faults and major shear zones, in shallow geothermal systems, on the sea floor, and in deeply buried metamorphic terranes (Meinert et al. 2005). Under certain conditions, gold mineralization in association with arsenopyrite, pyrrhotite, pyrite, or chalcopyrite may be deposited during skarn development.

In New Brunswick, examples of gold skarn mineralization include the Stephens Brook prospect and Lake George deposit. The Stephens Brook occurrence (2 on Fig. 1), in the northern part of the Province, contains anomalous gold (up to 347 ppb; Brunswick Mining & Smelting 1987) hosted by skarn developed in limestone and carbonate-bearing siltstone peripheral to a Devonian granodioritic pluton. Higher grade gold mineralization (up to 1.5 g/t Au over 0.25 cm; Brunswick Mining & Smelting 1987) is associated with cross-cutting arsenopyrite-rich veins containing pyrite, carbonate, and sphalerite. At the former Lake George antimony mine (10 on Fig. 1), southwest of Fredericton, gold mineralization occurs in skarn and later quartz-carbonate

Epithermal Gold

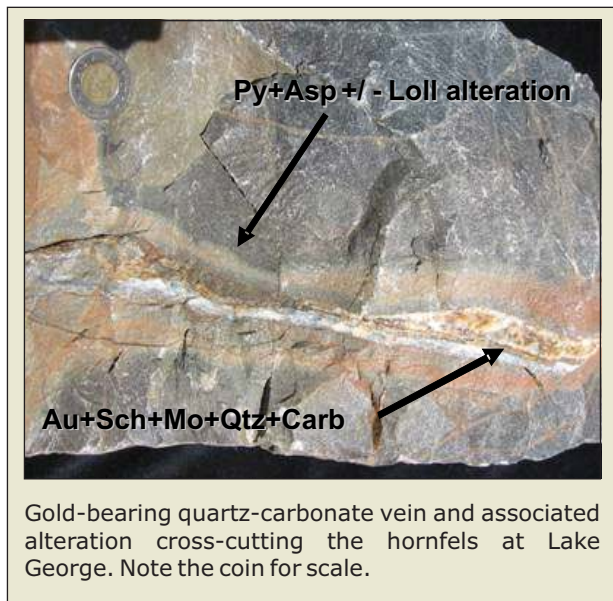
Epithermal deposits form at relatively shallow crustal depths from low temperature fluids that are convectively circulated through host rocks by heat related to nearby subvolcanic intrusions. Large zoned alteration haloes (created over areas from 1 to >100 m laterally) are characteristic of this deposit type and are key to honing in on the mineralized areas of a hydrothermal system (Hedenquist 1987). Epithermal deposits are generally formed in an extensional volcanic arc environment. In some cases, these deposits may overlie sizable porphyry copper deposits. Typically, they have a metal assemblage consisting of gold, silver, copper, and arsenic (Sillitoe and Hedenquist 2003). The majority of the native gold mineralization occurs with pyrite in irregularly shaped quartz-flooded zones, breccia zones, or pipes associated with steeply dipping faults at the core of these systems (Simmons et al. 2005). Veins located near the lower limits of these deposits are generally enriched in base metals and silver with minimal quantities of quartz whereas the veins located in the upper portions of the system tend to be wider and are gold- and quartz-rich (Corbett 2002).

The Chambers Settlement occurrence (12 on Fig. 1), located east of Sussex, is an example of an epithermal gold system. The old shaft and adit at the former Watson Silver Mine are still visible in the vicinity of the occurrence. An intense alteration zone, hosted by Neoproterozoic volcanic rocks, typically includes such minerals as quartz, pyrophyllite, kaolinite, topaz, alunite, and specularite. Highly siliceous sericitic, pyrite-rich rocks collected from the area surrounding the old adit yielded approximately 1 g/t gold (Geodex Minerals 2006).

Placer/Paleoplacer

Gold placer deposits are formed from the erosion of pre-existing auriferous deposits (i.e., gold-bearing quartz veins) in nearby bedrock, mainly as a result of glacial and fluvial processes. Weathering processes liberate the gold from the host rock by breaking down the less resistant rock-forming minerals. The high density of gold prevents it from being transported over great distances. Thus, larger placer deposits tend to form closer to the bedrock source and the particle size of the gold (and hence the grade) decreases away from the source. Placer deposits consist of gold nuggets and flakes contained within relatively recent deposits of unconsolidated sands and gravels. Gold deposits in lithified bedrock, formed by the same erosional mechanism in much older geological time periods, are referred to as paleoplacers.

Placer occurrences occur along the Bay of Fundy at Taylors Island, Musquash Harbour, and Big Salmon River, and further inland at New River and Lepreau River. Panned gold flakes up to 5 mm long have been reported from these rivers (Hay 1968). The Aboujagane occurrence (11 on Fig. 1), north of Sackville, is the best example of a paleoplacer occurrence in New Brunswick. Historic records indicate that Dome Exploration Ltd. (1964) obtained a drill intersection of 6 g/t gold over 1.4 m in Carboniferous grey sandstone and shale. Later investigations in the area uncovered a grab sample of sandstone that yielded up to 11.5 g/t gold (Johnson and McLeod 1998). Petrographic examination of this sample revealed the presence of native gold within quartz grains that comprise the sandstone. These quartz grains were likely derived from erosion of pre-existing gold veins formed in pre-Carboniferous bedrock. A high-grade gold-bearing, hematitized quartz boulder, containing up to 1320 g/t gold, was found along Harry Brook, north of Sussex (Johnson 2005). The source of this loose boulder remains questionable but similar quartz clasts (although barren of gold) are contained in nearby exposures of Carboniferous conglomerate, suggesting the possibility that local bedrock may be host to a paleoplacer deposit.



Gold-bearing quartz-carbonate vein and associated alteration cross-cutting the hornfels at Lake George. Note the coin for scale.

veins surrounding a buried Devonian granodioritic pluton (Lentz et al. 2002). Samples collected from underground workings carried gold grades up to 15.3 g/t Au (Morrissy 1991). The gold at Lake George occurs as microscopic inclusions in pyrite and arsenopyrite (Procyshyn and Morrissy 1990).

Porphyry Gold

Porphyry gold deposits are defined as large-tonnage, low-grade deposits occurring within and along the margins of fine-grained, porphyritic granodioritic intrusions. Porphyry systems are typically formed in arc settings along subducting plate margins where high-level, silica-rich magmas are generated (Sillitoe 1972, 1976). During the later crystallization stages of the magma, hydrothermal fluids deposit ore minerals as disseminations within stockworks and breccias in highly altered host rocks (Seedorff et al. 2005). Intrusion of several generations of dykes and small plugs may take place during and after ore deposition. Zoned alteration patterns are characteristic of porphyry systems and serve as valuable exploration tools.

Anomalous quantities of gold occur at Connell Mountain (7 on Fig. 1) in west-central New Brunswick. Gold assays up to 1.3 g/t gold have been obtained from gossanized quartzose sandstone within the roof pendants along the northeastern margin of an Ordovician granodioritic pluton. Significant gold mineralization is also found at the Upper Northampton occurrence (8 on Fig. 1), located along the eastern margin of the pluton (Fig. 2). Here gold mineralization assaying up to 6 g/t gold is contained in north-trending quartz veins, from 1–35 cm wide, occupying a fault zone within altered granodiorite. The gold mainly occurs as native gold grains within quartz but is also found as inclusions in pyrite, at pyrite grain boundaries, and in fractures within pyrite (Thomas and Gleeson 1988).

Summary

New Brunswick's geological diversity has provided favourable conditions for the generation of several types of gold deposits in this part of the Appalachian Orogen. The majority of these deposits were formed in response to two main geological events: (1) when the Iapetus ocean basin, volcanic arcs, and back-arc basins were opening during the Neoproterozoic to early Paleozoic (Cambrian to Ordovician); and (2) when the ocean closed, and deformation, uplift, and juxtaposition of various tectonic blocks took place later in the Paleozoic (Silurian to Permian). Only minor epithermal gold mineralization has been found associated with arc-related Neoproterozoic volcanic rocks. Gold-rich volcanic massive sulphide (VMS) deposits were deposited during the Ordovician in a back-arc basin environment. Later, orogenic gold deposits were formed and focussed along major fault structures related to ocean closure and development of accretionary complexes spanning Silurian to Permian time. Intrusion-related and skarn gold deposits were generated along with the large volumes of post-orogenic magma mainly during the Late Silurian to Early Devonian, while porphyry gold mineralization is found in both Ordovician and Devonian plutons. Some relatively minor paleoplacer gold occurrences, formed during erosion of the Appalachian mountain chain in the Late Carboniferous, may exist in the younger sedimentary rocks that cover much of eastern New Brunswick (Fig. 1).

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High-grade gold-bearing hematitized quartz boulder discovered on Harry Brook. A sample containing visible gold returned a value of 1320 g/t. Au. Note the coin for scale.

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For More Information

For more information on gold and other New Brunswick mineral commodities, please see the NBDNR Mineral Occurrence Database (NBDNR 2011) or contact:
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