MINERAL COMMODITIES OF NEWFOUNDLAND AND LABRADOR

COPPER

Newfoundland Labrador
Natural Resources
Mines Branch

Geological Survey
Mineral Commodities Series
Number 3

Mineral Commodities of Newfoundland and Labrador

Copper

Foreword

This is the third in a series of summary publications covering the principal mineral commodities of the Province. Their purpose is to act as a source of initial information for explorationists and to provide a bridge to the detailed repository of information that is contained in the maps and reports of the provincial and federal geological surveys, as well as in numerous exploration-assessment reports. The information contained in this series is accessible via the internet at the Geological Survey of Newfoundland and Labrador web site http://www.nr.gov.nl.ca/mines&en/geosurvey/

Publications in the Series

Zinc and Lead (Number 1, 2000); Nickel (Number 2, revised 2005);
Copper (Number 3, revised 2005, 2007); Gold (Number 4, 2005); Uranium in Labrador (Number 5)

Additional Sources of Information

Further information is available in the publications of the geological surveys of Newfoundland and Labrador and Canada. The Geological Survey of Newfoundland and Labrador also holds a considerable inventory of exploration-assessment files available for onsite inspection at its St. John's headquarters and for download via the Geological Survey of Newfoundland and Labrador web site http://www.nr.gov.nl.ca/mines&en/geosurvey/. Descriptions of individual mineral occurrences are available through the provincial Mineral Occurrence Database System (MODS), which is accessible from the Survey's web site. Up-to-date overviews of mining developments and exploration activity targeting copper are available on-line at http://www.nr.gov.nl.ca/mines&en/

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NOTE

DISCLAIMER

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Front Cover: Chalcopyrite-rich ore from the Buchans deposits, enlarged 2x.

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Introduction

Copper is the third most important metal to have been produced in Newfoundland and Labrador (after iron and zinc), but for a while in the late 19th and early 20th centuries it was the dominant metallic commodity. Historical production is estimated at 650 000 tonnes of copper but present and future developments at Duck Pond and Voisey's Bay may produce up to an additional 1.4 million tonnes. It is noteworthy that the Voisey's Bay deposit alone has the capacity to almost double the province's historical copper production (Table 1).

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Copper was first discovered in Newfoundland ca. 1776, but did not come into commercial prominence until the discovery of the copper deposits of Notre Dame Bay in the late 1850s. Tradition relates that this discovery came about when a prospector identified the ballast of a local fishing boat as copper ore. This ushered in the Newfoundland copper boom of 1875 to 1914, during which period Newfoundland ranked, for a while, as the world's sixth largest copper producer. Notre Dame Bay mines such as Tilt Cove (Figure 1), Betts Cove and Little Bay, which exploited small, but high-grade, deposits were prominent features of this boom. In 1928, the focus of copper production switched to central Newfoundland following the discovery of the Buchans volcanic-hosted Zn–Cu–Pb–Au deposits. These deposits remained in production until their eventual depletion in 1984 and formed the major single source of copper production in the province. A new surge of exploration in the 1950s and 60s led to reactivation of the Tilt Cove and Little Bay mines (1957–1969), the development of the Whalesback, Gullbridge and Little Deer mines (1965–1974), and also to the discovery of the Rambler deposits which were in production from 1964 to 1982. Since 1984, only small amounts of

Table 1. Principal remaining copper resources of Newfoundland and Labrador (2005 figures)

DEPOSIT NAME	RESERVES (TONNES)	AVERAGE GRADES and CONTAINED COPPER (TONNES)
Ophiolitic volcanic-hosted		
York Harbour	**255 000**	**2.68% Cu (6835);** 8.25 % Zn; 340 g/t Ag; <1.0 g/t Au;
Little Deer	**210 200**	**1.53% Cu (3220)**
Miles Cove	**200 000**	**1.45% Cu (2900)**
Colchester	**1 000 000**	**1.3% Cu (13 000)**
Arc volcanic-hosted; copper dominated		
Skidder	**900 000**	**2% Cu (18 000);** 2% Zn;
Ming Footwall (Rambler Camp)	**3 000 000**	**1.6% Cu (48 000)**
Great Burnt Lake	**762 000**	**2.55% Cu (19 430)**
South Pond	**293 000**	**1.3% Cu (3809)**
Lockport	**200 000**	**0.75% Cu (1500)**
Jacks Pond	**200 000 - 900 000**	**1.0% Cu (2000 - 9000)**
Victoria Mine	**55 000**	**2.6% Cu (1430)**
Little Sandy	**100 000**	**1.5% Cu (1500)**
Gullbridge	**100 000**	**2.0% Cu (2000)**
Pilley's Island	**1 159 010**	**1.23% Cu (14 255)**
Arc volcanic-hosted; zinc dominated		
Lake Bond	**1 325 900**	**0.38% Cu (5038);** 2.6% Zn
Point Leamington	**13 800 000**	**0.48% Cu (66 240);** 2.25% Zn, 18.1 g/t Ag, 0.9 g/t Au
Tulks Hill	**720 000**	**1.3% Cu (9360);** 5.6% Zn, 2% Pb, 41 g/t Ag, 0.4 g/t Au
Tulks East	**5 000 000**	**0.24% Cu (12 000);** 1.5% Zn, 0.12% Pb, 8.5 g/t Ag
Long Lake	**560 000**	**2.2% Cu (12 320);** 16.0% Zn, 1.3% Pb, 38 g/t Ag, 0.9 g/t Au
Hoffe's Pond	**1 233 000**	**1.06% Cu (13 070);** 6.91% Zn, 0.71% Pb, 16.8 g/t Ag, 0.2 g/t Au
Duck Pond and Boundary	**4 100 000**	**3.3%Cu (135 300);** 5.7% Zn, 59 g/t Ag, 0.9 g/t Au
Strickland (Cu zone)	**750 000**	**2.5% Cu (18 750)**
Mafic intrusion-hosted		
Voisey's Bay total	**137 000 000**	**0.85% Cu (1 164 500);** 1.65% Ni, 0.09% Co
Voisey's Bay, ovoid only	**32 000 000**	**1.68% Cu (537 600);** 2.83 % Ni, 0.1% Co

Note: Many of these are historical resource figures and thus predate NR 43-101.

Figure 1. *Newfoundland stamp of 1897, featuring miners at the Tilt Cove Mine; the first ever issued to commemorate mining.*

copper had been produced, as a by-product of gold mining at Hope Brook (1993–97), and also from a brief period of production (1995–96) at the Ming West (Rambler camp) deposit. However, new discoveries have been made at Duck Pond (1986) in Newfoundland, and Voisey's Bay (1994) in Labrador, both of which are now in production.

Copper is found in a number of mineralization environments that are described below.

Volcanic-Hosted Mineralization Environments

These environments are represented principally by the volcanic terranes of the Dunnage Zone in central and northern Newfoundland (Figures 2 and 3) but examples are also present in the Humber Zone of western Newfoundland, the Avalon Zone of eastern Newfoundland and the Nain Province of eastern Labrador.

The Dunnage Zone is an important volcanogenic massive sulphide district that contains more than 20 deposits of over 200 000 tonnes previous production or reserves (Table 1). It represents a collage of Cambro-Ordovician island-arc terranes, constructed on a substrate of ophiolitic oceanic crust, and structurally juxtaposed during Late Ordovician to Early Silurian ocean closure. The suture is the Red Indian Line (Figure 3). The arc terranes display an overall evolutionary trend from primitive- to mature-arc environments, usually associated with increasing proportions of calc-alkalic felsic volcanic rocks.

> *Tilt Cove was the largest deposit of its type in the Appalachian belt. Over 100 other similar occurrences exist within the northwestern Dunnage Zone making this one of the most richly mineralized parts of Newfoundland.*

The ore deposits are grouped into ophiolitic volcanic-hosted and arc volcanic-hosted environments (Figure 3). Geochemical studies have demonstrated that the most prospective rocks are those that have an arc signature and which also most likely developed during periods of arc rifting.

Ophiolitic volcanic-hosted environments are found predominantly within the sheeted dyke and overlying pillow lava components of the ophiolite complexes, most of which contain geochemical evidence for a supra-subduction zone setting. Deposits of this environment are concentrated in the Betts Cove complex and Lushs Bight Group (Figure 3) where they are characterized by simple chalcopyrite–pyrite± sphalerite mineralization of the so-called "Cyprus-type". Mineralization forms stringer and stockwork zones, and massive lenses. Gold has locally been recovered as a by-product but, with the exception of zinc, other metals are generally absent. Deposits are typically ellipsoidal and strongly deformed. Many are associated with high-magnesium basalts (boninites) and some also seem to favour the sheeted dyke–pillow lava contact or specific horizons within the pillow lavas (Figure 4). Chlorite schist is a common host rock and probably represents deformed hydrothermal alteration pipes.

Notable early producers (Figure 3) were Tilt Cove, Betts Cove, Terra Nova and Little Bay, followed in the 1960s by Whalesback and Little Deer. These mines, together with other smaller and short-lived operations, produced a total of 280 000 tonnes of copper during their life. Tilt Cove was the largest deposit of its type in the Appalachian belt, having produced about 8 million tonnes of ore at grades that varied from 4 to 6% in its early days, to 2% in its later period. Over 100 similar occurrences exist within the northwestern Dunnage Zone, making this one of the most richly mineralized parts of Newfoundland. Another example of this deposit type is the York Harbour Mine, which occurs in the Humber Zone of western Newfoundland (Figure 2). Reserves remain at York Harbour, Little Deer, Miles Cove and Colchester (Table 1), but are low in grade.

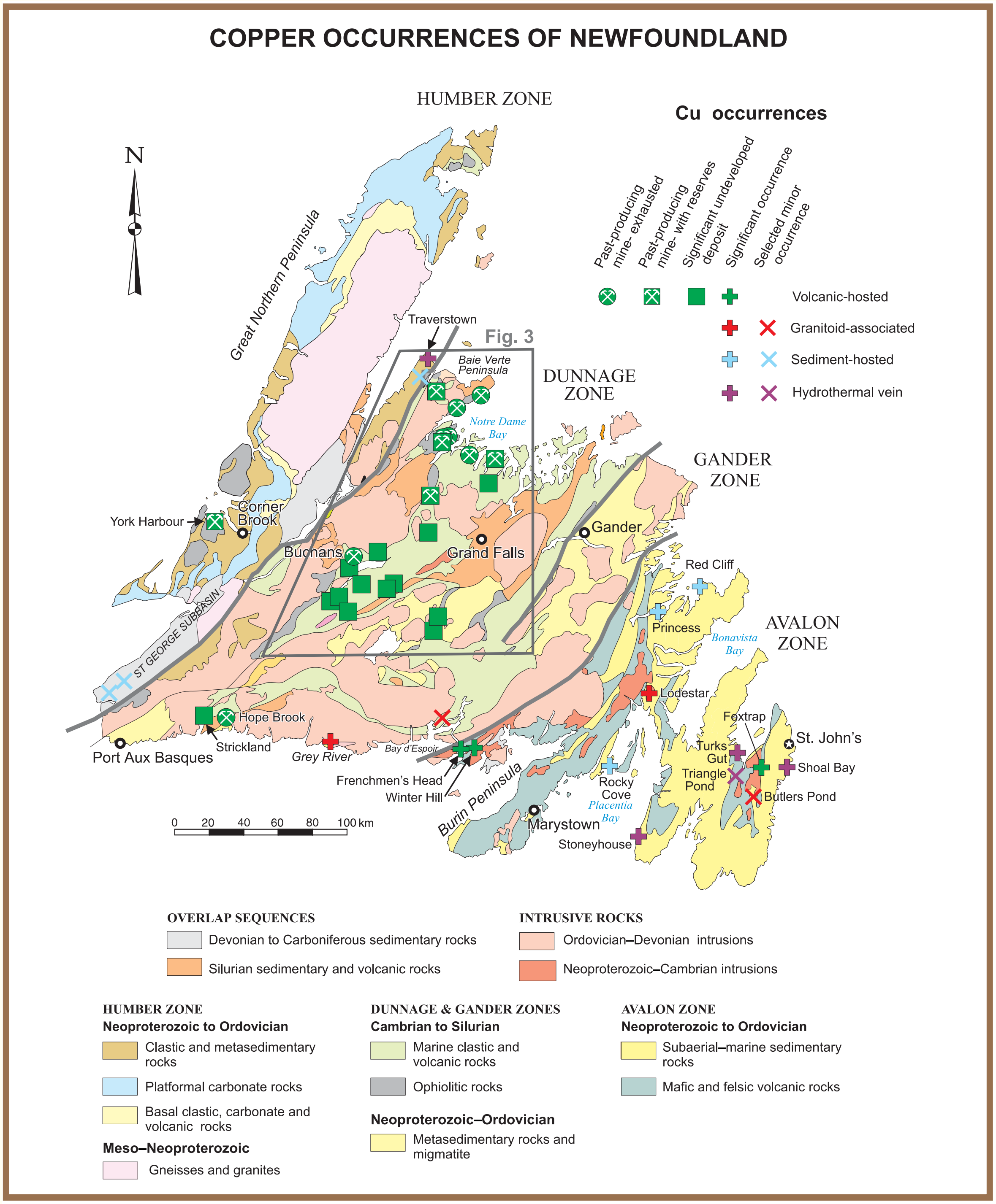

Figure 2. *Simplified geological map of Newfoundland showing location of major copper occurrences.*

Arc volcanic-hosted environments contain polymetallic deposits hosted by mixed mafic and felsic volcanic sequences. Those in mafic-dominated sequences tend to be copper-rich, but with increasing amounts of felsic volcanic rocks the mineralization becomes increasingly dominated by zinc and lead. Silver and gold are found as accessory elements in both environments.

The Early Ordovician *Pacquet Harbour Group* (Figure 3) is a strongly deformed mafic-dominated sequence of primitive-arc affinity. The principal deposits are those of the Rambler Camp, which has yielded 4.6 million tonnes of ore at average grades of 2.4% Cu, 0.64% Zn, 1.6 g/t Au and 13.1 g/t Ag, from five mines (Figure 5) between 1964 and 1996. The Ming Footwall deposit (Table 1) remains as an unde-

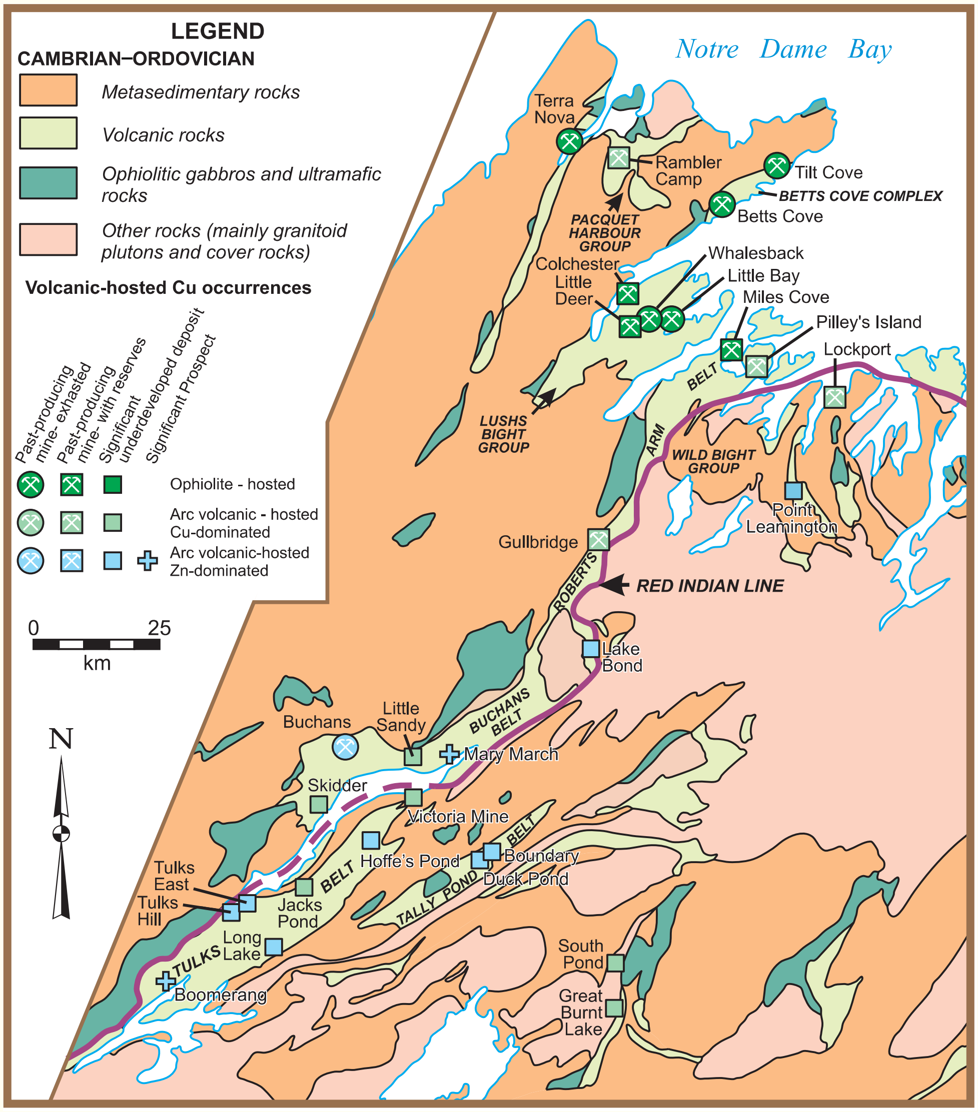

Figure 3. *Simplified map of the Cambro-Ordovician geology of the Dunnage Zone, showing copper deposits. For location, see Figure 2.*

veloped reserve. The Main Mine, Ming and Ming West deposits are stratiform massive sulphide lenses associated with a felsic dome, whereas the East Mine, Ming Footwall and Big Rambler Pond deposits are of stockwork or disseminated character and associated with felsic and mafic volcanic rocks.

The *Buchans–Roberts Arm belt*, also of Early Ordovician age, is characterized by bimodal calc-alkalic volcanic rocks of mature-arc character. Most of the deposits in the belt are zinc-dominated but contain considerable reserves of copper. The Buchans deposits produced 215 460 tonnes of the metal from an overall production of 16.2 million tonnes at average grades of 14.51% Zn, 7.56% Pb, 1.33% Cu, 1.37 g/t Au and 126.0 g/t Ag. Most of the mineralization is associated with felsic pyroclastic rocks and breccias and is of classic "Kuroko-type". The bulk of the production came from "in-situ" (exhalative or shallow replacement) or transported (debris flow) ores, but stockwork mineralization is also known. The other past producers in the Buchans–Roberts Arm belt were the Gullbridge Mine (3.5 million tonnes at 1.02% copper) which has remaining reserves (Table 1), and the Pilley's Island deposit, which produced copper as a by-product of pyrite mining (Figure 3). The belt also contains the mafic-hosted Skidder deposit and the felsic-hosted Little Sandy and Lake Bond deposits (Figure 3). A significant recent discovery is the Buchans-like Mary March prospect (Figure 3), where drilling in 1999 returned a 9.23 m intersection having grades of 0.66% Cu, 10.33% Zn, 1.62% Pb, 118.1 g/t Ag and 4.11 g/t Au.

The Early Ordovician *Wild Bight Group*, on the southern side of the Red Indian Line (Figure 3), is a predominantly volcaniclastic sequence containing intercalations of primitive-arc mafic and felsic vol-

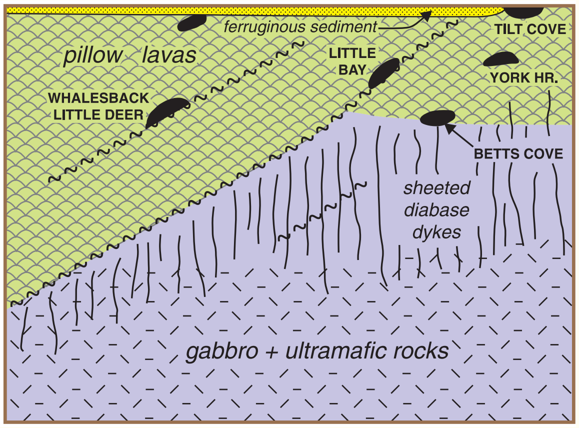

Figure 4. *Schematic section of an ophiolite sequence showing stratigraphic and structural setting of massive sulphide deposits (after Tuach* et al.*, 1988).*

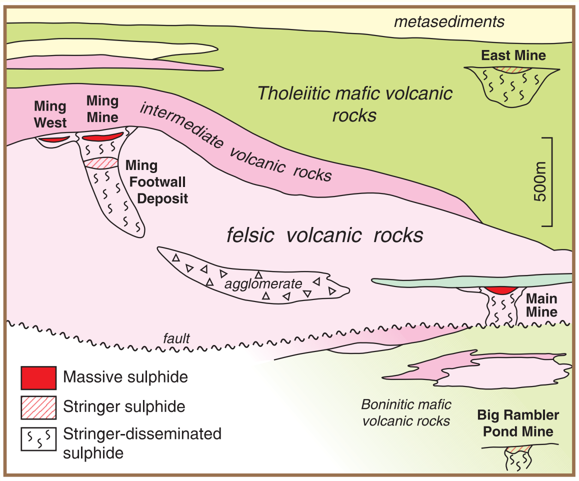

Figure 5. *Schematic representation of the Rambler Camp sulphide deposits showing restored stratigraphic setting in relation to the felsic dome (after Coates, 1991).*

canic rocks. The principal deposits are Point Leamington, which is zinc-dominated, and Lockport, which is copper-dominated. Both consist of massive sulphides capping extensive alteration stockworks. Point Leamington, at 13.8 million tonnes of reserves, is one of the largest massive sulphide deposits in Newfoundland but is very low grade. The similar aged *Tulks belt*, in the interior Dunnage Zone, consists of strongly deformed felsic and mafic volcanic rocks of both primitive- and mature-arc character. Copper-dominated deposits include Jacks Pond and Victoria "Mine" (which has not seen significant production) whereas zinc-dominated deposits include Tulks East (the largest deposit in the belt), Tulks Hill, Long Lake and Hoffe's Pond. A potentially significant discovery was made at the Boomerang prospect in late 2004, when a 13.9 m drill intersection of massive sulphide mineralization was obtained having grades of 0.7% Cu, 4.0% Pb, 13.6% Zn, 102 g/t Ag and 1.0 g/t Au. As of early 2005, this prospect was still underging evaluation. The Cambrian *Tally Pond belt* comprises a similar but better preserved volcanic belt and is also zinc-rich. The principal deposits are Duck Pond (also known as Tally Pond) and Boundary, which have combined reserves of 4.1 million tonnes grading 3.3% Cu, 5.7% Zn, 59 g/t Ag and 0.9 g/t Au. In addition, there are 1.1 million tonnes of inferred resources at a grade of 3.0% Cu, 7.1% Zn, 71 g/t Ag and 0.8 g/t Au, which are expected to be upgraded to reserves and mined. This had been the largest undeveloped volcanogenic massive sulphide resource in Newfoundland; it went into production in January 2007.

Other examples occur in the southern Dunnage Zone as the mafic-hosted Great Burnt Lake and South Pond deposits (Figure 3) and the felsic-hosted Strickland deposit (Figure 2).

Extensive areas of volcanic rocks, of Neoproterozoic age, also occur in the Avalon Zone of eastern Newfoundland (Figure 2). However, volcanogenic massive sulphide mineralization is rare, perhaps because the volcanism was predominantly subaerial. Known examples include the Winter Hill and Frenchman Head Zn–Pb–Cu occurrences of the southwestern Avalon Zone and the Foxtrap prospect near St. John's (Figure 2).

Volcanic rocks are also found in the Archean Florence Lake and Hunt River greenstone belts of eastern Labrador (Figure 6). These contain komatiite-type Ni–Cu mineralization in what are either meta-ultramafic sills or flows. The most notable example is the Baikie prospect, which has yielded drill results of up to 2.19% Ni, 0.22% Cu and 0.16% Co over 11.32 m. This environment is described in more detail in the companion volume in this series on nickel.

Mafic Intrusion-Hosted Environment

This environment generally contains copper in subordinate proportions to nickel, but probably represents the largest source of future copper production in the Province. This is by virtue of the Voisey's Bay deposit (Figure 6) which contains a total resource of 137 million tonnes of 1.65% Ni, 0.85% Cu and 0.09% Co and could thus yield up to 1.165 million tonnes of copper. The deposit is hosted within the conduit system that fed a Mesoproterozoic troctolite intrusion, the most significant components being the Ovoid (Table 1) and Eastern Deeps deposits. The Voisey's Bay deposit began production in late 2005. An analogous prospect occurs at Pants Lake (Figure 6) 100 km

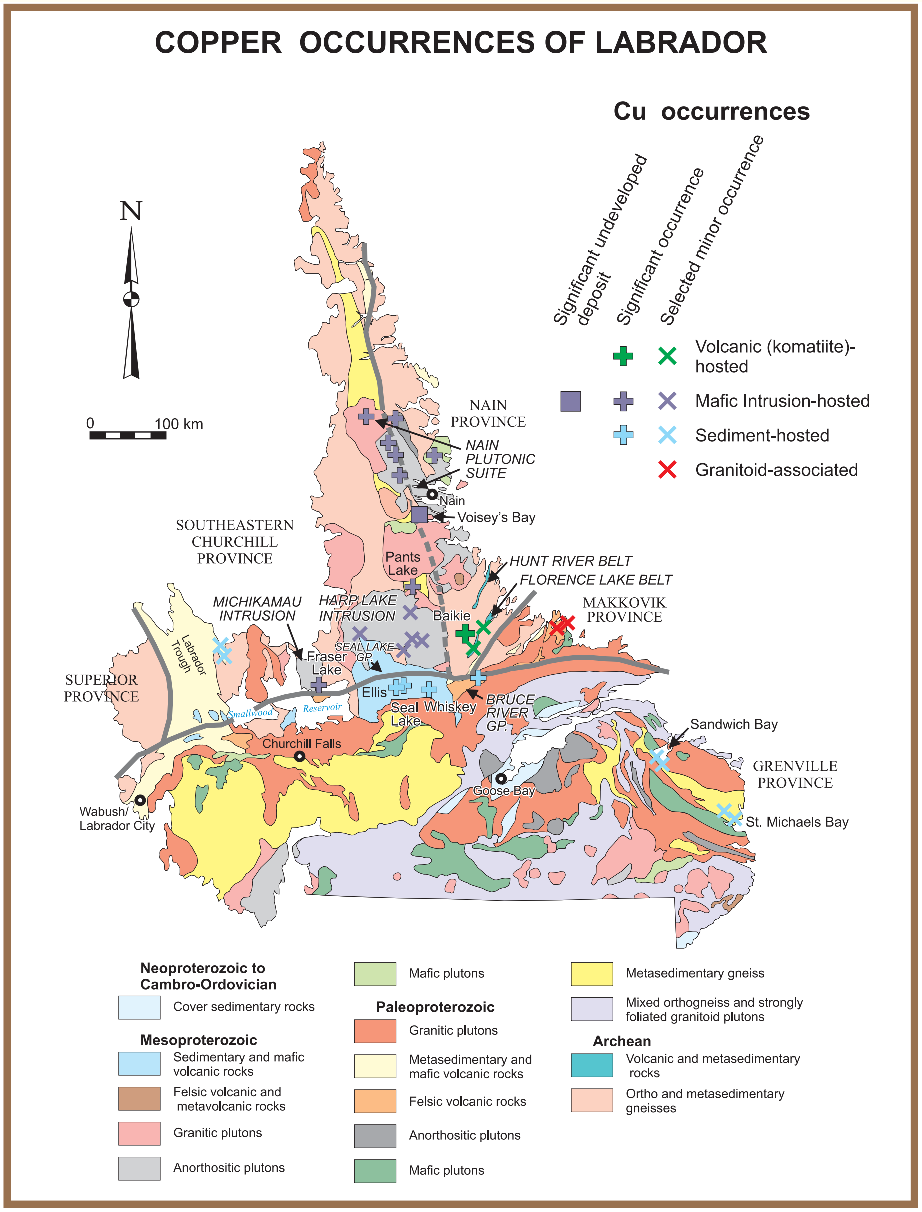

Figure 6. *Simplified geological map of Labrador showing location of major copper occurrences.*

to the south, where Ni–Cu–Co mineralization has been discovered at the base of a sheet-like gabbroic intrusion. Other Ni–Cu occurrences are found in the anorthosite intrusions of the Nain Plutonic Suite and the Harp Lake and Michikamau intrusions, but appear to be of minor importance. The mafic intrusion-hosted environment is described in more detail in the companion report on nickel.

Felsic Intrusion-Associated Environments

The important *copper porphyry environment* is poorly developed in the Province, probably because of the relatively deep level of erosion compared to more recent plutonic belts. A recently discovered example occurs in rocks of the Burgeo Batholith on the south coast of Newfoundland near Grey River (Figure 2), where a number of small stocks appear to be associated with Mo–Cu porphyry-style mineralization and alteration. The association with a number of peripheral acid sulphate gold occurrences suggests a possible combined porphyry–epithermal gold environment. Epithermal gold mineralization is also fairly widespread in the volcanic belts of the Avalon Zone, particularly on the Burin Peninsula and eastern Avalon Zone where, it has been suggested it may be associated with deeper level Cu–Au porphyry systems (e.g., the Lodestar prospect) in latest Proterozoic rocks. A related environment may be represented by the Butlers Pond Fe-oxide–Cu–Au occurrence (eastern Avalon Zone, Figure 2), which is hosted by hydrothermal breccias of possible porphyry association.

Copper mineralization is also found in vein and pegmatite systems in southern Newfoundland (Figure 2) and eastern Labrador (Figure 6), but is subordinate to molybdenum.

Sediment- and Sediment-Volcanic-Hosted Environments

There has not been any production from these environments but they represent important exploration targets.

Volcanic redbed or Keweenawan-type environments are represented by the Mesoproterozoic Seal Lake Group of Labrador, which contains numerous occurrences of native copper, bornite and chalcocite that were explored extensively in the 1950s and 60s. Generally, these occurrences are vein-hosted but are largely restricted to the upper slates and basalts of the group and are thus broadly stratabound. It is likely that mineralization was introduced, or at least extensively remobilized, during Grenvillian deformation. Principal occurrences are Seal Lake Main, Ellis and Whiskey Lake (Figures 6 and 7), some of which also carry accessory silver. Vein-hosted copper mineralization is also found in sedimentary rocks of the adjacent Bruce River Group and is likely of similar genesis. A similar environment appears to be present in the Newfoundland Avalon Zone where native copper–bornite–chalcocite mineralization is present in redbed–basalt units of the Neoproterozoic Musgravetown Group on the west side of Placentia Bay (e.g., Rocky Cove prospect, Figure 2), near Bonavista Bay (Princess and Red Cliff prospects, Figure 2), and also in basalts of the Harbour Main Group near St. John's.

Besshi-type mineralization is considered to be represented by numerous sulphide occurrences in the eastern part of the Paleoproterozoic Labrador Trough of western Labrador (Figure 6). The mineralization occurs as finely laminated pyrrhotite, associated with minor chalcopyrite, in black shales that are intercalated between thick gabbro sills. The mineralization is syngenetic and thought to have formed by seafloor exhalative activity.

Minor Cu–Zn–Pb mineralization of uncertain genesis is found in the Carboniferous St. George subbasin of western Newfoundland (Figure 2), where it occurs as veins in black shale, sandstone and evaporitic limestone. Similar mineralization occurs in limestones of the rift-facies Fleur-de-Lys Supergroup of

Figure 7. *Copper mineralization in vein, Seal Lake Group redbeds, Labrador.*

the Baie Verte Peninsula, northern Newfoundland. This unit also hosts several vein-type Zn–Pb–Cu deposits (e.g., the Traverstown occurrence) although these may be unrelated to the sediment-hosted mineralization.

Pyrite–chalcopyrite-mineralization is also found in high-grade paragneisses of the eastern Grenville Province, Labrador (Figure 6). The mineralization forms prominent gossans but is of low grade (typically <1% Cu).

Hydrothermal Vein-Hosted Environments

Vein-hosted copper mineralization occurs in mafic volcanic rocks of the eastern Avalon Zone. Some of these occurrences may be related to the volcanic redbed environment described above, others may be related to the epithermal gold-associated alteration and mineralization that has affected the core of the eastern Avalon Zone. Examples are Shoal Bay, Turks Gut and Stoneyhouse, all of which were explored in the 1850s and 60s (Figure 2).

Exploration Potential

Copper production, when it resumes, will be dominated by the mafic intrusion- and volcanic-hosted deposits and it is the search for these deposit types that will probably dominate future exploration. The mafic intrusions of Labrador, particularly those that contain primitive rocks of troctolite–gabbro composition, offer good potential for further discoveries (*see* companion volume on nickel), as do the volcanic terranes of central Newfoundland. The search for VMS deposits will most likely focus on the intermediate- to mature-arc environments, which possess the best potential for high-value, polymetallic deposits of Buchans type. The recent Boomerang discovery is a promising example in this respect. The Avalon Zone volcanic rocks have seen relatively little exploration for VMS deposits, however, it has been suggested that the shallow water–subaerial environments that typify these rocks may have potential for gold-rich VMS deposits.

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The sediment-hosted environments, notably the redbed and volcanic redbed environments, represent promising grass-roots targets that elsewhere in the world have proved to be major sources of copper.

The porphyry environment is also an under-explored grass-roots target that may have considerable further potential, particularly in the granitoid batholiths that comprise much of the Newfoundland south coast. The possible association of Cu–Au, porphyry mineralization with the epithermal systems of the Avalon Zone is a promising target for a large part of the central and western Avalon Zone. The potential for iron-oxide–copper–gold (plus uranium) mineralization in the granite-volcanic terranes of the Makkovik Province has also emerged as a new exploration target in Labrador.

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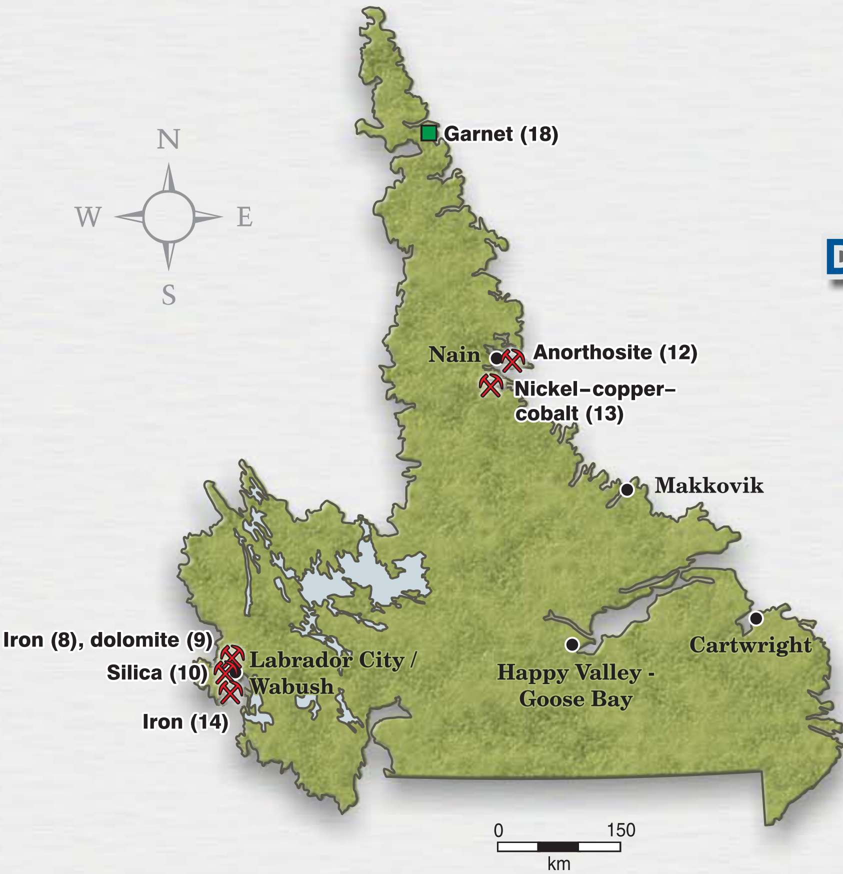
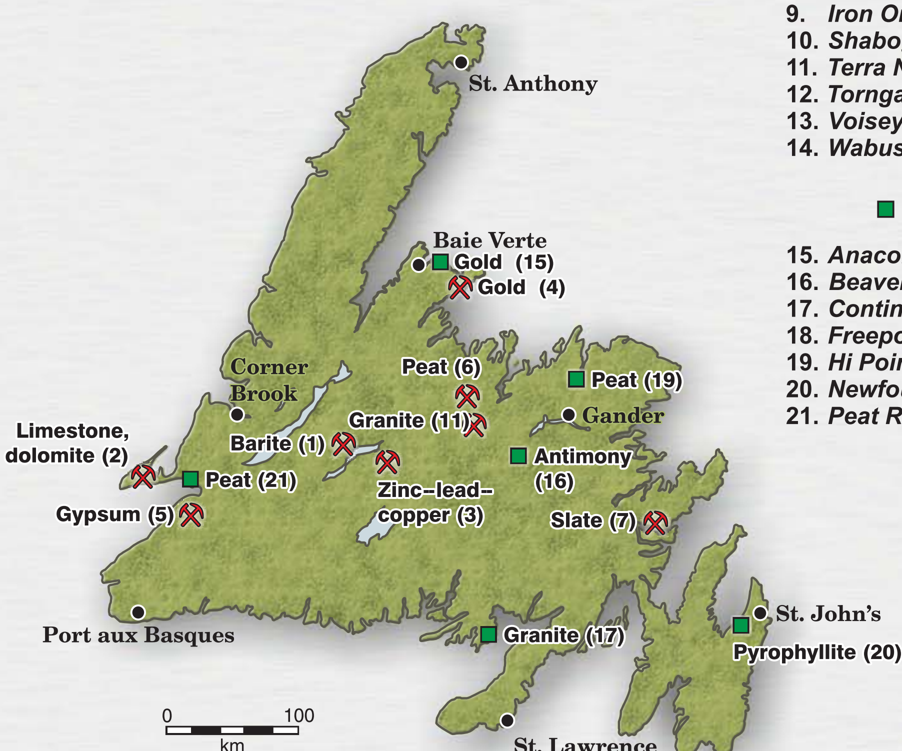
PRODUCING MINES AND DEVELOPING PROPERTIES

WINTER 2008



* Note scale differences of Labrador and Newfoundland maps



Commodities in production

1. *Atlantic Barite Ltd.,* Buchans
2. *Atlantic Minerals Ltd.,* Lower Cove
3. *Aur Resources Inc.,* Duck Pond
4. *Crew Gold Canada Ltd.,* Nugget Pond
5. *Galen Gypsum Mines Ltd.,* Coal Brook
6. *Hi Point Industries (1991) Ltd.,* Bishop's Falls
7. *Hurley Slateworks Company Inc.,* Burgoynes Cove
8. *Iron Ore Company of Canada,* Labrador City
9. *Iron Ore Company of Canada,* Labrador City
10. *Shabogamo Mining & Exploration Ltd.,* Labrador City
11. *Terra Nova Granite Inc.,* Jumpers Brook
12. *Torngait Ujaganniavingit Corp.,* Ten Mile Bay
13. *Voisey's Bay Nickel Company Ltd.,* Voisey's Bay
14. *Wabush Mines Ltd.,* Wabush

Commodities in development

15. *Anaconda Mining Inc.,* Pine Cove
16. *Beaver Brook Antimony Mine Inc.,* Beaver Brook
17. *Continental Stone Ltd.,* Belloram
18. *Freeport Resources,* Hutton Beaches
19. *Hi Point Industries (1991) Ltd.,* Gander Bay
20. *Newfoundland Pyrophyllite,* Manuels
21. *Peat Resources Ltd.,* Stephenville