

Spatial and temporal distribution of gold mineralization in the New Brunswick segment of the Northern Appalachians, Eastern Canada



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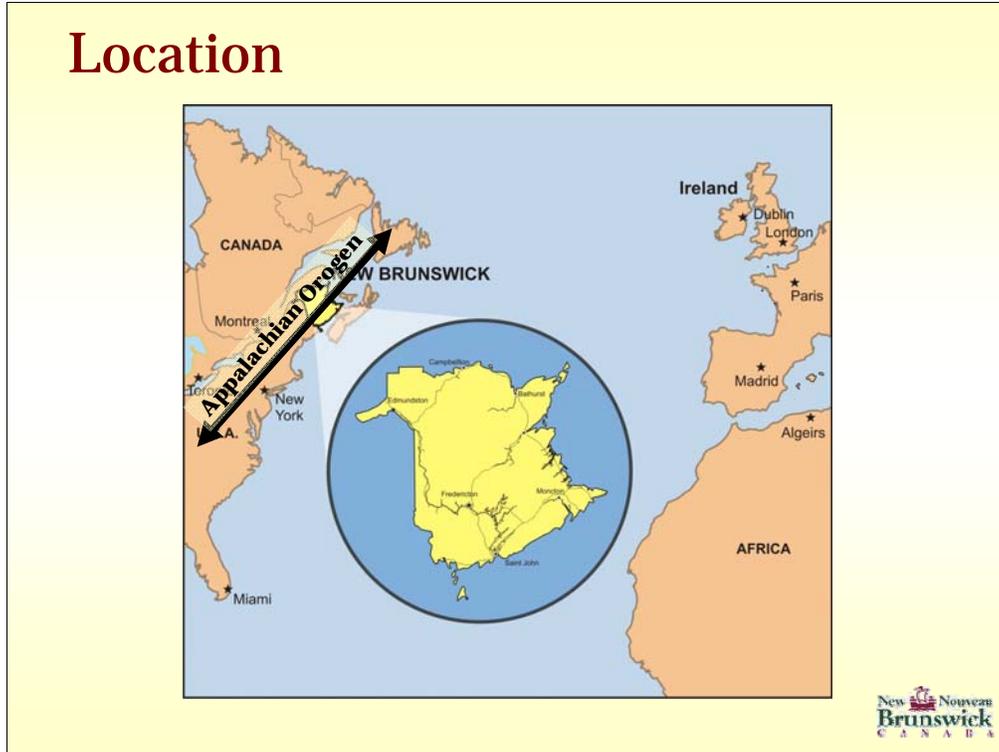
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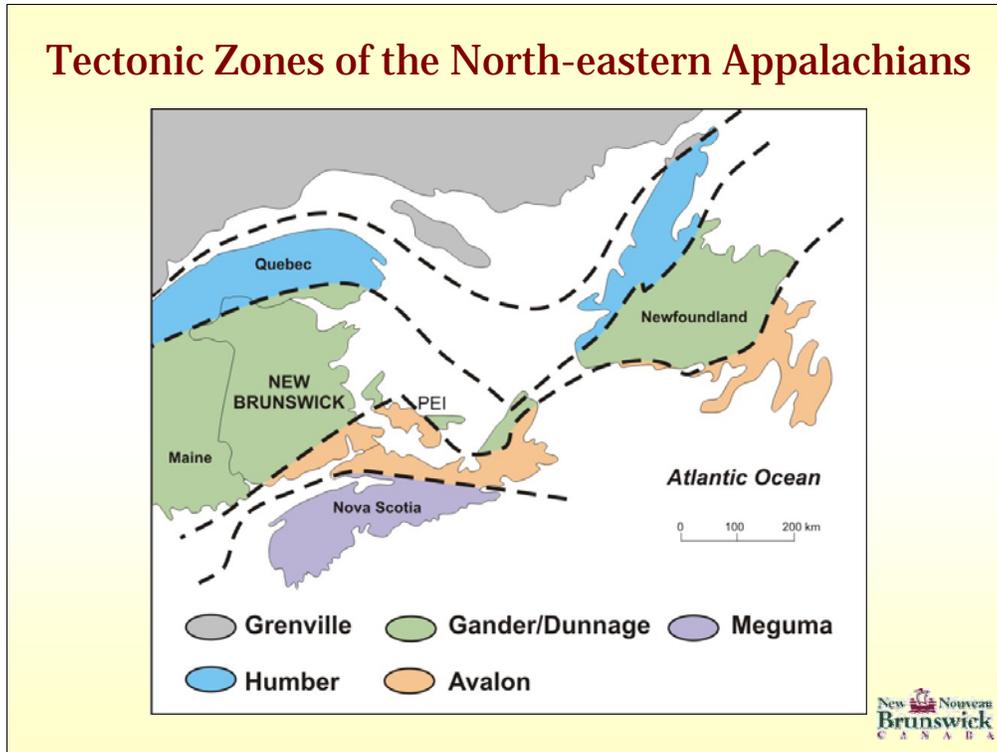


Location



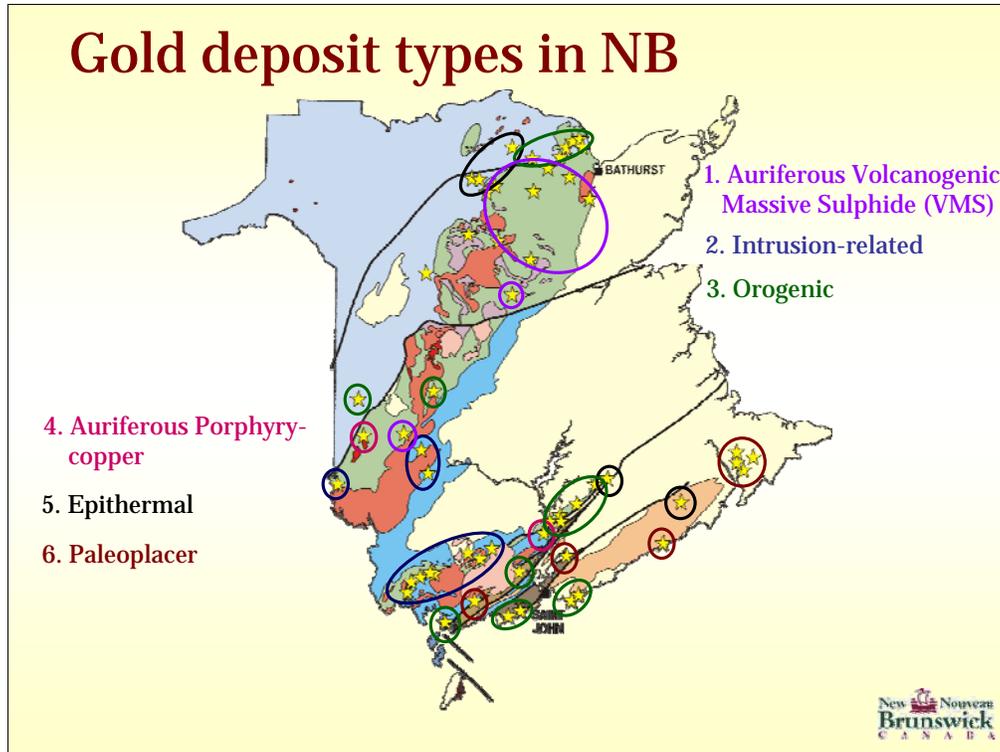
New Brunswick is located in Eastern Canada and forms a part of the North-eastern Appalachian Mountain Belt that stretches along the eastern seaboard.

Tectonic Zones of the North-eastern Appalachians



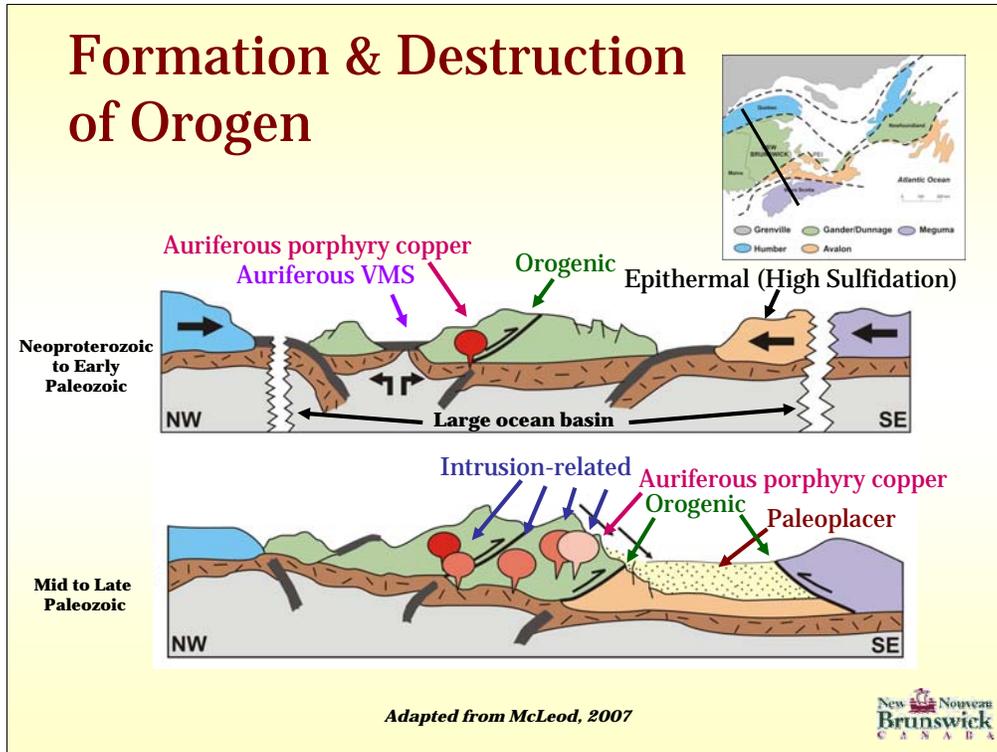
For those of you who are unfamiliar with the geology of Eastern Canada, New Brunswick is situated within the central mobile belt of the Appalachian Orogen that formed as a result of continent-continent collision. The Grenville, shown in grey, represents the ancestral margin of the North American craton and the Humber, in blue, was its continental platform. These two zones together formed the north-western margin of the Iapetus Ocean. The south-eastern margin of the Iapetus is represented by the Avalon Zone, shown in orange, which consists of numerous accreted peri-Gondwanan Precambrian terranes. The green Gander-Dunnage Zone represents the remnants of the Iapetus Ocean and the Cambro-Ordovician arcs and back-arc basins associated with its closure. The Meguma Zone, shown in purple, was formerly a segment of the African continent left behind as a result of the opening up of the Atlantic Ocean.

Gold deposit types in NB



This map shows the distribution of some of the major gold occurrences and deposits throughout the province. The majority of them are focused along large structures (some of them major tectonostratigraphic boundaries) and/or are situated peripheral to felsic plutons. Because of the diversity in geological environments found throughout the province, there are several gold deposit types that are present. The ones highlighted in this presentation include auriferous VMS deposits that are mostly concentrated in the northern part of the province; intrusion-related deposits, the majority of which occur in the southern part of the province; orogenic deposits that are mainly focused along structural corridors throughout the province; auriferous porphyry copper deposits associated with both Ordovician and Devonian felsic plutons; epithermal deposits, and finally, several paleoplacer gold deposits within the Carboniferous cover sequence, mainly in the south-eastern part of the province.

Formation & Destruction of Orogen



The majority of these deposit types were formed as a result of tectonic processes during the formation and subsequent destruction of the Appalachian Orogen. This slide shows a schematic cross section of the province during two very important time periods for the formation of the province's mineral deposits. The first section illustrates the paleotectonic environment during Neoproterozoic to Early Paleozoic time where ocean closure via subduction was taking place in both the northern and southern portions of the province in conjunction with the development of associated arcs and back-arc basins. The second section shows the paleotectonic setting from Middle to Late Paleozoic following juxtaposition of the various tectonic zones. The majority of the deposits are hosted by the Gander-Dunnage Zone. The VMS deposits were formed during Ordovician time in a back-arc basin environment, whereas the recently recognized intrusion-related deposits were formed primarily during the Middle to Late Paleozoic in association with post-orogenic magmatism. The orogenic deposits span both time periods throughout the various tectonic blocks and are focused along major structures associated with accretionary complexes and thrusting events. The epithermal high sulphidation gold mineralization is hosted by the Neoproterozoic volcanic rocks that comprise the Avalon Zone. The auriferous porphyry copper deposits were formed in both Ordovician and Devonian time within the Gander-Dunnage Zone. The Paleoplacer deposits are primarily Carboniferous in age. The following slides highlight examples of these various styles of gold mineralization.

Auriferous VMS

- Ordovician VMS deposits occur in the Bathurst Mining camp
- Formed during submarine volcanism in a back-arc setting
- Supergene enrichment in gossan zones; refractory gold in pyrite and arsenopyrite (McClenaghan et al., 2003; Martin et al., 2006)



The auriferous VMS deposits were formed as a result of submarine volcanism in a back-arc setting during Ordovician time. They are focused within the Bathurst Mining camp in northern New Brunswick. Gold occurs in these deposits as refractory gold in pyrite and arsenopyrite and also is enriched by supergene processes in gossan zones that overlie these deposits.

Auriferous VMS Caribou

(Ordovician)

- Estimated resource of 70 Mt of 1.6% Pb, 4.3% Zn, 0.5% Cu, 51 g/t Ag, and 1.7 g/t Au (Cavalero, 1993)
- Heap leach operation in 1983 extracted 88,583 g Au and 1.7 million g Ag from a gossan zone



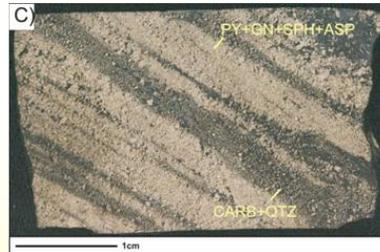
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The Caribou VMS deposit, which is currently being re-commissioned, was a former gold producer in the province. The Caribou massive sulphide deposit is enveloped within a folded sequence of porphyritic rhyolite, felsic and mafic tuffs, and graphitic phyllite. It has the highest gold grade of the various VMS deposits in the Bathurst Mining Camp and has been documented to have contained an estimated resource of 70 million tonnes of 1.6% Pb, 4.3 % Zn, 0.5% Cu, 51 g/t Ag, and 1.7 g/t Au (Cavalero, 1993). At the Caribou mine, a heap leach operation extracted almost 89,000 g of Au from the gossan that contained a supergene enrichment of gold and 1.7 million g of Ag as well.

Auriferous VMS Brunswick No. 12

(Ordovician)

- Geologic reserve of 230 Mt grading 7.66 wt.% Zn, 3.01 wt.% Pb, 0.46 wt.% Cu, and 91 g/t Ag (Goodfellow & McCutcheon, 2003)
- Average grade 0.67 g/t Au; refractory in pyrite (Martin et al., 2006)
- Au currently produced as a by-product



6.34 g/t Au;
Martin et al., 2006

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At Brunswick No. 12, the giant 230 Mt Cu-Pb-Zn VMS deposit has an average gold grade of 0.67 g/t Au (Martin et al., 2006). This is the only mine in the province that is currently producing gold, albeit as a by-product of the Cu-Pb-Zn operation.

Intrusion-Related

- NB intrusion-related deposits genetically associated with primitive I-type Late Silurian to Early Devonian intrusions
- Structurally controlled
- Au-As-Sb (-W-Mo) association
- Significant deposits



The intrusion-related deposits are primarily associated with I-type Late Silurian to Early Devonian post-orogenic intrusions. The deposits are structurally controlled and typically have an Au-As-Sb-W-Mo association. These recently recognized deposit types are the most significant in terms of gold endowment in the province.

Intrusion-Related Clarence Stream

(Devonian)

- Au+Sb in quartz veins and disseminated in gabbro/metasedimentary host rocks, aplite/pegmatite dykes
- Indicated resource (Roscoe and Ross, 2006):
 - Central Zone: 347,904 t @ 7.42 g/t Au
 - AD Zone: 180,443 t @ 7.83 g/t Au



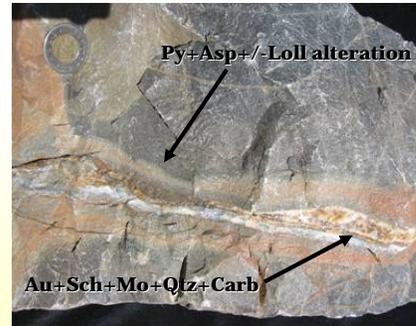
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The best example of an intrusion-related deposit in New Brunswick (and the Northern Appalachians for that matter) is the Clarence Stream gold deposit where a direct genetic relationship has been established between the gold mineralization and the Early Devonian Magaguadavic Granite. Gold mineralization along with abundant arsenic and antimony occurs within quartz veins and as disseminations within their Silurian metasedimentary and metagabbroic host rocks, and also within aplite/pegmatite dykes that grade laterally into auriferous quartz veins. Between the two most significantly mineralized zones, a combined indicated resource of ~126,000 ounces of gold at an average grade that ranges from about 7.5 to almost 8 g/t Au (Roscoe and Ross, 2006) has been outlined and a significant inferred resource has been defined as well. The deposit remains open along strike and at depth. Presently, work is underway to upgrade the resource with deeper drilling and it is anticipated that this deposit will be brought into production in the near future.

Intrusion-Related Lake George

(Devonian)

- Sb-W-Mo-Au mineralization within contact aureole of Devonian granodiorite
- Au associated with W-Mo mineralization & stibnite-quartz veins
- Au-bearing structure averages 2.95 g/t Au over 26.2 m with a width of 2.96 m (Morrissy, 1991)



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Another example of an intrusion-related deposit is the former Lake George antimony mine where Sb-W-Mo-Au mineralization is hosted by Silurian greywackes within the contact aureole of the Devonian granodiorite. The gold is hosted within quartz carbonate veins mantled by pyrite+arsenopyrite and occasionally lollingite within the alteration halo. A gold-bearing structure has been identified at the mine that averages 2.95 g/t Au over 26.2 m with a width of almost 3 m (Morrissy, 1991).

Orogenic

- Range in age from Ordovician (i.e., Bathurst mining camp; Annidale Belt) to Permian (i.e., Cape Spencer)
- Controlled by brittle-ductile structures
- Associated with subduction-related accretionary complexes and late tectonic features associated with exhumation; thrusting during orogenesis

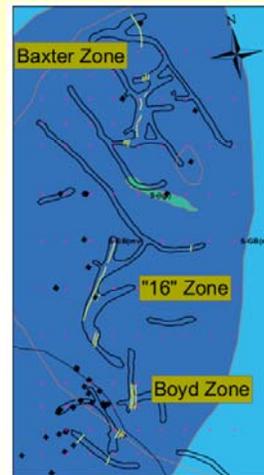
The deposits that can be classified as orogenic range in age from Ordovician to Permian. They are controlled by brittle-ductile structures where gold is hosted by quartz±carbonate veins or disseminated within the host rocks. The structural features are primarily associated with subduction-related accretionary complexes and late tectonic features associated with exhumation and thrusting during orogenesis.

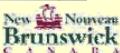
Orogenic

Annidale Belt (Devil Pike Bk)

(Ordovician?)

- En echelon vein set hosted by mafic volcanic rocks
- Au-pyrite-chalcopyrite-tetrahedrite in brecciated quartz veins
- 3 mineralized zones of which the Boyd has the highest grade intersections including 18.7 g/t Au over 4.35 m (Fosters Resources, 1995)



Lafontaine, 2006 

The Annidale Belt in south-central New Brunswick is located near the Gander-Avalon boundary and is host to several occurrences that exhibit features typical of mesothermal orogenic deposits. Of these occurrences, the Devil Pike Brook deposit contains the highest grades in a set of northerly-trending en echelon quartz veins hosted by mafic volcanic rocks. Drilling of this deposit has revealed three main mineralized zones (Baxter, 16, and Boyd) with assays in excess of >200 g/t Au over 0.5 m (Fosters Resources, 1995). The gold is associated with pyrite and chalcopyrite and the quartz exhibits a brecciated texture. The exact timing of the mineralization and the relationship to local felsic intrusions in the area is currently being investigated.

Orogenic Cape Spencer

(Permian)

- Hosted by altered Neoproterozoic granitoid and Cambrian sedimentary rocks in a Hercynian fold-thrust belt
- Heap leach operation in the late 1980's recovered 0.15 million g Au (4,833 oz) (NBDNR statistical Reports)
- Proven reserve of 551,627 t grading 2.5 g/t Au (non 43-101 compliant; Canadian Mines Handbook, 1989-90)



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The youngest example of an orogenic gold deposit in the province is the former Cape Spencer Mine where gold is hosted along shallow thrusts within deformed Neoproterozoic granitoids of the Avalon Zone and Carboniferous sedimentary rocks. These thrusts and associated north-westerly directed folding are interpreted to be linked to the docking of the Meguma Zone along the south-eastern margin of the Avalon Zone. Gold is associated with pyrite in illitic altered host rocks with variable quantities of specularite, chalcopyrite, and ankerite. This aerial photo shows the former mine site where almost 5,000 ounces of gold was extracted by a heap leach operation during the late 80's. The bottom photo shows the typical illite alteration of granitic rocks that contain disseminated pyrite, which is cross-cut by quartz veins that locally contain high grade concentrations of gold.

Auriferous Porphyry Copper

- Associated with both Ordovician and Devonian aged intrusions
- Mineralization as disseminations within intrusion and in cross-cutting quartz veins
- Cu-Mo (-Au) metal assemblage



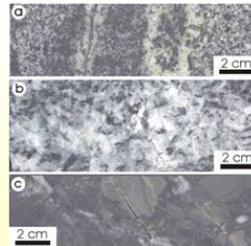
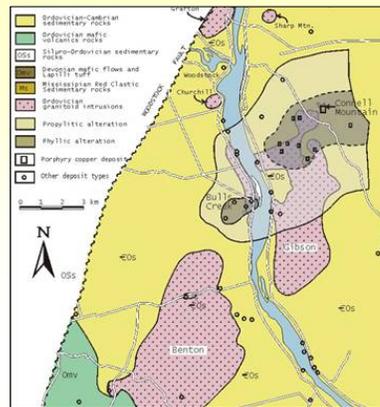
There are only a few examples of auriferous porphyry copper deposits in the province. They are associated with both Ordovician and Devonian aged felsic intrusions. The mineralization occurs as disseminations within the intrusion as well as in cross-cutting quartz veins that bear a typical Cu-Mo-Au metal assemblage.

Auriferous Porphyry Copper

Connell Mountain

(Ordovician)

- Cu and low grade Au mineralization hosted in tonalite and brecciated metasedimentary host rocks
- Up to 1.5 g/t Au (Thomas & Gleeson, 1988)
- Associated with chalcopyrite, pyrrhotite and minor molybdenite and sphalerite



Lentz et al., in press

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The Connell Mountain occurrence within the Gander Zone is associated with an apophysis of the Early Ordovician Connell Mountain stock related to the nearby Gibson Pluton. It is the largest known deposit of this type in the province. Although it is low grade, up to 1.5 g/t gold have been reported in association with chalcopyrite, pyrrhotite and minor amounts of molybdenite and sphalerite. Mineralization is hosted by tonalite and metasedimentary rocks of the Cambro-Ordovician Tetagouche Group. The photo shows the mineralized samples including the tonalite, quartz-carbonate vein breccia with metasedimentary clasts, and metasedimentary breccia.

Auriferous Porphyry Copper

Evandale

(Devonian)

- Mineralized quartz veins in Devonian granodiorite
- 20 cm drill intersection of quartz vein in granodiorite:
 - 16.1 g/t Au, 322.3 g/t Ag, 2.4% Cu, 4.7% Pb, 6.7% Zn (Dome, 1980)



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At the Evandale occurrence, copper-molybdenum-gold mineralization is hosted by the Late Devonian Evandale granodiorite near the Gander-Avalon boundary. The majority of the mineralization occurs along NW-trending fractures. A second set of NE-trending fractures is also weakly mineralized. Mineralization at the Evandale occurrence consists mainly of chalcopyrite and minor molybdenite associated with narrow quartz veinlets as well as in fractured and altered (chloritic and hematitic) granite. Drilling at the deposit by Dome in 1980 intersected a high grade interval that yielded ~16 g/t Au over 20 cm with appreciable quantities of Ag, Cu, Pb, and Zn.

Epithermal (High Sulphidation)

- Only one known occurrence of this type in the province
- Topaz±pyrophyllite±kaolinite+quartz alteration of volcanic rocks
- Au-Ag assemblage



There are several occurrences that can be classified as epithermal throughout the province. The next slide will focus on the high sulphidation variety in southern New Brunswick. One known occurrence of this type has been recognized only recently. It exhibits topaz-pyrophyllite-kaolinite-quartz alteration within volcanic rocks of the Avalon Zone and has a Au-Ag metal assemblage.

Epithermal (High Sulphidation)

Chambers Settlement

(Neoproterozoic?)

- Topaz±pyrophyllite±kaolinite+ quartz alteration of volcanic rocks
- Up to 1 g/t Au in grab samples
- Preliminary stages of exploration



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Although there are several important high sulphidation epithermal style mineral deposits hosted by similar rocks in Newfoundland, the only known mineralization of this type demonstrated within the Avalon Zone in New Brunswick is the Chambers Settlement occurrence. There, intensely silicified Neoproterozoic felsic volcanic rocks contain topaz, pyrophyllite, and/or kaolinite alteration assemblages, but only minor gold - up to 1 g/t Au in grab samples has been reported.

Paleoplacer

- Recognized within the Cumberland Group of the Carboniferous cover sequence in south-eastern New Brunswick
- Host rocks include quartz-pebble conglomerate and sandstone
- Derived from eroded deposits



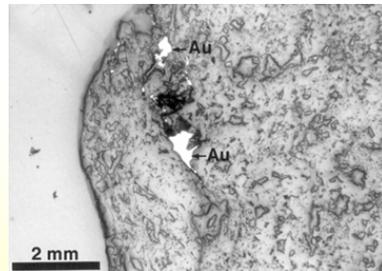
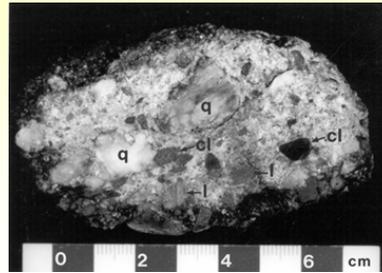
The last deposit type, are the Paleoplacer deposits which are relatively insignificant at this stage in terms of their metal endowment. However, the presence of these types of deposits is important to mention as they are hosted by Carboniferous quartz-pebble conglomerate and sandstone that indicates that significant lode gold deposits occurred in the surrounding orogenic belts from which they were derived.

Paleoplacer

Aboujagane

(Carboniferous)

- Drill intersection within Boss Point sedimentary rocks: 6.9 g/t Au over 1.8 m (Dome, 1964)
- Grab sample of Boss Point sandstone float contained 11.5 g/t Au



**Johnson and
McLeod, 1998**

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The best example of this deposit type is the Aboujagane occurrence where historic records indicate a drill intersection of 6.9 g/t Au over 1.8 m was obtained by Dome (1964). A grab sample of sandstone from that same area yielded up to 11.5 g/t Au (Johnson and McLeod, 1998). Petrographic examination of the same sample revealed the presence of native gold within quartz grains that you can see in this polished thin section.

Conclusions

- Diverse geological environments
- Favourable conditions for the formation of several types of gold deposits of variable ages (Neoproterozoic to Permian)
- **Intrusion-related** and **orogenic** types are most significant; main exploration targets peripheral to major structures and/or intrusions
- Potential for other deposit types (i.e., IOCG, skarn)
- Potential for sizeable and economically viable gold deposits



In conclusion, the geological setting of New Brunswick comprises several diverse geological environments, many of which provided favourable conditions for the formation of several types of gold deposits of variable ages (from Neoproterozoic to Permian). Of the varieties discussed in this presentation, the intrusion-related and orogenic types are the most significant in terms of their potential to become economically viable deposits and are thus the most sought after by exploration companies in the province. The main exploration targets include major structures and/or felsic intrusions. The potential does exist for other deposit types in the province. Gold production is part of New Brunswick's history and with further exploration, gold production may be in the province's not so distant future as it has the potential to host sizeable, economically viable gold deposits.

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