Gold Deposit Types
Models & Exploration Methods
November 29th, 2017
Overview

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- Different types of Gold Mineralization
- Gold Deposit Models
- Exploration Methods
- Concluding Remarks
Introduction

- As of November 29, 2017, gold was trading at approx. $1,280.00 oz/T.
- Recent resurgence of gold exploration in Newfoundland and Labrador.
- The majority of exploration is being conducted in west-central Newfoundland.
- Work has led to several new discoveries being made but more importantly, has spurred a staking rush.
- Explorers are evaluating other areas as well (i.e., Avalon Peninsula, Baie Verte area, Burin Peninsula, etc.)
Introduction

Photo 1: Gold Occurrences in Newfoundland (2017)

Photo 2: Gold Occurrences In Labrador (2017)
Two basic types of occurrences or deposits are recognized, and are referred to as primary and secondary.

Primary deposits form where gold precipitates during chemical reactions between hydrothermal (hot fluids) mineralizing solutions (metal-bearing) and rocks in the Earth's crust (e.g., Valentine Lake).

Secondary deposits form later during the chemical and mechanical processes of weathering and erosion, and the physical re-concentration of gold-bearing sediment into placer deposits (e.g. Witwatersrand Basin).

The likelihood of placer deposits existing in Newfoundland and Labrador is greatly diminished as a result of recent glaciation.
Gold Deposit Models

• Numerous deposit models where gold is the main commodity.

• There are also a significant number of models where gold is a by-product (secondary or tertiary commodity).

• While models provide valuable information, they should only be used as a guide.

• Most occurrences and/or deposits will share attributes however, there are often characteristics present that complicate assigning mineralization to just one deposit model.

• Models discussed herein are the most common types and ones that we have direct evidence of in Newfoundland and Labrador.
Schematic cross section showing the key geologic elements of the main gold systems and their crustal depths of emplacement. Modified from Poulsen et al. (2000), Robert (2004a), and Brommecker et al. (2016).
Low Sulphidation Epithermal Deposits

- High-level hydrothermal systems (i.e., surficial hotspring settings to depths of approximately 1 kilometre).

- Occur in volcanic island and continent-margin magmatic arcs, and continental volcanic fields with extensional structures (i.e., normal faults, fault splays, etc.).

- Quartz veins, stockworks and breccias carrying gold, silver, electrum, argentite, and pyrite (lesser amounts of sphalerite, chalcopyrite, galena, and sulphosalt minerals).

- Deposits can be zoned vertically and laterally. Base metal poor at top but Au-Ag-rich; Ag-rich base metal zone; base metal-rich zone at depth grading to pyrite.

- Deposits typically controlled/hosted by structures however, mineralization can also be present in permeable rocks (e.g., clastic and epiclastic sedimentary rocks).

- Common textures include: open-space filling, symmetrical layering, comb-like veins, crustification, colloform banding, and multi-phase brecciation.
Low Sulphidation Epithermal Deposits

Photo 3: Quartz veining and brecciation, Burin Peninsula

Photo 4: Multi-phase brecciation accompanying high-grade gold mineralization, central Newfoundland

Photo 5: Crustification and colloform banding, eastern Newfoundland
High Sulphidation Epithermal Deposits

Schematic cross section showing the key geologic elements of the main gold systems and their crustal depths of emplacement. Modified from Poulsen et al. (2000), Robert (2004a), and Brommecker et al. (2016).
High Sulphidation Epithermal Deposits

- High-level hydrothermal systems (i.e., depths of approximately 1 kilometre).

- Extensional and transtensional settings, commonly in volcano-plutonic continent margin, and oceanic and back-arcs. Often associated with high-level magmatism.

- Quartz veins, stockworks, vuggy breccias, and sulphide replacements ranging from pods to massive lenses. Multiple episodes of veining is common.

- Irregular deposit shapes are common and are the result of host rock permeability and the geometry of mineral-bearing structures.

- Common textures include: vuggy silica, drusy cavities, banded veins, hydrothermal breccias, and massive silicification of wall rock.

- Mineralogy can consist of: gold, silver, electrum, base metals, sulphosalts, and tellurides. Two main types: massive enargite-pyrite and/or quartz-alunite-gold.
High Sulphidation Epithermal Deposits

Photo 6: Banded quartz veining and brecciation, eastern Newfoundland

Photo 7: Banded quartz veining accompanied by adularia alteration, eastern Newfoundland

Photo 8: Drusy quartz cavity overprinted with hematite alteration, eastern Newfoundland
Schematic cross section showing the key geologic elements of the main gold systems and their crustal depths of emplacement. Modified from Poulsen et al. (2000), Robert (2004a), and Brommecker et al. (2016).
Sedimentary-Hosted (Carlin-Type)

- Mid-level mineralizing systems (i.e., depths of greater than 1 but less than 5 kilometres) once thought to be akin to epithermal deposits.

- Passive continental margins with subsequent deformation and intrusive activity. Possibly island-arc terranes.

- Very fine-grained gold and lesser sulphide minerals (pyrite, arsenopyrite, stibnite, etc.) disseminated in zones of decarbonated/decalcified calcareous rocks and associated jasperoids. Gold is typically evenly distributed throughout host rocks.

- Generally tabular, stratified bodies localized at contacts between differing lithologies. Ore bodies often exhibit irregular shapes with higher grade zones commonly being discordant breccias developed in steep fault zones.

- Common textures include: silica replacement of carbonate is accompanied by volume loss resulting in brecciation of host rocks (dissolution breccias).
Sedimentary-Hosted (Carlin-Type)

**Photo 9** Sedimentary-hosted gold ore, Nevada

Gold Ore
Carlin Mine
0.116 Ounces Per Ton
Donor: Newmont Mining Company

**Photo 10** Mineralized jasperoid, Nevada

Mineralized Jasperoid. Specimen is from the large boulders of subcrop found in the pediment. The Jasperoid formed from complete silica replacement of the regionally mineralized triassic limestone.

**Photo 11** Decalcified limestone, Nevada
Porphyry Cu +/- Mo, Au Deposits

Schematic cross section showing the key geologic elements of the main gold systems and their crustal depths of emplacement. Modified from Poulsen et al. (2000), Robert (2004a), and Brommecker et al. (2016).
Porphyry Cu +/- Mo, Au Deposits

- Mid- to deep-level mineralizing systems (i.e., depths of approximately 5 kilometres) however, the higher-level stocks and related dykes are commonly mineralized. Subdivided into three different types: (1) Volcanic-type; (2) Classic; and (3) Plutonic-type.

- Orogenic belts at convergent plate boundaries; commonly linked to subduction-related magmatism. High-level stock emplacement in volcano-plutonic arcs, commonly oceanic volcanic island and continent-margin arcs.

- Stockworks of quartz veinlets, quartz veins, closely spaced fractures and breccias containing pyrite and chalcopyrite with lesser molybdenite, bornite, and magnetite. Gold, enargite and tetrahedrite/tennantite are subordinate.

- Typically large zones of hydrothermally altered rock containing quartz veins and stockworks, sulphide-bearing veinlets (D-veins), fractures and lesser disseminations. Coincident with hydrothermal or intrusion breccias and dyke swarms.
Porphyry Cu +/- Mo, Au Deposits

Photo 12: Cu-Mo mineralization in quartz-latite porphyry, Utah

Photo 13: D-veins cutting quartz-latite porphyry, Utah

Photo 14: Cross-cutting veinlets in equigranular monzonite, Utah
Schematic cross section showing the key geologic elements of the main gold systems and their crustal depths of emplacement. Modified from Poulsen et al. (2000), Robert (2004a), and Brommecker et al. (2016).
Orogenic Gold Deposits

• Deep-level mineralizing systems (i.e., depths of greater than 5 kilometres). Includes the following sub-types: (1) Greenstone; (2) Turbidite; and (3) Banded Iron Formation.

• Contained in moderate to gently dipping fault/suture zones related to continental margin collisional tectonism (Phanerozoic). Can also be associated with major transcrustal structural breaks within stable cratonic terranes (Archean).

• Gold-bearing quartz veins and veinlets with minor sulphides (base metals, stibnite, molybdenite, etc). Cross-cut a wide variety of host rocks and are localized along major regional faults and related splays. Wall rock is characterized by silica-pyrite-muscovite (sericite) within a broader carbonate halo.

• Tabular fissure veins in more competent host rocks; veinlets and stringers forming stockworks in less competent rocks. Veins usually have sharp contacts with wall rocks and exhibit a variety of textures including massive, ribboned or banded, and stockworks with anastomosing gashes and dilations.
Orogenic Gold Deposits

Photo 15 Gold-bearing quartz vein (+ pyrite & galena), southern Newfoundland

Photo 16: Chalcopyrite-bearing quartz vein, central Newfoundland

Photo 17: Mineralized quartz vein, Wilding Lake Area (photo courtesy of Altius Resources Inc.)
For Low Sulphidation deposits, mineralization can occur in most types of volcanic rocks as well as clastic and epiclastic lithologies.

Alteration typically consists of:
- extensive silicification (which is often chalcedonic).
- silicification can be accompanied by adularia and carbonate.
- clay alteration (intermediate) can form adjacent to veins.
- advanced argillic alteration may form along the tops of mineralized zones.
- propylitic alteration typically dominates at depth and peripherally.

Weathered outcrops often exhibit resistant quartz +/- adularia ridges. Bleached, clay-altered zones with supergene alunite, jarosite and other limonite minerals.

Elevated Au, Ag, Cu, Pb, and Zn; As, Sb, Ba, F, and Mn (locally Te, Se, and Hg).

VLF-EM to trace structures; radiometric to outline zones of strong potassic alteration.

Prospecting for siliceous and silica-carbonate float or vein material with diagnostic features.
Exploration Methods – Epithermal
Exploration Methods – Epithermal

- For High Sulphidation deposits, mineralization occurs in volcanic pyroclastic and flow rocks; commonly subaerial andesite to rhyodacite, and their subvolcanic intrusive equivalents; permeable volcanosedimentary rocks can also host ore.

- Alteration typically consists of:
  - quartz, clay (kaolinite/dickite), alunite, barite, hematite, jarosite.
  - sericite/illite, amorphous clays, pyrophyllite, tourmaline, dumortierite.
  - advanced argillic alteration is characteristic and can be areally extensive.
  - quartz occurs as fine-grained replacements and as vuggy, residual silica.

- Weathered outcrops may contain abundant limonite in a groundmass of clay and quartz.

- Elevated Au, As, Cu dominate but also Ag, Pb, Zn, Sb, Mo, Bi, Sn, Te, W, B and Hg.

- Magnetic lows in hydrothermally altered (acid-leached) rocks.

- Typically found in higher order structures adjacent to crustal-scale fault zones (both normal and strike-slip). Postulated to overlie porphyry deposits and underlie acid-leached siliceous lithocaps.
Exploration Methods – Epithermal

Schematic reconstruction of a high-sulfidation deposit

Schematic reconstruction of a high-sulfidation deposit

(modified from Sillitoe, 1999)

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Porphyry stock

Dome

Ignimbrite

Steam-heated acid leached zone

Vuggy quartz

Illite out to illite/smectite

Quartz-dickite/kaolinite

Quartz-elunite

Intermediate argillic alteration (sericite up to pyrophyllite)

K-silicate alteration

Porphyry stock

Porphyry stock
For Carlin-Type deposits, mineralization mainly occurs in thin-bedded silty limestones and/or limy siltstones. Non-carbonate siliciclastic, rare metavolcanic, and felsic plutons and dykes can also be host rocks (less productive).

Alteration typically consists of:
- central core of strong silicification (close to mineralization) with veining and jasperoid formation.
- peripheral argillic alteration and decalcification of carbonate rocks.
- carbonaceous detritus is sometimes present.

Weathered outcrops may contain widely developed supergene alteration (kaolinite and alunite). Sulphides (if present) converted to hematite.

Elevated Au, As, Hg, Sb, Tl (toxic element suite).

Resistivity lows for some deposits. Aeromagnetic and Satellite Imagery surveys could highlight associated intrusions and regional structures.
Exploration Methods – Carlin-Type

Carlin-Type Gold Mineralization

Signature characteristics of Carlin deposits:

- Favorable sedimentary rocks (silty limestone & limey siltstones)
- Favorably faulted structure
- Gold-bearing hydro-thermal solutions
- Nearby gold deposits
- Gold: lots of it – these are the ‘elephants’ of gold deposits

*Schematic of Carlin-type Deposit (from Robert et al. 2007)*
• For Porphyry deposits, mineralization occurs in intrusive rocks ranging from coarse-grained, phaneritic to porphyritic stocks, batholiths and dyke swarms.

• Alteration typically consists of:
  ▪ central and early formed potassic zones (K-feldspar and biotite).
  ▪ grades outward into propylitic alteration assemblage.
  ▪ older alteration can be overprinted by phyllic and argillic assemblages.
  ▪ advanced argillic alteration can be present in uppermost parts of deposit.

• Secondary (supergene) zones carry chalcocite, covellite and other Cu-bearing minerals. Oxidized and leached zones at surface are characterized by iron-bearing “caps” and can be accompanied by clay minerals, limonite and residual quartz.

• Central zones with Cu enrichment commonly have coincident Mo, Au, and Ag (+/-Bi, W, B and Sr). Peripheral enrichment in Pb, Zn, Mn, V, Sb, As, Se, Te, Co, Ba, Rb, and possibly Hg.

• Ore zones can be associated magnetite-rich rocks (magnetic highs). Zones of phyllic alteration show as magnetic and resistivity lows. IP surveys may work.
Exploration Methods – Porphyry

Schematic of Alteration Zones of a Porphyry Copper-Gold Deposit (from Geopacific Resources Limited)
For Orogenic Gold deposits, mineralization occurs in varied lithologies usually of greenschist metamorphic grade (from undeformed to completely schistose).

Alteration typically consists of:
- silicification, pyritization, and potassium metasomatism occur adjacent to veins and within broader zones of carbonate alteration.
- presence of different carbonate minerals is an indication of the ferromagnesian content of host rock.
- fuchsite, sericite, tourmaline, and scheelite are common when veins are associated with felsic to intermediate intrusions.

Distinctive orange-brown limonite due to oxidation of Fe-Mg carbonates. Green Cr-mica may also be present. Abundant quartz float in overburden.

Elevated Au, Ag, As, Sb, K, Li, Bi, W, Te and B (+/- Cd, Cu, Pb, Zn and Hg) in rock and soil.

Magnetic surveys can show important structures. Areas of alteration can exhibit magnetic lows due to the destruction of magnetite.
Exploration Methods – Orogenic Gold

Schematic of tectonic setting for Orogenic Gold Mineralization (from Salier et al., 2006)
• Many other gold and/or gold associated deposit models (e.g., gold-rich VMS, turbidite-hosted, skarn, etc.).

• With the exception of Porphyry Cu +/- (Au, Mo) and Low Sulphidation Epithermal deposits, most other types (discussed) are highly variable in size.

• Faults, folds, and other geological/structural features have an important role.

• Small-scale features can greatly contribute to understanding the regional geology, e.g., parasitic folds, micro-fracturing, etc.

• Prospecting requires a keen eye for subtle differences in the rock, especially when exploring for gold. Sample, Sample, Sample!

• Compile your data and have it plotted. Highly beneficial to you as an explorer and as a mineral property vendor.
Concluding Remarks

Schematic of the various gold deposits (from Corbett, 2014)
Concluding Remarks
Concluding Remarks

North ore shoot (Cu Skarn Deposit), Bingham Canyon, Utah
Concluding Remarks
Concluding Remarks

- Helpful DNR links for the prospector.

Geoscience
http://www.nr.gov.nl.ca/nr/mines/Geoscience/index.html

Matty Mitchell Prospectors Resource Room
http://www.nr.gov.nl.ca/nr/mines/prospector/matty_mitchell/index.html

Prospectors Grants, Training & Application Forms
http://www.nr.gov.nl.ca/nr/mines/exploration/mip/prospectorast.html

Genuine Prospector Designation
http://www.nr.gov.nl.ca/nr/forms/mines/genuineprospector.pdf

Guidelines for Exploration & Assessment Reporting
http://www.nr.gov.nl.ca/nr/mines/exploration/guidelines/index.html