**INTRUSION-RELATED DEPOSITS**

Mineralization associated with and/or hosted by plutonic or intrusive igneous rocks.

**Gabbro- & Ultramafic-Related Deposits:**
1. Magmatic Deposits (e.g., chromite, nickel, PGE) - these deposits are hosted by mafic (e.g., gabbro), and ultramafic (e.g., pyroxenite) rocks.

**Granite-Related Deposits:**
Granite-related mineral deposits (Cu, Mo (Molybdenum), Sn (Tin), W (Tungsten), U (uranium), F Fluorine), rare metals, etc.) occur as ore bodies with one or more metals. The composition mainly reflects the chemical composition and less so the tectonic setting of the associated igneous rocks.

1. **Granophile Metal Deposits** (e.g., Sn, W, F, Mo, U, rare metals including REEs) – these deposits are associated with light coloured granitic rocks; includes pegmatites.

2. **Porphyry Copper & Molybdenum Deposits** (e.g., Cu, Mo and Au) – these deposits are associated with felsic intrusive rocks (porphyries).
MAGMATIC DEPOSITS

Deposits in which the ore minerals have crystallized directly from a magma.

Generally found in mafic or ultramafic igneous rocks, typically layered complexes.

Three major deposit types:

i) Nickel-Copper Deposits
ii) Chromite Deposits
iii) Platinum Group Elements Deposits

Minor amounts of Cr and PGE are also recovered from eluvial or alluvial (placer) deposits.

Discovery Hill, Voisey’s Bay
Silicate Magma

Gravity Settling

Massive Sulphide

R-VALUE:
Ratio of Silicate Magma to Sulphide Liquid it can exchange metals with.
MAGMATIC NICKEL-COPPER DEPOSITS
(+/- PGE)

BACKGROUND: Most important source of nickel.

ENVIRONMENT: They occur in:

Plutonic Rocks (form deep in the crust)……
  a) layered plutons … typically very old (Precambrian), and
generally hosted by gabbroic-troctolitic rocks (e.g., Sudbury and Voisey’s Bay).
  b) ultramafic rocks in old ocean floor (ophiolite) settings (e.g.,
NL, Quebec);
  c) orogenic (rift-related) gabbroic and ultramafic intrusive rocks (e.g., Retty Lake in the Quebec Labrador Trough).

Extrusive Rocks (form on the surface from lava flows)……
 Komatiitic (ultramafic rocks) flows or sills, mainly
Precambrian (e.g., Kambalda, possibly Florence Lake, Labrador); spinifex textures are a distinctive feature.
(PGE as a secondary by-product).

ORIGIN: Form by magmatic processes - as a magma chamber begins
to crystallize, nickel (+/-copper and PGE) become concentrated
and combine with sulphur to form massive sulphides.
STYLE:  Stratiform, blanket-shaped bodies consisting of massive to stringer, net-textured sulphides located in the basal portions of both the layered intrusions (troctolite-gabbro-norite common host; occur locally in ultramafic rocks-pyroxenite, peridotite) and the ultramafic flows. Ophiolitic-hosted mineralization consists of veins, pods, lenses, sometimes focused along faults.

MINERALOGY:  Pyrrhotite, pyrite, pentlandite, chalcopyrite and possibly significant PGE (platinum, palladium, iridium, etc.), e.g., Noril’sk.

ALTERATION:  None; however, sulphides may form large gossans.

DISTRIBUTION AND SIZE:

Newfoundland... A few small occurrence associated with ultramafic rocks in ophiolitic settings (e.g., Tilt Cove); possibly associated with layered intrusions in the Grenville, and central Newfoundland.
# Nickel Mineralization, Noril’Sk-Talnakh

<table>
<thead>
<tr>
<th>Layered series of intrusive and host rocks</th>
<th>Geological column</th>
<th>Intrusive rocks</th>
<th>Sulphide ores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volcanogenic and sedimentary metamorphic rocks</td>
<td><img src="image" alt="Geological Column" /></td>
<td>Contact gabbro-dolerites, anorthosites, leuocratic anorthitic gabbro</td>
<td>Stringer-disseminated ores, veins of massive sulphide</td>
</tr>
<tr>
<td>Upper gabbro layered series</td>
<td></td>
<td>Chromite-bearing taxitic gabbroic rocks</td>
<td>Rare sulphide dissemination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prismatic granular gabbro-dolerites and diorites</td>
<td></td>
</tr>
<tr>
<td>Main layered series</td>
<td></td>
<td>Quartz-bearing olivine-free gabbro-dolerites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olivine-free and olivine-bearing gabbro-dolerites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olivine gabbro-dolerites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olivine-biotites gabbro-dolerites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Picritic gabbro-dolerites, plagi-oliviniterites clinopyroxenites, froctolites</td>
<td>Disseminated ores with ovoid and interstitial sulphide aggregates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plagiochromittites</td>
<td></td>
</tr>
<tr>
<td>Lower gabbro layered series</td>
<td></td>
<td>Taxitic olivine gabbro dolerites</td>
<td>Disseminated ores with xenomorphic stringer-like sulphide aggregates</td>
</tr>
<tr>
<td>Sedimentary metamorphic rocks</td>
<td></td>
<td>Olivine-free gabbro-dolerites, contact dolerites</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Homogeneous and zoned massive sulphides</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Stringer-disseminated ores</td>
</tr>
</tbody>
</table>
Nickel Mineralization, Komatiitic Flow

- Aphyric komatiite
- Spinifex texture
- Porphyritic komatiite
- Interflow sediment (predominantly sulphidic)
- Volcaniclastic breccia
- Massive basalt
- Komatiitic dunite
- Massive nickel sulphide ore
- Pillow basalt
NOTE: Tilt Cove produced about 100 tonnes of nickel in the 1870’s = about 20% of the world production at that time!

Labrador ...... Nain Plutonic Suite (e.g., Voisey’s Bay - 150 million tonnes); Pant’s lake Intrusion; Michikamau Intrusion

Florence Lake greenstone belt e.g., Baikie Prospect; ultramafic volcanic and intrusive rocks.

Gabbroic -ultramafic sills in the Labrador Trough.

Massif-type anorthosite plutons (e.g., Harp Lake intrusion)

PROSPECTING METHODS:

Geological Look for gossans and sulphides, ultramafic rocks weather reddish brown.

Geophysical Pyrrhotite gives good mag response; EM for shallow deposits-disseminated ores in intrusive rocks will not respond to EM but may respond to IP. Komatiitic ores respond to EM.

Geochemical Ni, Cu, Cobalt and PGE are good indicators.
Some Nickel properties on the Island
Layered Troctolite-Olivine Gabbro
Red Cross Lake
Layered Troctolite: Voisey’s Bay
Banded Pyroxenite-Peridotite
Komatiitic Flow – Florence Lake Group
Massive sulphide pod: Okak Showing
Voisey Bay Ore
Voisey’s Bay Ore
Voisey’s Bay Disseminated (Net) Ore (Leopard Texture)
Copper and Nickel: Baikie Showing Florence Lake Group
**CHROMITE DEPOSITS (+/- PGE)**

**BACKGROUND:** Chromite is mined almost exclusively from massive to heavily disseminated segregations in ultramafic or mafic igneous rocks. 75% of the world production comes from South Africa. Uses include stainless steel and nonferrous alloys; it really is an industrial mineral.

**ENVIRONMENT:** Two deposit types

i) **Stratiform:** (Bushveld-type)…intercratonic layered intrusive complexes (e.g., Bushveld and Stillwater) accounts for 90% of known reserves; generally of Precambrian age. PGEs may be the primary product (PGE-enriched chromititites).

ii) **Podiform:** (Alpine-type)…ophiolite complexes associated with orogenic belts, account for 55% of world production, generally Paleozoic or younger.
CHROMITE DEPOSITS (cont’d)

STYLE:  
  i) **Stratiform:** blanket shaped or sheet-like accumulations, in the lower parts of layered ultramafic to mafic igneous intrusions; individual chromite layers vary from <1 cm to >2m thick and may extend for kilometers. They are usually associated with ultramafic rocks.

  ii) **Podiform:** disseminated and narrow layers 1 to 40 cm thick, lenticular or pod-shaped deposits that range from a few kilograms to several million tonnes. This style is discontinuous with no lateral extent. Almost exclusively in the ultramafic rocks, being most abundant in the tectonites, especially dunitic tectonites.

MINERALOGY:  
Chromite \((\text{Mg, Fe})\text{Cr}_2\text{O}_4\) is the only mineral of chrome. Stratiform deposits may have associated PGEs (platinum, palladium, iridium, etc.).

ALTERATION:  
None; however, ultramafic host rocks typically weather reddish-brown.
Ophiolite sequences with Chromite

- Pillow Lava
- Sheeted Dikes
- Gabbroic Rocks
- Layered Ultramafic and Nafic Cumulates with Chromite Deposits in Basal Dunite
- Foliated Dunite
- Banded Harzburgite and Dunite with Small Concentrations of Chromite in Dunite Bands, Discordant Bodies and Dikes
- Strongly Deformed Harzburgite and Lherzolite
- Metamorphic Sole, Foliated Granulites and Amphibolites

BAY OF ISLANDS OPHIOLITE

- Sediments, Vesicular Lava and Volcanic Tuffs
- Pillow Lava
- Diabase Sills
- Gabbroic Rocks
- Ultramafic Cumulates
- B - Pyroxenitic Zone
- A - Dunitic Zone with Basal Dunite and Chromite Deposits Overlain by Wehlite
- Harzburgite with a Large Number of Discordant Bodies and Dikes of Dunite with Podiform Concentrations of Nodular Chromite
- Dunite Bodies
- Harzburgite and Banded Harzburgite and Dunite and Scattered Discordant Dunite Bodies
- Strongly Deformed Harzburgite
- Wedges of Foliated Amphibolite

THETFORD MINES OPHIOLITE

ALPINE-TYPE PERIDOTES (LOWER UNIT)
Chromite (cont’d)

DISTRIBUTION:

Newfoundland....Numerous small podiform deposits associated with the Cambro-Ordovician ophiolites sequences. Largest are Springer Hill and Bluff Head in the Lewis Hills Massif; marine placers occur in western Newfoundland.

Labrador.........Large layer intrusions offer the best potential.
PROSPECTING METHODS:

Geological: Gossans formed by oxidation of sulphides; ultramafic rocks weather reddish-brown / brown. Peridotite host for podiform mineralization; pyroxenite and gabbro hosts for stratiform mineralization.

Geophysical: Does not respond geophysically; however, associated sulphide may be responsive.

Geochemical: Cr, Ni, Cu, Co anomalies; panned concentrates from streams or tills
Chromite in Ultramafic Rock
PLATINUM GROUP ELEMENT (PGE) DEPOSITS

ENVIRONMENT: Similar environments and host rocks as chromite and nickel-copper. (Platinum refers to an element, a mineral and a mineral group. Three main deposit types (only concerned with magmatic here):

1. MAGMATIC
   
   i) Associated with stratiform chromite mineralization in layered intrusions. In many cases as the primary product associated with both sulphide (Merensky Reef, Platreef, J-M Reef, Great Dyke) and chromitites (UG2 Reef).

   ii) Associated with Ni-Cu mineralization in both layered plutons (Sudbury, Noril’sk), and extrusive rocks (komatiites) (Kambalda, Thompson); associated with sulphides and is a by-product.

   iii) Alaskan-type... zoned, concentric ultramafic to mafic intrusions of dunitic composition. High grade, low tonnage deposits; occurs as a primary product and is associated with chromitite and sulphides.
2. ALLUVIAL

i) Placer: platinum was discovered by the Spanish in stream beds with detrital gold in Columbia in mid-16th-century (the Rio Platino del Pinto). As the unknown metal has an extremely high melting point, it was regarded as useless and hindrance to the refining of gold, and was called platino meaning silver of poor quality. Most commonly spatially associated with ultramafic/mafic complexes of the Alaskan-type examples, Columbia, Urals.

ii) Paleoplacer: only known significant deposit is the auriferous-uraniferous conglomerates of the Witwatersrand.

3. HYDROTHERMAL: formed from epigenetic fluids and associated with shear zones cutting mafic/ultramafic host rocks with alkaline porphyry, copper-precious metal deposits and with late diagenetic flow of metal-bearing brines in carbonaceous sediments.
PGE (cont’d)

ORIGIN: Magmatic processes; placer; deuteritic alteration; epigenetic fluids

MINERALOGY: PGE (platinum, palladium, iridium, Os, Ru, Rh): pyrrhotite, pyrite, pentlandite, chalcopyrite and Au.

ALTERATION: None; however, associated sulphides may form gossans.

DISTRIBUTION:

Newfoundland: Layer plutons in central NL, such as the Red Cross Lake intrusion, and those in the Grenville of Western NL.

Labrador: i) Massif-type anorthosite plutons in the Nain, Churchill and Grenville provinces, e.g., Harp Lake Intrusive Suite.
ii) Layered gabbroic plutons such as the Kiglapait Intrusion. Others include gabbros associated with the Nain Plutonic Suite, Harp Lake, etc.

iii) Massive to weakly layered plutons. Examples include gabbro and norite Intrusions within the Grenville and include the Shabogamo, Red Wine Mts and White Bear Arm intrusive suites.

iv) Gabbro and ultramafic sheets and sills, includes high level intrusions located within or adjacent to supracrustal sequences, e.g., Labrador Trough sills (Retty Lake), basaltic rocks of the Seal Lake Group, ultramafic sills in Archean greenstone belts.

v) Archean layered anorthosite-gabbro-ultramafic intrusives. Sheet-like bodies In reworked Archean rocks of the northeastern Churchill Province and the Nain Province

vi) Hornblende gabbro-diorite-monzonite intrusions, e.g., Adlavik Intrusive Suite of eastern Labrador.
MAFIC MAGMATIC ASSOCIATION AND POTENTIAL NI-SULPHIDE ENVIRONMENTS OF LABRADOR
PGE (Cont’d)

Prospecting Methods

**Geological:** Gossans formed by oxidation of sulphides; ultramafic rocks Weather reddish-brown / brown.

**Geophysical:** Associated sulphides; pyrrhotite gives a good mag response; Komatiitic ores respond to EM; disseminated ores in intrusive rocks will not Respond to EM, but may respond to IP.

**Geochemical:** Ni, Cu, Co and PGE anomalies; panning.
Platinum