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Matty Mitchell - prospector, trapper, woodsman and guide: discoverer of the Buchans Mines

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PROSPECTORS COURSE

METALLIC MINERAL DEPOSITS

B.F.KEAN

(Adapted from Kean and Evans <u>in</u> Introduction To Prospecting, Course Notes, pp. 326-410, and revised version pp. 137-180)



METALLIC MINERAL DEPOSITS OUTLINE

1. Introduction A. Prospecting Skills B. Course Objectives C. Terminology

2. Classification of Metals & Minerals A. Ore-Forming Metals B. Ore-Forming Minerals 3. Metallic Mineral Deposits A. Deposit Models B. Deposit Types (with reference to NF & Labrador) i) Volcanic-Hosted Deposits Sediment-Hosted Deposits a) MVT b) Sedimentary Copper c) SEDEX iii) Intrusion-Related a) Magmatic Deposits b) Granophile Metal Deposits c) Porphyry Deposits iv) Uranium Deposits



INTRODUCTION

Required Prospecting Stalls (1A):

To successfully prospect you need an understanding of ...

i) Basic Rock and Mineral Identification, and Geological Principles

ii) Characteristics of Different Mineral Deposit Types (i.e., what they look like)

iii) Where to look for the Different Mineral Deposit Types

iv) Prospecting Methods Applicable to the Different Deposit



Types - A

This part of the course deals with sections ii), iii) and iv)

Course Objectives (1B) - Topics

i) Terminology

ii) Brief rock and mineral identification.

iii) Description of deposit types found to date and those that may be found in the future in the province.

iv) Provide an idea where to prospect for each type. Specific types of mineralization are only found in certain rock types and environments . Therefore, rock types are indicators of what kind of mineralization may be present.

v) Provide an idea of the prospecting techniques for each deposit type. Prospecting methods vary according to the type of deposit being sought.



In summary, the course aims to leave the prospector with a general impression of what ore deposits look like, how they are formed, what to look for and where, and the relevant prospecting method for each type.

Hopefully, you will have a feeling for the diversity of ore deposits, the dependence of their occurrence on the local geology, and some characteristic features of the different deposit types found in Newfoundland and Labrador that will serve as prospecting guides.



1C. GEOLOGICAL TERMINOLOGY

Element : An element is a substance composed of atoms; it cannot be broken down by chemical means into simpler substances (e.g., Cu, Pb, Zn, Ni, Au, etc.).

Mineral vs Rock

Mineral: Naturally formed substance that is composed of one or more elements, e.g., gold (Au), lead (PbS), sphalerite (ZnS), etc. Most minerals are formed by inorganic processes. Minerals have characteristic properties that aid in their identification, such as hardness, specific gravity, streak, crystal form.

Rock: An aggregate of one or more minerals and/or rock particles.



Sedimentary Rock: Rock made from pieces of other rock (e.g., conglomerate, sandstone, shale); from the remains of animals or plants (e.g., coal, limestone); from chemical precipitation (e.g., salt, gypsum. limestone); or a mixture.

Limestone: A sedimentary rock consisting of calcium carbonate : can be either organic, chemical or clastic in origin.

Dolostone: Basically a limestone with more than 15% magnesium carbonate. Also known as dolomite.

Igneous Rock: Formed by cooling and solidification of molten magma. Igneous rocks can be divided into three classes:

i) Intrusive: Igneous rock that forms beneath the earth's surface, generally has large crystals, and is emplaced into other rocks (e.g., gabbro, granite); see also Plutonic Rocks.

ii) **Extrusive**: Igneous rock that forms on the earth's surface, generally small crystals; also referred to as volcanic rocks (e.g., flows, lava, pyroclastics).



iii) Hypabyssal: Igneous rock intermediate between i & ii; generally found in high-level dykes and sills.

Plutonic Rocks

Igneous rocks that form at depth in the earth's crust; emplacement mechanisms may vary (see Intrusive Rocks).

Igneous Rocks can be grouped based on chemistry/mineralogy and/or texture

Felsic: Igneous rocks that contain abundant quartz and feldspar, generally light coloured (e.g., dacite, rhyolite).

Mafic: Igneous rocks that contain abundant Fe- and Mg-rich minerals, such as pyroxene, olivine and hornblende and are therefore dark coloured (e.g., basalt and gabbro). These rocks also contain a Ca-rich feldspar.

Ultramafic: Igneous rocks that contain greater than 90% Fe-Mg-rich minerals such as pyroxene and olivine and very rarely quartz and feldspar – hence the rocks are very dark in colour (e.g., dunite, pyroxenite, peridotite).

Porphyry: An igneous rock that contains large crystals in a fine-grained matrix (i.e., like raisins in a bun).



Extrusive Igneous Rocks: Rhyolite

A fine-grained, quartz and alkali-feldspar rich rock = a felsic volcanic rock.

Basalt

A fine-grained volcanic rock composed of Ca-rich feldspar, pyroxene and sometimes olivine = a mafic rock. When extruded under water, it forms pillow lava.

Pillow Lava.... Pillow-like structures formed in submarine eruptions of basaltic and andesitic lava.

Komatiite

Ultramafic, extrusive (lava) rock high in MgO. Commonly exhibiting spinifex texture (i.e., interpenetrating, lacy, elongate olivine crystals; formed by quenching... named after a type of Australian grass).

Intrusive Igneous Rocks:

Granite

A medium- to coarse-grained, plutonic igneous rock rich in quartz, alkalifeldspar; muscovite, biotite, hornblende may be present.



Granitoid

Group of granite-textured intrusive igneous rocks varying from diorite to granite.

Gabbro

A coarse-grained, mafic intrusive igneous rock consisting of calcicplagioclase and pyroxene; +/- olivine and hornblende.

Troctolite

Plutonic rock of the gabbro family consisting of olivine, calcic plagioclase, with little or no pyroxene.

Peridotite

A general term for ultramafic plutonic rock consisting of essentially olivine +/- other mafic (Fe-Mg rich) minerals.

Dunite

An ultramafic, plutonic rock with ~ 90% mafic (Fe-Mg) minerals; mostly olivine with accessory pyroxene and chromite.

Pyroxenite

An ultramafic rock consisting essentially of pyroxene.



Ophiolite

A distinctive sequence of igneous rocks that form at spreading centres or rifts, and make up the earth's crust under the major oceans.

Island Arc

Chain of volcanic islands (e.g., around the western side of the Pacific - ("Fiery Ring of the Pacific"); rocks formed in such an environment, i.e., above subduction zones (destructive plate margins), and characterized by felsic rocks.

Submarine

Refers to rocks or mineral deposits formed on the seafloor.

Subaerial

Rocks or mineral deposits formed on the earth's surface.

Volcanogenic

Formed by processes directly related to volcanic activity; directly or indirectly of volcanic origin.

Volcaniclastic



Pertaining to a clastic rock containing volcanic rock material without any consideration for origin or environment.

Country Rock

The rocks surrounding and penetrated by mineralization; rocks from which metals are derived; rocks intruded by an igneous intrusion.

Host Rock

The wall rock of a mineral deposit; rocks surrounding an igneous intrusion.

Fault or Shear Zone

Fault: A fracture along which there has been movement; also referred to as a shear zone; important for some types of mineralization.

Hydrothermal Fluid

Hot-water solutions, generally chloride- or carbonic-rich, which can dissolve (leach) and carry elements (e.g., gold, copper, etc.) by percolating through small pores in rock and along fault zones. These fluids alter the rocks with which they come in contact, and through which they pass.

Alteration (Altered Rock)

Any change in the mineralogic composition of a rock by physical or chemical means, e.g., by the action of hydrothermal fluids.



Metallic vs. Industrial Minerals

Metallic Minerals: Substances that have a metallic luster, are opaque, and electrically conductive. Two broad types Ferrous (iron) & nonferrous (e.g., nickel, copper, lead, zinc, gold, silver, tin and tungsten, etc.).

The mining of these minerals is typically price-driven. A deposit of economic size and grade usually goes into production. Thus, the economic viability of a metallic mineral deposit is mainly dependent on the price of the metal(s).

Industrial Minerals: Minerals/rocks used in industrial/construction applications, exclusive of metallic ores, mineral fuels and gemstones (e.g., gypsum, graphite, sand, gravel, limestone, building and dimension stone).

The development of these is market driven, i.e., development depends not only on finding a deposit of significant size, but also on being able to find a market. Must have a buyer for the product.



Ore and Orebody

Ore: A naturally occurring material from which a mineral or minerals can be extracted at a reasonable profit.

Orebody: A continuous, well defined mass of ore, which can be mined economically.

Syngenetic vs. Epigenetic

Syngenetic: A mineral deposit that is approximately the same age as (i.e., coeval) and formed by the same processes that formed the host rock.

Epigenetic: A mineral deposit that formed later (therefore is younger) than the host rocks.



Stratabound vs. Stratiform

Stratabound: A mineral deposit confined to a single stratigraphic unit, not necessarily the same age as the rock unit.

Stratiform: A type of stratabound deposit that is coextensive with a rock unit, approximately coeval.

Exhalative

A deposit formed by hydrothermal fluids venting into water, such as onto the sea floor.

Black Smoker

Underwater 'geysers' of heated seawater (hydrothermal fluid) rich in sulphide minerals and from which the sulphides precipitate.

Sulphide

A compound of sulphur and one or more other elements, commonly iron and copper.



Disseminated

The minerals are scattered throughout the rock.

Stockwork

A network of mineralized veins, plus disseminated minerals; generally related to hydrothermal activity.

Massive Sulphide

A great mass of sulphide minerals with very little non-sulphide material.

Volcanogenic Massive Sulphide Deposits (VMS)

Massive sulphide deposits formed by the discharge of hydrothermal solutions into/onto the seafloor; typically associated with submarine volcanic or volcanogenic rocks.

<u>Sedimentary</u> <u>Exhalative Deposits</u> (SEDEX)

Zn-Pb deposits formed by the discharge of fault-controlled hydrothermal fluids into sedimentary basins. The deposits are typically hosted by fine-grained sedimentary rocks that overlie thick sequences of coarsegrained clastic sedimentary rocks.



Magmatic Deposits

Formed by processes related to the formation of plutonic (intrusive igneous rocks) that are typically of mafic or ultramafic composition. Deposits usually formed by gravity settling of minerals in a magma.

Chromitite

Layers containing 50-90% of chromite; may contain olivine, orthopyroxene and plagioclase; rarely biotite.

Polymetallic

A mineral deposit that contains economically important concentrations of three or more minerals.

Gossan

Leached and oxidized near surface portion of a mineral deposit; especially applicable to deposits rich in iron-sulphide minerals. Consist of a yellowish, rusty 'burn' (weathering) on pyritic outcrops; different from ochre-coloured carbonate alteration.

Greisen

Altered granitic or country rock composed largely of quartz, white mica and topaz. Tourmaline, fluorite, rutile, cassiterite and wolframite are common accessory minerals.



Pegmatite

Very coarse-grained igneous rock associated with granitic rocks, rich in potassic-feldspar and muscovite; may carry rare metals (beryl, etc.).

Hanging Wall vs. Footwall

Hanging Wall: An old mining term which refers to the wall rock above an orebody.

Footwall: An old mining term which refers to the rock beneath an orebody (i.e., beneath your feet).

Placer

A surficial mineral deposit formed by the concentration of mineral particles from weathered sources (e.g. beach or river).

Alluvial A placer formed by running water.



Geochemistry

The study of the composition of rocks, minerals, soil and stream and lake samples etc and application of results to search for ore deposits.

Types of Geochemical Surveys

Soil Survey: Weathering of a mineral deposit causes dispersion of elements such as gold, copper etc to become concentrated in the overlying soil. Prospectors carry out either detailed or reconnaissance surveys all year round. Soil samples results may outline a zone of elevated values (an anomaly).

Rock Survey: Analysis of whole rock samples or individual minerals, often used to distinguish alteration zones (also referred to as lithogeochemical surveys).



Stream Sediment Survey: Sample of sediment collected from stream bed, used mainly for reconnaissance studies in drainage basins. Samples are usually panned to produce a heavy mineral concentrate.

Lake Sediment Survey: Sample of sediment collected from lake bottom, used for reconnaissance surveys.

Note: When carrying out soil surveys in areas of glacial drift, we need to consider the transported nature of glacial material (where is the source of the main material in the soil). An anomaly may be far removed from the mineral deposit that produced it.



GEOPHYSICAL TERMINOLOGY

Geophysics The study of the physical properties of the earth.

Magnetic Survey (mag)

Measures the magnetic susceptibility of rocks. Mafic rocks and sulphide bodies have high magnetic susceptibility (they will distort the earths magnetic field and produce a magnetic high).

Self Potential (SP)

A sulphide body will act as a weak natural battery because of the interaction of ground water with the sulphide minerals. The SP survey measures the weak electric current that is present.

Induced Potential (IP)

An alternating electric current is applied to bedrock. After the current is switched off, sulphide minerals like pyrite briefly hold a voltage. This voltage can be measured as it decays slowly over time.



Electromagnetic Surveys (EM)

Theory

Passing a current (AC) through a wire induces a primary magnetic field in the vicinity of the wire. The primary magnetic field induces currents in bedrock conductors (if present). The currents in the conductor induce a secondary magnetic field. The secondary magnetic field is measured by a receiver either on the ground or in an aircraft.



GEOPHYSICAL TERMINOLOGY (cont'd)

Radiometric Surveys

Energy released during radioactive decay can be in the form of alpha, beta and gamma rays. A gamma-ray spectrometer measure the gamma rays given off from three naturally occurring radioactive elements....uranium, potassium and thorium. Maps showing ratios of these elements are useful in distinguishing alteration zones.



2. CLASSIFICATION OF METALS & MINERALS

2A. METALS

Metals are elements. Those metals of importance in Newfoundland and Labrador can be classified into three groups.

i) Base Metals - The more common (and more chemically active) metals, e.g., copper, lead, zinc, nickel. These are most common economic minerals, and therefore the most sought after.

- *ii) Precious Metals Less common or rarer metals, e.g., gold, silver and the platinum group elements (PGEs... platinum, palladium, etc).*
- *iii)* Granophile Metals Metals usually associated with granitoid rock e.g., molybdenum, tin, tungsten, fluorite, uranium and rare metals (such as beryllium, yttrium, zirconium and the Rare Earth Elements (REEs)); these are also known as lithophile elements.



Most of the metals/elements of interest do NOT occur in nature in their pure (elemental/native) form - they are found in minerals.

Ore-forming metals are commonly concentrated in nature as compounds with reduced sulphur, called sulphides, and less commonly oxides, carbonates, sulphates and tungstates. Copper, gold and silver may occur in native or elemental form. Gold and silver form an alloy called 'electrum'.



2B. PRINCIPAL ORE-FORMING MINERALS

Element Sulphides Copper (Cu) Zinc (Zn) Lead (Pb) Nickel (Ni) Silver (Ag) Antimony (Sb)

Molybdenum (Mo)

Mineral

Chalcopyrite (CuFeS₂) Chalcocite (Cu₂S) Bornite (Cu₅FeS₄) Sphalerite (ZnS) Galena (PbS) Pentlandite ((Fe,Ni)₉S₈) Millerite (NiS) Argentite (Ag₂S) Stibnite (Sb₂S₃) Tetrahedrite (Cu₁₂Sb₄S₁₃) Tennantite (Cu₁₂As₄S₁₃) Molybdenite (MoS₂)

Important sulphides that typically accompany ore deposits include pyrite (FeS₂), pyrrhotite (FeS), marcasite (FeS) and arsenopyrite (FeAsS)



<u>Mineral</u> <u>Element</u> Oxides Chromium (Cr) Chromite ((Mg,Fe)Cr₂ O_4)) Tin (Sn) **Cassiterite** (SnO₂) Uranium (U) Uraninite/Pitchblende $(UO_2 - U_3O_8)$ **Tungstates** Tungsten (W) Wolframite ((Fe,Mn)WO₄) Scheelite (CaWO₄) Native Elements Copper (Cu) Copper Silver (Ag) Silver Gold (Au) Gold, Electrum (Au,Ag) Platinum Platinum (Pt) Other Fluorine (F) Fluorite (Fluorspar) (CaF₂)

Malachite $((Cu_2(CO_3)(OH)_2))$

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Copper (Cu)

3. METALLIC MINERAL DEPOSITS

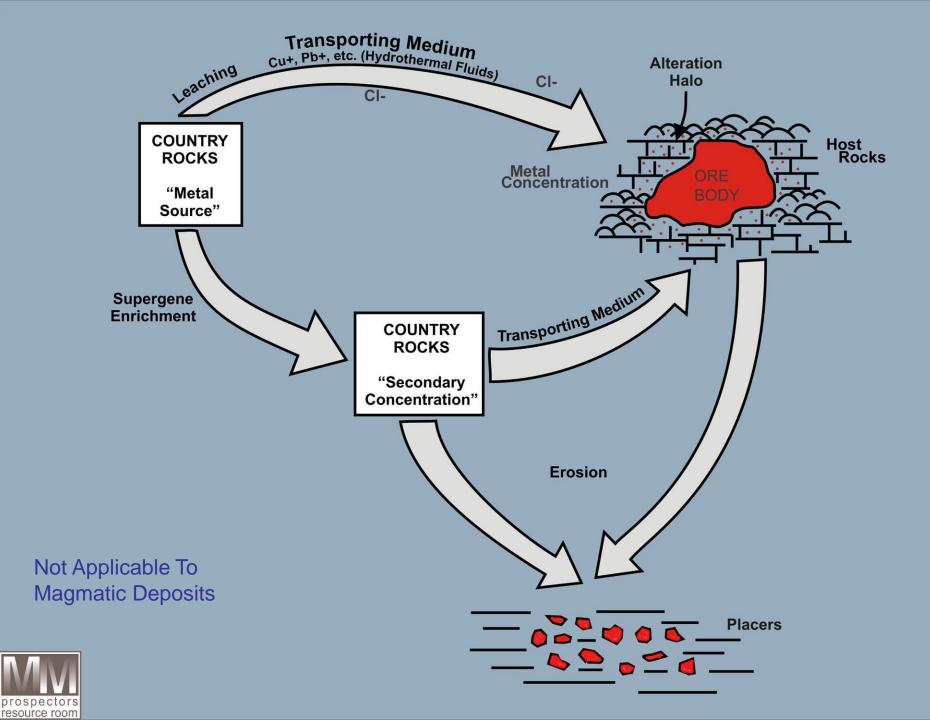
Mineral deposits - An accumulation of minerals that contain elements or minerals that are useful to society and which can be extracted from the earth at a profit.

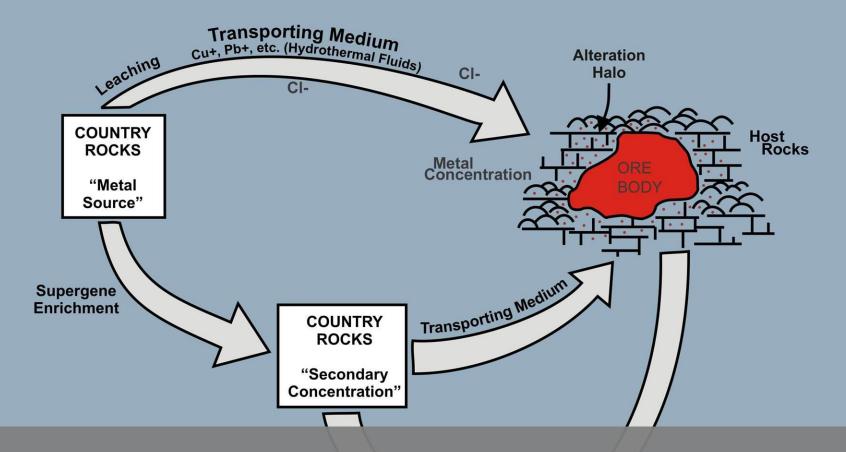
The formation of most mineral deposit requires three essential geological components:

 i) A source of the metal of value
ii) A means of concentrating and transporting the metal
iii) A mechanism for depositing it in economic concentration

Magmatic mineral deposits differ somewhat.



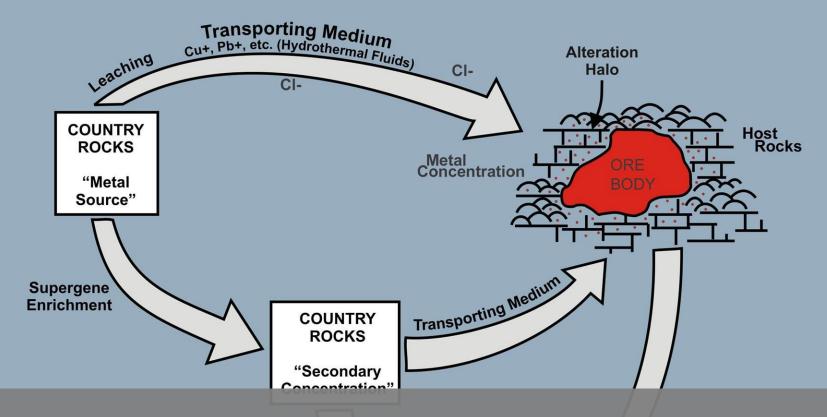




The source of the metals is generally the most difficult to identify, and the least likely to be useful in prospecting. Source areas for metals are not always easily identified. Furthermore, the metals in most deposits have been carried a long way from their source, and therefore knowing the source is of little value in locating where mineral deposits form.

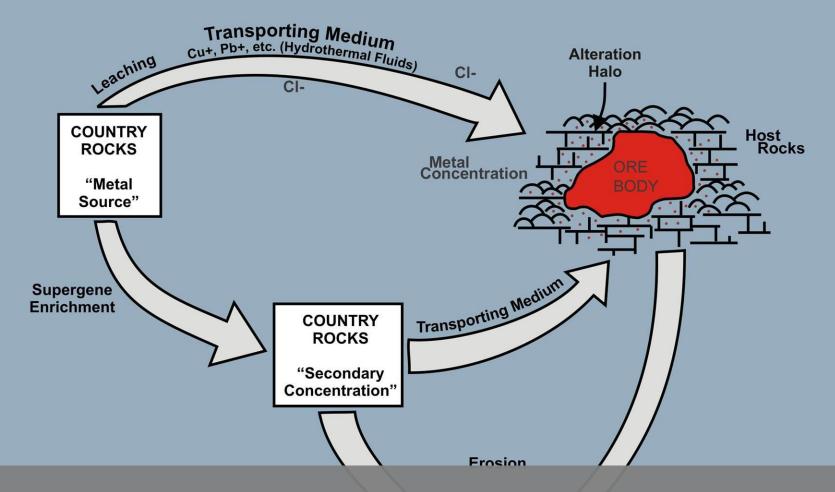






Metals are generally leached from the source rocks by, and transported in, hot aqueous solutions that contains chloride or carbonic complexes (hydrothermal fluids). Large amounts of metals can be carried this way for considerable distances...10s of m to 10s of km. This process cause changes in the source rocks , but also in the rocks through which they pass. This 'hydrothermal alteration' may include the addition and/or removal of elements, changes in the mineralogy of the rocks, deposition of quartz and carbonate, veining, sulphide deposition, etc. Alteration is an important prospecting tool for many deposits types, as alteration haloes form much larger targets than the deposits themselves; note that magmatic or Zn-Pb Mississippi type deposits do not have alteration haloes.





Metal precipitation or deposition varies substantially for different deposit types. Deposits associated with volcanic rocks may be concentrated along a particular time-stratigraphic unit. Carbonate-hosted mineralization generally occur in rocks that are porous. Faults may be the key in conjunction with other factors. Knowing the deposition or precipitation characteristics of a deposit type helps in defining the prospecting target.



3A. DEPOSIT MODELS

Mineral deposit models have a descriptive (deposit characteristics) and a genetic component. We will be only concerned with characteristics of deposits such as location (setting), host rock, mineralogy, shape (morphology) and alteration.

Purpose of Models: To focus on what, where and how to explore for ore deposits. Models are only a guide and are to be used prudently.



Guidelines That Models Provide To Prospectors:

- *i)* Enables comparison of local geology with various deposit models to decide which deposits may occur in the area. Concentrating on only one type in a geologically complex area may result in overlooking other possibilities.
- *ii) Is the deposit type economically significant...is it worth prospecting for?*
- *iii) The right model allows you to decide what prospecting methods to use. Different deposit types have different characteristics.*
- *iv)* Comparison of field observations with the appropriate model facilitates the evaluation of the significance of the mineralization. May provide a guide as to where to further look.

Remember that ideas and concepts change ... mineralization is where you find it !! Case-in-point Voisey's Bay.



3B. DEPOSIT TYPES

Non-ferrous metallic mineral deposits (excluding gold and uranium) - discussed in terms of host rock and/or environment of formation, and in the context of Newfoundland and Labrador examples.

Using this approach, it is evident that an appreciation of the type of mineral deposit(s) that you may expect to find in an area may be gleaned from:

i) The geology of the area MAPS & REPORTS

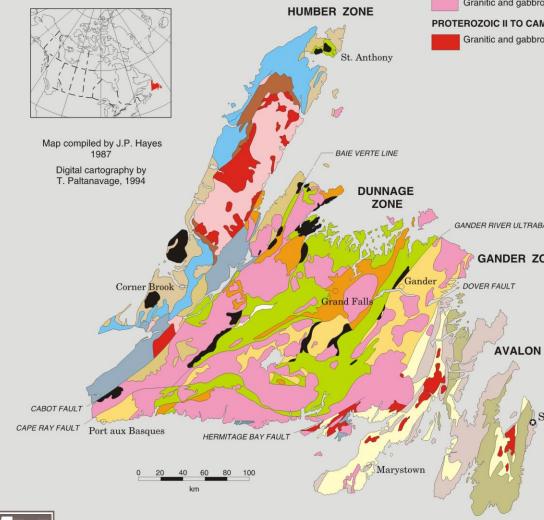
ii) Known mineral occurrences/deposits ... they indicate what has been found in the area and may indicate its mineral potential MINERAL OCCURRENCES.

iii) The types of mineral deposits that are known to occur in similar rocks/geology elsewhere MINERAL DEPOSIT MODELS

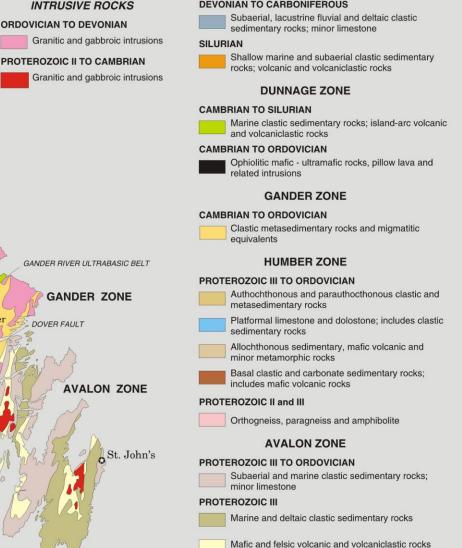
Most of this information and resources is available from the Dept. of Natural Resources, e.g., publications, project geologists, Geoscience Resources Atlas, website, etc.



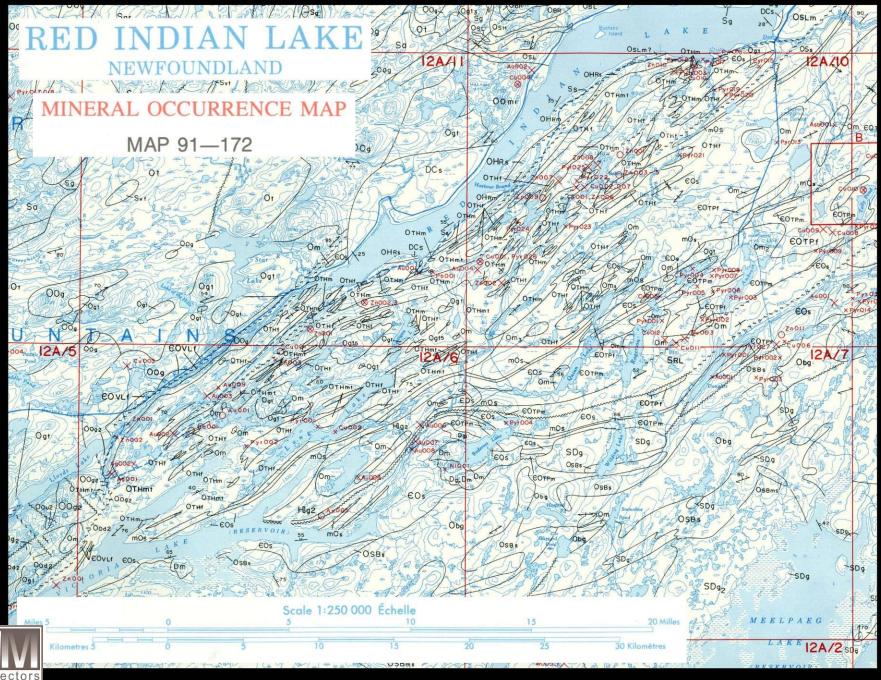
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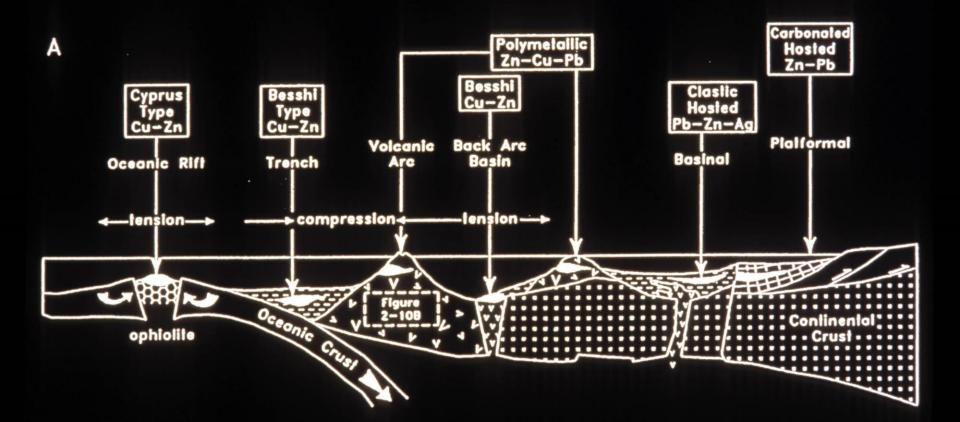






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Typical Geological Locations for the Formation of Major Deposits





METALLIC MINERAL DEPOSITS (Excluding Gold)

Rambler Mine

Newfoundland and Labrador Metallic Mineral Deposits are discussed as follows:

A.Three types defined by Host Rocks i) Volcanic-Hosted Deposits ii) Sedimentary-Hosted Deposits iii) Plutonic-Related Deposits

B. One type independent of rock type; structure is often an important factor (e.g., gold, uranium).

