Three Main Types

1. Mississippi Valley Type (MVT)
   “Epigenetic” stratabound Zn-(Pb) deposits hosted by carbonate sedimentary rocks.

2. Sediment-Hosted Copper Deposits
   “Epigenetic” disseminated Cu deposits hosted in reduced sedimentary rocks.

3. Sedimentary-Exhalative (SEDEX) Type Deposits
   “Syngenetic” stratiform, bedded Zn-Pb deposits hosted by fine-grained clastic sedimentary rocks.

These three types may be considered as a spectrum of base-metal ore deposits which form in sedimentary rocks at some time during the evolution of a sedimentary basin.
SEDEX AND MVT ENVIRONMENTS

SHALE BASIN

Mixing of metalliferous fluids with H₂S-rich seawater at or above sea floor

CARBONATE PLATFORM

Mixing zone within reef of H₂S-rich seawater and metalliferous fluids

Reef

O₂

H₂S

SO₄ → H₂S

MVT

Sea floor

SEDEX

Pb-Zn-chloride hydrothermal fluid

CONTINENTAL CRUST
MISSISSIPPI -VALLEY TYPE DEPOSITS (MVT)

BACKGROUND: Zn-Pb deposits; generally <2 Mt, occur in clusters; generally < 10% Pb + Zn, and Zn dominated. A viable mine requires an overall grade > 8%, with ore beds > 15%Zn, and thicknesses >3m.

ENVIRONMENT: Ordovician platformal carbonate rocks (Appalachian Zinc, e.g., Daniel’s Harbour), and Carboniferous basinal carbonate rocks (SW Mississippi Pb-Zn).

ORIGIN: Shallow, low temperature (90° to 150° C), epigenetic mineralization. Metals derived from compaction of sediments, carried by pore waters into porous units, particularly dolostone where porosity has increased.

This porosity may be primary (e.g., reefs, carbonate sands), or secondary (e.g., fracturing, dolomitization, paleokarst, faults, breccias). Organic matter and petroleum acts as a reducing agent, and enable precipitation of sulphides.

Colloform Sphalerite: Daniel’s Harbour Mine
STYLE: Stratabound deposits - occur in specific carbonate rock layers with lots of porosity and permeability as inter-crystalline pores, fractures, breccias and open cavities. Sulphides crystallize in significant concentrations in areas characterized by an abrupt increase in porosity as late cements in veins, pores, breccias, and fractures, and partially replacing the surrounding rock.

Ordovician age deposits tend to be lensoid or linear (sinuous porosity channels); Carboniferous age deposits are irregular, coarsely crystalline, locally form veins with calcite.

MINERALOGY: Ordovician mineralization is generally light coloured, coarsely crystalline sphalerite with relatively little galena; Carboniferous mineralization is generally light-coloured sphalerite and galena, lesser marcasite and pyrite. Accessories include barite, gypsum, and fluorite.

ALTERATION: No related alteration, and sphalerite and galena do not rust; dolomitization and collapse breccias are pre-mineralization. Primary and secondary porosity is important.
MISSISSIPPI VALLEY TYPE DEPOSITS

Trace of premineralized and prefluid alteration strike-slip fault

Rubble breccia

Crackle breccia

Stratified sediments

Mineralized breccia

Barren breccia

BRANCHING SHOOT - TYPE ORE BODIES

BREAKTHROUGH - TYPE ORE BODY

Limestone

Primary dolomite
DISTRIBUTION:

Newfoundland

Ordovician platformal carbonate rocks deposited in a continental margin setting, western Newfoundland; Silurian carbonates, south of Hampden; Carboniferous rocks of the St. George Basin-marine interval of limestone and associated clastic rocks (Ship Cove Limestone, Codroy Group).

Labrador

Proterozoic carbonates Labrador City to Schefferville; possibly in the Ramah Group
MVT
2- Labrador Trough
3- Ramah, Snyder & Mugford Groups?
PROSPECTING METHODS:

GEOLOGICAL  Ore bodies narrow and hard to find; low relief and glacial drift. Characterized by regional dolomitization; more specifically occur at the base of dolostones - transitions between limestones and dolostones; porosity critical; coarse-grained, grey and white (sparry) dolostones in mottled black and white rocks (pseudobreccia); commonly beneath unconformities; in dolostone beneath impermeable shale; and ‘pinch-outs’ against basements highs; faults and associated collapse breccias; organic trash important as a reducing agent; limestone breccias and reef facies carbonates. Boulder tracing.

GEOPHYSICAL  Sphalerite is non-magnetic and lacks electromagnetic conductivity; galena or pyrite may produce an IP anomaly.

GEOCHEMICAL  Zn in soils, streams and lakes, not much metal mobility in carbonate-dominated environments.
Carbonate Terrain: Great Northern Peninsula
Bedded Dolostone: Daniels Hbr Mine

6.6 Mt @ 7.9% Zn
(Contained in >12 Lenses)
Dolostone Breccia
Matrix Breccia in Dolostone
Zinc-mineralization in Sparry Dolostone; Daniel’s Harbour Mine
Ryan’s Brook Cu-Pb-Zn, Ship Cove Limestone
SEDIMENT-HOSTED COPPER DEPOSITS - SSC

Characterized by a prominent copper-rich zone in a red and grey bed sedimentary sequence; includes Redbed-Copper and Volcanic-Redbed types.

BACKGROUND: 20% - 25% of the world’s Cu production (2nd only to porphyry Cu); significant Co (Central Africa), Pb (Poland), Ag (USA); may also contain Au, U, PGEs, rare metals.

ENVIRONMENT: Located in, or associated with, sedimentary basins filled with large thicknesses of continental red beds (may be volcanic rocks present), and overlain by grey/green rocks. The grey/green rocks are/were enriched in sulphur (pyrite, gypsum/anhydrite, carbonaceous material). Mineralization occurs in reduced grey/green rocks near the oxidation-reduction boundary; may be associated with gypsum & anhydrite beds (evaporites).

Most major deposits occur in shallow marine or saline lake rocks immediately overlying red, continental clastic sedimentary rocks.
Deposits contained entirely within continental red bed sequences (Redbed-Copper type) are of lesser importance. Those deposits in red bed sequences containing volcanic rocks are called Volcanic-Redbed type.

**ORIGIN:** Metals leached from sediments as water expelled by compaction, fluids migrate along porous horizons and faults to basin margins, metals deposited where reduced sulphur encountered.

**STYLE:** Disseminated sulphides that are usually stratiform along bedding planes. Mineralization usually continuous within beds or may follow old channels – in some places the mineralization may cut beds.

**MINERALOGY:** Fine grained, disseminations or clusters (around organic material) of chalcocite and bornite with lesser native Cu, chalcopyrite, galena, hematite and pyrite. May contain significant Ag, Co, U, Au and PGE sometimes.

**ALTERATION:** Bleaching of sediment due to reduction. Mineralization occurs at reduction fronts; oxidizing (red sandstone) to reducing (green sandstone); gossans.
Reduction Front

Fine-grained
Grey-beds
with sulfur-rich
reducing conditions

Unmineralized Zone

S^2- + Cu ----> Cu-bearing sulfides

Cupriferous Zone

Coarse-grained
Red-beds
with oxidizing
conditions

Cu_d

Cu_d
Volcanic-Redbed Cu

- Conglomerate
- Flow-top breccia
- Dense lava flow

Movement of ore fluid ..............
Fault occupied by copper-bearing vein with mineralogy indicated ....
Fault ....................................

Cu: native copper
cc: chalcocite
bn: bornite
cp: chalcopyrite
py: pyrite
paa: pale argillic alteration
aba: pink albite alteration

Mineralogical zonation

~1-5 m
Variable scale
REDBED CU-DEPOSITS

Grey mudstone, sandstone, conglomerate
Red mudstone, sandstone, conglomerate

Mineralogical zone boundary
Flow direction of cupriferous formation water
Coalified wood fragment

bn: bornite
cc: chalcocite
cp: chalcopyrite
gn: galena
py: pyrite
sp: sphalerite
SEDIMENT-HOSTED COPPER DEPOSITS (cont’d)

**DISTRIBUTION:**

**Newfoundland:** Sandstone and shale of the Carboniferous St. George Sub-basin (Snakes Bight Fm. of Anguille Group; Barachois and Codroy groups); Avalon Peninsula; central Newfoundland red bed sequences.

**Labrador:** Middle Proterozoic intra-continental red and grey beds, local mafic volcanics. Chalcocite, bornite and native copper as disseminations fracture- and breccia-fillings, and vesicular flow tops, e.g., Seal Lake Group.
GEOLOGY OF THE ISLAND OF NEWFOUNDLAND

INTRUSIVE ROCKS

ORDOVICIAN TO DEVONIAN
- Granitic and gabbroic intrusions

PROTEROZOIC II TO CAMBRIAN
- Granitic and gabbroic intrusions

DEVONIAN TO CARBONIFEROUS
- Subaerial, lacustrine fluvial and deltaic clastic sedimentary rocks; minor limestone

SILURIAN
- Shallow marine and subaerial clastic sedimentary rocks; volcanic and volcanioclastic rocks

DUNNGAGE ZONE

CAMBRIAN TO SILURIAN
- Marine clastic sedimentary rocks; island-arc volcanic and volcanioclastic rocks
- Ophiolite mafic - ultramafic rocks, pillow lava and related intrusions

CAMBRIAN TO ORDOVICIAN
- Clastic metasedimentary rocks and migmatitic equivalents

GANDER ZONE

PROTEROZOIC II AND III
- Orthogneiss, paragneiss and amphibolite

HUMBER ZONE

PROTEROZOIC III TO ORDOVICIAN
- Subaerial and marine clastic sedimentary rocks; minor limestone

PROTEROZOIC III
- Marine and deltaic clastic sedimentary rocks
- Mafic and felsic volcanic and volcanioclastic rocks

Map compiled by J.P. Hayes 1987
Digital cartography by T. Paitanavage, 1994
SEDIMENT-HOSTED MASSIVE SULPHIDE ENVIRONMENTS

[Map showing regions such as Quebec, Churchill Province, SLG, and Labrador]
SEDIMENT-HOSTED COPPER DEPOSITS (cont’d)

PROSPECTING METHODS:

**GEOLOGICAL:** Red and grey clastic sedimentary rocks of a terrestrial and shallow marine-saline lake origin in a continental setting; organic and carbonaceous material, and pyrite provide good reducing agents. Look for cross-faults and gossans.

**GEOPHYSICAL:** EM - disseminated sulphide may not give a good response; IP should work.

**GEOCHEMICAL:** Cu and Ag in soil, stream and lake sediments. May be weakly radioactive because of uranium.
REDBED CU-DEPOSITS

Cu zones

Evaporites
Red mudstone, sandstone, conglomerate
Grey sandstone
Grey siltstone
Limestone/marl

1 metre to 10s of metres
Blue Point Prospect (chalcocite)
Crown Hill Fm, Musgravetown Group
Red-Beds with Black Organic Debris
Windsor Point Group
Chalcocite & Native Cu, Ellis Showing, Seal Lake Group
SEDIMENTARY EXHALATIVE TYPE (SEDEX)

BACKGROUND: Accounts for 30% of the world’s Zn production and 25% of Pb production; 50% and 60% of world’s Zn & Pb reserves, respectively. Also known as shale-hosted stratiform sulphide deposits.

ENVIRONMENT: Form in reducing marine basin environments associated with fine-grained carbonaceous rocks. Environments include continental shelves, intra-continental basins, and flysch basin sequences that cap thick sequences of coarse-grained clastic sedimentary rocks; sediment covered rift-basins. A high organic carbon content is essential. Barite is a major constituent.

ORIGIN: Through the discharge of metal-laden hydrothermal fluids, heated by magmatic activity, along faults into a reducing environment on basin floor. Host rocks typically black shale/siltstone (turbidite), mafic/felsic volcanic rocks nearby, occasional chert and limestone.

Rowsells Harbour
SEDEX AND MVT ENVIRONMENT

**SHALE BASIN**
- Mixing of metalliferous fluids with H$_2$S-rich seawater at or above sea floor

**CARBONATE PLATFORM**
- Mixing zone within reef of H$_2$S-rich seawater and metalliferous fluids

- Reef
- SEDEX
- Pb-Zn-chloride hydrothermal fluid

CONTINENTAL CRUST
STYLE: Stratiform blanket-shaped massive sulphide +/-stockwork. Characterized by thin layers to massive thick beds.

MINERALOGY: Pyrite, pyrrhotite, sphalerite, galena, silver, barite and minor chalcopyrite (maybe significant in the stockwork), typically fine-grained except where metamorphosed (recrystallized).

ALTERATION: Altered feeder zone (Stockwork) of silica, chlorite, dolomite, tourmaline, pyrite and pyrrhotite; look for gossans.

DISTRIBUTION:

Newfoundland: Unknown; prospective areas include the Fleur de Lys belt, and western Newfoundland equivalent rocks.

Labrador: Schefferville & Howse Zones of Labrador Trough; Central Mineral Belt; basal clastic sequences of Moran Lake & Lower Aillik groups; Ramah, Snyder & Mugford groups; Grenville Province; Paradise River metasedimentary belt.
SCHEMATIC OF THE CHARACTERISTIC FEATURES OF THE IDEALIZED SEDEX DEPOSIT

VENT COMPLEX
Massive, brecciated, crudely bedded pyrite, galena, sphalerite, Fe-carbonates and Fe-Mg-Ca carbonates, barite (at top) ± pyrrhotite, sulphosalts

BEDDED ORES
Laminated, and occasionally fragmented, pyrite, sphalerite, galena, chert, barite, Fe-Mg carbonates ± beds of host lithologies

DISTAL HYDROTHERMAL PRODUCTS
Chert, barite ± minor sphalerite, pyrite, Ca-Mg carbonates, magnetite, hematite, Mn enrichment

SEDIMENTARY FRAGMENTAL LITHOLOGIES
(Breccia flows, talus breccias, conglomerates, etc.)

SYNSEDIMENTARY FAULT ZONE

FEEDER ZONE
Veins and replacement galena, sphalerite, Fe-carbonates and Fe-Mg-Ca carbonates, pyrite, pyrrhotite, minor chalcopyrite

Pb:Zn decreases
Ba:Zn increases

Ore grade decreases
Pb:Zn ratio decreases
Ba:Zn ratio increases
Thickness decreases

average scale
0 m 100 m
0 m 20 m

GEOLOGY OF THE ISLAND OF NEWFOUNDLAND

Ordovician to Devonian
- Granitic and gabbroic intrusions

Proterozoic II to Cambrian
- Granitic and gabbroic intrusions

Devonian to Carboniferous
- Subaerial, lacustrine fluvial and deltaic clastic sedimentary rocks; minor limestone

Silurian
- Shallow marine and subaerial clastic sedimentary rocks; volcanic and volcanoclastic rocks

Dunnage Zone
- Cambrian to Silurian: Marine clastic sedimentary rocks; island-arc volcanic and volcanoclastic rocks
- Cambrian to Ordovician: Ophiolitic mafic - ultramafic rocks, pillow lava and related intrusions

Gander Zone
- Cambrian to Ordovician: Clastic metasedimentary rocks and migmatitic equivalents

Humber Zone
- Proterozoic III to Ordovician: Autoclastic and paraautoclastic clastic and metasedimentary rocks
- Platformal limestone and dolostone; includes clastic sedimentary rocks
- Allochthonous sedimentary, mafic volcanic and minor metamorphic rocks
- Basal clastic and carbonate sedimentary rocks; Includes mafic volcanic rocks

Avalon Zone
- Proterozoic III to Ordovician: Subaerial and marine clastic sedimentary rocks; minor limestone
- Proterozoic III: Marine and deltaic clastic sedimentary rocks
- Mafic and felsic volcanic and volcanoclastic rocks

Map compiled by J.P. Hayes 1987
Digital cartography by T. Paltanavage, 1994
SEDIMENT-HOSTED MASSIVE SULPHIDE ENVIRONMENTS

1 - Moran Lake & Lower Aillik Groups
2 – Labrador Trough
3 – Ramah, Snyder & Mugford Groups
4 – Grenville Province
PROSPECTING METHODS:

GEOLOGICAL

Setting: Marine basin sequences with volcanic rocks of same age, i.e., thick sequences of clastic sedimentary rock consisting of interbedded greywacke, sandstone, conglomerate, mudstone/ chert and abundant black shale/siltstone units.

Stockwork Zone: Silica, chlorite, dolomite, tourmaline, pyrite and pyrrhotite alteration.
Barite; cross-faults; gossans.

GEOPHYSICAL

EM: Black shales are very conductive and will mask less conductive sphalerite.
Mag: Pyrrhotite-rich deposits will exhibit a positive mag anomaly.

GEOCHEMICAL

Zinc, lead, manganese, barium haloes in soils, stream and lake sediments.
Folded Redcliff Shale with Greywacke Beds
Flysch Sequence
Central Nfld

Flysch = Sediments eroded off mountains
Sediment-Hosted Sulphide, Chigaco Lake, Labrador Trough
Pyrite in grey chert bed in Shale, Howse Lake, Labrador Trough