Deposits related to submarine volcanism and sedimentation – Sediment Hosted, Stratiform, Base Metal Sulphide Deposits

- GLY 361 - Lecture 12
SedEx deposits

- Ore deposits that are interpreted to have been formed by release of ore-bearing hydrothermal fluids (metal-bearing brines) into a water reservoir (usually the ocean), resulting in the precipitation of stratiform ore.
SedEx deposits vs. VHMS deposits

• **Similarities:**
  – Scale of deposits
  – Convective hydrothermal fluids

• **Differences:**
  • Hydrothermal fluids source:
    – SEDEX = fault movement
      • (heat source is rifting and crustal thinning, resulting in faulting, producing increased geothermal gradients. Not a magma complex)
    – VHMS = magma body
SedEx deposits vs. VHMS deposits

- **VHMS:**
  - Proximal to submarine volcanism.

- **SedEx:**
  - “Distal“ to submarine volcanism (e.g., Broken Hill, Australia)
SedEx mineralisation types

- Two major groups:
  - *Cu Type* (sediment hosted)
  - *Pb-Zn Type* (carbonate/sandstone hosted)
## SedEx mineralisation types

<table>
<thead>
<tr>
<th>Cu-type</th>
<th>Pb-Zn-type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disseminated (scale of dissemination varies with coarseness of host sediments).</td>
<td>Massive or banded.</td>
</tr>
<tr>
<td>Rarely densely disseminated - “massive”</td>
<td>Interbed parting of barren shale: mm to m scale.</td>
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</tbody>
</table>
SedEx mineralisation types

- Largest resource of Zn, Pb, barite
- Significant source of Ag, Au, Cu, Bi, W
Zn reserves and resources

Zinc (A) reserves and (B) Resources in 2004, broken down by deposit type. After (Goodfellow Lydon, 2007), from (Hunt 2006).
Zn reserves and resources

In mining it is common for an ore to be financially viable to mine when only very small occurrences are present (0.1% - 3%). SEDEX deposits have a mean of 6.7% which is very high concentrations relative to other ores. The Red Dog deposit of North America contains 165 Mt at 16%!

Histogram of metal grades and tonnage for global SEDEX deposits. (Goodfellow Lydon, 2007)
SedEx mineralisation types

• Fe:
  – Cu-type – low Fe (low pyrite content)
  – Pb-Zn-type – higher Fe contents
  • spatially associated with sulphide or oxide facies iron-formation (Pb→Zn→Mn halo).
SedEx mineralisation types

- **Ag:**
  - Extremely variable – significant in some deposits.

- **Co:**
  - Economically significant in many Cu-type deposits.

- **Ba:**
  - Massive barite deposits associated with many of the shale-hosted Pb-Zn deposits.
  - Absence of major barite accumulations associated with Cu-type.

- **Re and Mo:**
  - Anomalous concentrations in Cu-type deposits – genetically and sometimes economically significant.
SedEx Mineralization Types

- Vast majority of the world's barite deposits.

- Scheelite (tungsten) deposits of the Erzgebirge in the Czech Republic.

- Gold deposits of Nevada are considered to be stratiform chert or spoilite formed by SEDEX processes on the seafloor.
Ore Minerals

- Chalcocite ($\text{Cu}_2\text{S}$), bornite ($\text{Cu}_5\text{FeS}_4$), galena ($\text{PbS}$), chalcopyrite ($\text{CuFeS}_2$), sphalerite ($\text{ZnS}$), native metals.

- Stratiform parallel to layering in the rock mass.
Distribution

Examples:

- **Central African Copperbelt**: Shaba Tenke Fungurume 350Mt @ 4.5%Cu 0.3% Co

- **Namaqualand**: Gamsberg 160Mt @ 6.5% Zn, 0.5% Cu, Broken Hill, >38Mt @ 0.45% Cu, 6.38% Pb, 2.87% Zn, 82g/t Ag

- **White Pine**: S of Lake Superior ~550 Mt @ ~1.2% Cu

- **Kupferschiefer**: Lubin >1000Mt @ ~ 2 % Cu

- **McArthur River**: HYC deposit 237Mt @ 9.2% Zn, 4.1% Pb, 0.2% Cu

- **Dzhezkazgan**: Kazakhstan ~ 1000Mt @ 1.5% Cu, 0.5 – 1% Pb
Ore Minerals

- Ores preferentially developed at the time of maximum continental amalgamation (Wilson Cycle) – evolved preferentially during intracratonic rifting and sea-level low-stand.
General Features of SedEx deposits

Time of emplacement:

• Proterozoic to Tertiary

  – 9 of the 15 largest deposits were formed in the Meso-Palaeoproterozoic

  – 3 major SEDEX forming events (late Cambrian, early Silurian, late Devonian)
General Features of SedEx deposits

global anoxic periods, and the temporal distribution of SEDEX deposits. After (Goodfellow Lydon, 2007)
General Features of SedEx deposits

Vent-proximal:

• Buoyant hydrothermal fluids
• Forming “wedge” shaped deposits
General Features of SedEx deposits

**Vent-distal:**

- Fluids denser than seawater, pooled in bathymetric depressions, far from vents
- Forming “saucer” shaped deposits
General Features of SedEx deposits

• Tabular bodies composed predominantly of Zn, Pb, and Ag
  – bound in sphalerite and galena
  – that occur interbedded with iron sulphides and basinal sedimentary rocks,
  – and that were deposited on the seafloor
    • and in associated sub-seafloor vent complexes

• from hydrothermal fluids
  – vented into mostly reduced sedimentary basins
  – in continental rifts.
General Features of SedEx deposits

- The stratiform lenses can be up to 40 km thick and have a lateral extent of 100 km's.

- Strong lateral continuity of mineralization with thinning and thickening dependent on structural and sedimentary facies variation.

- Feeder zones identified below some deposits.
General Features of SedEx deposits

• Often more than one ore layer present.
• Zonal distribution of metals (minerals).
• Deposits vary in tonnage from several hundred millions down to sub-economic sizes.
General Features of SedEx deposits

• Occur in sedimentary rocks (no igneous or metamorphic activity needed)
  – majority occur in non-volcanic marine or deltaic environments (fault movement)

• But: There are also deposits with volcanic association/ black smokers!

• Host rocks:
• (organic-rich) sedimentary rocks in anoxic basins with a $\text{H}_2\text{S}$-rich water column.
  – carbonaceous shales, siltstones, sandstone, dolomite and carbonates
    ➢ low energy environment
  – debris flows, conglomerates and breccias
    ➢ high energy environments
General Features of SedEx deposits

- marine basin usually adjacent to fault bounded basin margin;
- extensional tectonic environment
  - often intracratonic

**Tectonic settings:**

1. First marine transgressions over continental deposits (Kupferschiefer, Zambia, White Pine).

2. Carbonate shelf sequences (Ireland).

3. Fault-controlled sedimentary basins (Selwyn Basin, Yukon; Belt-Purcell Basin, British Columbia).
General Features of SedEx deposits

- Typical sediment stratigraphy in a continental rift basin:
  - overlain by post-rift basinal shales/carbonates
  - related volcanic rocks
  - syn-rift clastics
General Features of SedEx deposits

• A typical deposition sequence would therefore be:
  – Basinal shales/ carbonates
    • Fine grained + relatively impermeable
  – Rift related volcanics
  – Clastics
    • coarse grained + permeable
What would we see in the field?

**Distal Sediments**

- i.e. Sediments BEFORE SedEx mineralisation
- most cases gradational
  - Distal hydrothermal sediments: pyrrhotite and pyrite containing disseminated sphalerite interlaminated
  - with fine-grained turbiditic sedimentary rocks,
What would we see in the field?

Distal hydrothermal sediments: pyrrhotite and pyrite containing disseminated sphalerite interlaminated with fine-grained turbiditic sedimentary rocks, Concentrator Hill, Sullivan deposit, B.C.
What would we see in the field?

Bedded Ore

- i.e., Sediments AFTER SedEx min.
- Bedded facies: sphalerite and galena interlaminated with pyrite, hydrothermal carbonate, and carbonaceous chert
- e.g., Howards Pass deposit, Yukon
Bedded facies: sphalerite and galena interlaminated with pyrite, hydrothermal carbonate, and carbonaceous chert, Howards Pass (XY) deposit, Yukon and Northwest Territories
What would we see in the field?

Feeder Zone rooted in synsedimentary fault zone

• Extensional environment, faults, block movement
• Would see
  – Fault-scarp breccias,
  – debris flow deposits,
  – basin wide turbidite siltstones / sandstones
What would we see in the field?

SEDEX-Type related turbidite sequence. (Wilkinson, 2007)
What would we see in the field?

Feeder veins. (Wilkinson, 2007)
What would we see in the field?

Vent Complex / Feeder Zone
- Unlike regularly layered bedded ore complex
- Heterogeneous, zoned, replacement patches, veins,
- Contact is discordant replacement contact (Turner, 1990, Kelley et al. 2004)
- Vent complex: tourmalinized breccia
  - infilled with pyrrhotite, sphalerite, and chalcopyrite,
- e.g., Sullivan Deposit, B.C.
What would we see in the field?

Vent complex: tourmalinized breccia infilled with pyrrhotite, sphalerite, and chalcopyrite, Sullivan Deposit, B.C. (Goodfellow Lydon, 2007)