# METALLIC MINERALS: PROCESSES OF FORMATION

## CONTENTS

<table>
<thead>
<tr>
<th>Igneous Processes</th>
<th>Sedimentary Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magmatic Segregation</td>
<td>Residual Deposits</td>
</tr>
<tr>
<td>Hydrothermal Ore Deposits</td>
<td>Placer Deposits</td>
</tr>
<tr>
<td></td>
<td>Secondary Enrichment (copper)</td>
</tr>
<tr>
<td></td>
<td>Secondary Enrichment (uranium)</td>
</tr>
</tbody>
</table>
Secondary Enrichment (Sedimentary Process)

Ore Deposit - chalcopyrite (copper iron sulfide) forms → copper

1. Above water table (zone of oxidation), rainwater chemically reacts with insoluble chalcopyrite changing it into soluble copper sulfate.
2. Copper sulfate dissolves & carried downwards in solution by groundwater.
3. Below water table (zone of reduction), chemical reactions change copper sulfate back into insoluble “secondary” copper sulfides.
4. All the copper that was spread out above water table is now concentrated in smaller volume (higher grade).
5. Insoluble iron oxides which were in chalcopyrite left at surface forming a cap (gossan).

Requirements
- Exposed vein of chalcopyrite (formed by igneous processes)
- Rain water
- Water table boundary

---

Secondary Enrichment (Sedimentary Process)

Ore Deposit - uranium in igneous rocks forms → concentrated uranium in sandstone

1. Above water table (zone of oxidation), rainwater reacts chemically with uranium in igneous rocks.
2. Uranium easily dissolves & carried downwards in solution by groundwater.
3. Below water table (zone of reduction), chemical reactions reprecipitate uranium into porous sandstone aquifers.
4. Highly likely that sulphur-reducing bacteria present in decaying vegetation are involved in this process (examples of individual fossil logs entirely replaced by uranium metals).
5. Curved “roll-type” uranium ore deposits form at oxidation-reduction (redox) boundary; often the water table.

Requirements
- Exposed igneous rocks containing uranium
- Rain water
- Porous & permeable aquifer rock
- Sulphur-reducing bacteria
- Water table boundary
**Placer Deposits** (Sedimentary Process)

Ore Deposit - mineral vein with metals in → concentrated deposits of **cassiterite** (tin), **gold & diamonds**

1. Above water table (zone of oxidation), rainwater chemically reacts with & physically breaks up mineral veins separating ore and gangue minerals into individual grains.
2. Weathered material transported by rivers further sorting these grains.
3. Hard, resistant and chemically inert materials survive.
4. Dense ore metals are deposited first and concentrated in areas of low velocity.
5. These sites of deposition include: meander bends, plunge pools, upstream projections, confluences & on beaches.

Requirements

- Exposed vein (formed by igneous processes)
- Dense, physically & chemically resistant ore minerals
- Erosion & transportation down rivers to sort ore form gangue minerals
- Suitable sites of deposition (low energy environments)

---

**Residual Deposits** (Sedimentary Process)

Ore Deposit - granite or impure limestone forms → **bauxite** (aluminium)

1. Aluminium-rich & iron-poor rocks (granite or impure limestones) exposed at surface in tropical environment.
2. Rainwater chemically reacts with these rocks weathering them into a deep clay soil or regolith.
3. Heavy rainfall removes soluble elements in solution (leaching),
4. Soluble elements are deposited deeper underground.
5. Insoluble aluminium elements are left behind & concentrated at the surface as a residue which may be sufficiently rich to form an economic ore deposit.

Requirements

- Hot (increases rate of reactions) & humid (water causes intense hydrolysis) tropical climate.
- Intense chemical weathering (hydrolysis).
- Exposed aluminium rich-rich & iron-poor rock (granite or impure limestone).
- Jointing & fractures (more joints increases permeability which increases surface area available for chemical weathering)
- Groundwater with pH between 4 & 10 (higher pH would dissolve aluminium).
**Magmatic Segregation/Differentiation** (Igneous Process)

Ore Deposit - mafic or ultramafic magma forms → magnetite, chromite & ilmenite.

1. Mafic and ultramafic magmas are high temperature & low viscosity.
2. Deep underground they cool slowly & allow high temp metallic minerals like magnetite to crystallise first (1600°C).
3. Magnetite is a dense metal (5.2 g/cm³) which sinks to the base of the less dense liquid magma chamber by gravity settling.
4. The rest of the intrusion is depleted in magnetite as it becomes concentrated in a cumulate layer at the base of the magma chamber.
5. Magmatic segregation can also result from the separation of sulfide and silicate liquids which are immiscible (denser immiscible droplets of iron, copper, nickel & platinum join together & sink).

Requirements

- Mafic or ultramafic magma (high temperature & low viscosity magma)
- Slow rates of cooling

---

**Hydrothermal Ore Deposits** (Igneous Process)

Ore Deposit - silicic intrusions (granite) form → tin, tungsten, copper, galena, zinc, gold & silver.

1. Silicic batholith cools slowly deep underground.
2. Edges of the intrusion cool & crystallise first, forming a solid shell.
3. As it continues to cool & crystallise volatiles and incompatible metals which do not fit into the rock-forming minerals collect as a hydrothermal fluid at top of intrusion.
4. Heat from the intrusion cracks & fractures, allowing the escape of these fluids to form hydrothermal veins.
5. As water is evaporated the metallic minerals are precipitated in a symmetrical pattern to form a mineral vein (the less soluble minerals are precipitated at higher temperatures).

Requirements

- Heat source
- Water source
- Source of metals