HYDROTHERMAL ORE DEPOSITS

TYPES OF ORE DEPOSIT

- 1. Ores formed by hydrothermal processes
- 2. Ores formed by **igneous processes** within the earth
- 3. Ores formed by sedimentary processes at the Earth's surface
- A hydrothermal fluid = a hot, aqueous fluid containing dissolved metals in solution.
- A mineral vein is formed when minerals precipitate in a fracture.
- Country rock is the older rock (usually sedimentary) into which an igneous rock is intruded.
- Precipitation occurs when minerals come out of solution (i.e. insoluble precipitate forms that cannot dissolve).



FORMATION OF HYDROTHERMAL DEPOSITS

Hydrothermal ore deposits are an important and varied group of ore deposits that form many of the world's **richest ore deposits**. Ores, including those of **tin**, **tungsten**, **copper**, **lead**, **zinc**, **gold**, **silver**, **mercury** and **uranium**, can all form by **hydrothermal processes**.

All hydrothermal deposits have formed from **hot**, aqueous (watery) fluids containing metals in solution.

The three key requirements are therefore a source of **heat, water and metals.**

There are many possible sources for each of these factors making hydrothermal ore deposits complex.

- 1. Heat may come from magma in an intrusive or volcanic setting: it may come from metamorphism or simply from the increase in temperature with depth due to the thermal gradient.
- 2. The water may be from fluid magma (as water/volatiles evaporate), groundwater, seawater or from chemical reactions during metamorphism.
- 3. The metals could come from magma or be leached from any rock types as water passes through it.









HOW DO HYDROTHERMAL VEINS OF CASSITERITE, GALENA AND SPHALERITE FORM IN ASSOCIATION WITH IGENOUS INTRUSIONS?

Disseminated ore forms when ore minerals precipitate within the pore spaces of country rock

Silicic intrusions such as granite batholiths are rich in water and other volatiles. Hydrothermal processes take place late in the cooling history of these intrusions during the final stages of crystallisation. Magma is the source of heat, water and metals.

The sequence of formation of a hydrothermal mineral vein is:

- The outer margin of the intrusion is the quickest to cool, solidifying as an outer shell. As the magma continues to cool and crystallise, water and 'incompatible' metals that do not fit into silicate minerals (immiscible with silicates) collect at the top of the intrusion to form a hydrothermal fluid. All the metals that were once present in the magma are concentrated into the hydrothermal fluid at the end of crystallisation.
- As the intrusion cools further it contracts and cooling joints form. The hydrothermal fluid moves out into the surrounding faults, joints and bedding planes. These then control the pattern of mineral veins. Groundwater may be drawn into the intrusion and a hydrothermal circulation system is set up.
- 3. As the hydrothermal fluid moves away from the intrusion, it cools and may encounter chemically reactive rocks such as limestone. This results in the precipitation of a mixture of ore and gangue minerals (e.g. calcite) from the fluid.



- 4. Veins are formed when minerals precipitate in fractures. Veins commonly show a symmetrical pattern with the first minerals crystallising at the edges and later formed minerals in the centre.
- 5. Ore minerals precipitate out in order of temperature and solubility. This gives concentric zones of ore minerals around an intrusion, with the highest temperature, least soluble minerals being precipitated first, close to the intrusion (e.g. cassiterite). The lowest temperature, most soluble minerals can migrate further from the intrusion before precipitating (e.g. galena and sphalerite).

A good example of hydrothermal mineral zoning can be found in the granites of southwest England.

Shap Granite in the Lake District has veins of iron pyrite running through it.

CASE STUDY: DEVON AND CORNWALL

Devon and Cornwall have a long history of mining dating back to the Bronze Age. A **variety of metals** including tin, tungsten, copper, lead and zinc have been mined from numerous 'Lodes' – the local miner's term for **mineral veins.**

The **hydrothermal veins** originate from a **large Granite batholith** that was intruded in the Carboniferous. The country rocks are **metamorphosed** Devonian sandstones and shales.

Many hydrothermal veins **formed along** NNE-striking **faults in the country rock**. Within the veins, the metal ores are **concentrically zoned around the intrusion** (tin, then copper, then lead, then zinc, then finally the furthest being iron).

Cornish tin mining has left an international legacy – with Cornish miners that have taken heir expertise all over the world.



Hydrothermal veins of cassiterite, galena and sphalerite in association with igneous intrusions



Figure 1 Cross-section diagram showing how hydrothermal veins form around igneous intrusions with insert showing a magnified view of a hydrothermal vein



Figure 2 Block diagram showing hydrothermal mineral veins around a granite in southwest England

CASE STUDY: BUSHVELD IGNEOUS COMPLEX

Probably the single most valuable deposit in the world. Located in South Africa, North of Pretoria.

Saucer shaped basic intrusion 6 to 8km thick. 300km wide and occupying 67, 000 km².

Lower third is peridotite, upper part is gabbro. Overlain by granite, formed by the melting of crustal rocks.







The complex has 5 zones of cumulate

layering. It contains 29 separate chromite layers, each one up to 1m thick.

Reserves of **chromite**, **platinum** and **magnetite** are present. Also small amounts of gold, ruthenium, rhodium, palladium, osmium and iridium.

One of the sulfide-rich layers, the Merensky Reef, contains 80% of the world's **aluminium.**