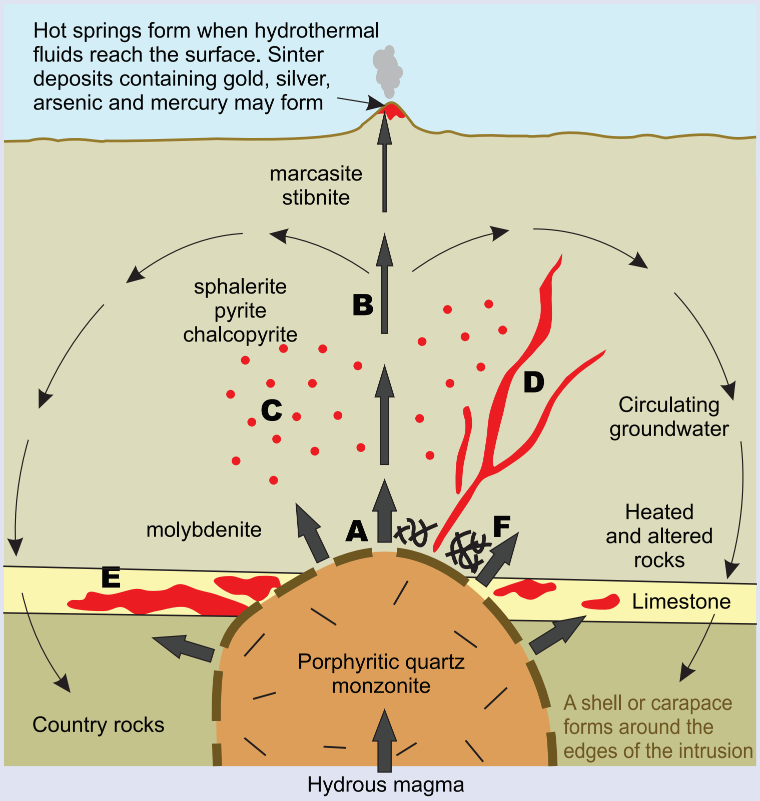
Case study 1 - Porphyry copper deposits

Porphyry deposits typically form very large, low-grade zoned deposits commonly associated with convergent plate margins and andesitic volcanism. The majority of deposits are formed at shallow depths along destructive plate margins above the subduction zones of the oceanic crust. Porphyry deposits are principally mined for copper, but many of them contain significant amounts of molybdenum, gold, silver, tungsten and tin mineralisation. Very large deposits are found at Bingham, U.S.A., in Chile and Namibia. The age of these deposits are variable, with the majority of deposits being formed during the last 75 million years. One of the youngest deposits is the Ok Tedi mine in New Guinea, which is 1.2 million years old.

The deposits form from the forceful emplacement of hydrous magmas into rocks at relatively shallow depths in the crust. Early crystallisation of the magma forms a shell or carapace around the edges of the intrusion. As crystallisation continues any residual liquid tends to concentrate in the upper region of the intrusion. Trace elements like copper, molybdenum, iron, zinc, silver, gold, arsenic, lead and sulfur become concentrated in these water-rich residual fluids. As cooling and crystallisation continues the internal vapour pressure increases until the shell of the intrusion fractures and the super-heated residual fluids are expelled into the surrounding country rocks. With the sudden release of pressure these highly saline fluids begin to boil. These hot fluids, known as **hydrothermal fluids**, react with the surrounding wall rocks and mix with meteoric (surface-derived groundwater) water as they move upward and away from the intrusion. Cooling of the fluids causes the precipitation of primary ore minerals, like pyrite, chalcopyrite and bornite with minor sphalerite and molybdenum.



A Heated fluids are expelled into the surrounding rocks via fractures in the carapace

B Hydrothermal fluids move upward and away from the intrusion, mixing with meteoric water and reacting with the surrounding cooler wall rocks

C Disseminated ore: copper, zinc

D Vein deposit: lead, zinc, gold, silver, (arsenic, mercury)

E Replacement skarn deposit: copper, gold, molybdenite, silver

F Stockwork zone: copper, (gold, molybdenite, silver)

Sulfide ore minerals are deposited as the hydrothermal fluids encounter progressively cooler rocks. Molybdenum precipitates out close to the intrusion, sphalerite, pyrite and chalcopyrite precipitate at an intermediate distance and stibnite and marcasite are precipitated furthest from the intrusion. The ore minerals may be found disseminated throughout the host rock, in veins or as large replacement bodies.

Figure 4.19: Diagrammatic representation of a Porphyry Copper Deposit (not to scale).

Inside the magma chamber, the sudden release of the residual liquids causes the intrusion to cool at a faster rate and a mass of fine-grained crystals form amongst the larger already crystallised minerals. This rock texture of larger crystals amongst a finer-grained groundmass is called a **porphyritic texture**. This texture is typical of the intrusions associated with porphyry copper deposits and hence they are called ‘porphyry’ copper deposits.

Case study 2 - Hydrothermal gold vein deposits such as the Eastern Goldfields

Hydrothermal vein deposits form along joints or fractures in rocks that have been filled with minerals precipitated from heated mineralised fluids. These high-grade vein deposits contain a variety of minerals and were the main type of deposit to be mined by man throughout the ages. In the present day hydrothermal vein deposits are mined for tungsten, tin, gold, uranium, cobalt and silver. **A significant proportion of Australia’s gold production is won from hydrothermal vein deposits within the Archean greenstone belts of the Yilgarn Craton in Western Australia.**

Figure 4.20: Woodvale SHS students panning for gold on a trip to the mining Hall of Fame in Kalgoorlie.

The hydrothermal gold vein deposits found in the Eastern Goldfields region of the Archean Yilgarn Craton of Western Australia were are formed by the precipitation of minerals from hot saline fluids of predominantly a metamorphic origin. Many cubic kilometres of deep **regional metamorphism** generated large volumes of metamorphic water which was expelled from the predominantly mafic volcanic rocks by dehydration reactions during metamorphism. These hot metamorphic fluids leached gold and other metals from the surrounding rocks through which they circulated. Large volumes of these hot saline fluids were channeled upwards along major fault structures until they encountered favourable brittle and fractured rock units. The fluids flowed through the larger, open fractures and as the fluids cooled minerals grew along the sides of the fracture, eventually filling it completely. Gold and other sulfide mineralisation is found predominantly within the quartz and carbonate veins.

Many of the gold deposits in the Eastern Goldfields are contained within quartz veins situated within mafic basaltic volcanic rocks. Native gold is the dominant economic mineral contained within the hydrothermal quartz veins which can vary in thickness from a few centimetres up to 5 metres, and from 10 to 1000 m along strike with depths up to 1 km. The gold may be present in its native form or **as tellurides as is the case at the Golden Mile, at Kalgoorlie**. Other minerals present at the Golden Mile include: pyrite, galena, chalcopyrite, sphalerite, stibnite and arsenopyrite. The most common gangue (waste or non economic) minerals are quartz and carbonate. The gold mineralisation has a highly irregular distribution throughout the greenstone belts and many small open-cut operations near existing mill facilities are able to mine deposits with grades as low as 1.0 g/t gold.