

### Mineral Resources

- Mineral deposits are defined as every geological body present in the lithosphere that can be the subject of mining activity due to the presence of useful and economically exploitable materials.
- Deposits are the product of **natural processes** (chemical, physical, biological) that form part of the greater lithogenic cycle.
- **Extraction activities** (or **mining**) remove each year a greater quantity of material from the Earth's surface than that removed by the action of erosion carried out by rivers and water courses.
- The exploration and extraction costs of a resource and market prices are factors that are strongly interdependent, so it is imperative, for the purpose of extraction, to make use of concentrations of elements that are higher than the average: the **concentration factor**, which is fundamental economically, is the ratio between the abundance of an element in a deposit and its average abundance in the crust.
- **Metal deposits** are deposits of minerals from which metals can be advantageously extracted; minerals containing metals (called metal ores) include **sulphides, oxides and silicates**, and are composed of metallic elements with, respectively, sulphur, oxygen, and silicon oxide.
- Mineral deposits are formed through **magmatic, sedimentary and metamorphic processes** and exhibit a wide variety of forms, structures and origins.

### Mineral deposits of magmatic origin

- Mineral deposits formed during the cooling process of magma are categorised into three groups: **magmatic segregation deposits, vein deposits** and **diffuse hydrothermal deposits**.
- **Magmatic segregation deposits**, typically rich in chromium, titanium and platinum, accompanied by nickel, iron and copper, were formed when the minerals that constitute them crystallised before others in the course of the cooling of the magma and, due to their high density, they sank through the still molten mass, to accumulate in its lower part, within rocks that are called "cumulus". In other cases such accumulations were formed by direct crystallisation of a very dense magmatic fluid, which separated from the silicate melt that was cooling it, and then migrated downwards under gravity.
- **Vein deposits** were formed by minerals that had been chemically precipitated from hot aqueous solutions; they are typically present in the form of **veins**, i.e. filled fissures through which the aqueous solutions have circulated, but also as an impregnation of the surrounding rocks ("rock walls") that have been altered by heating and by the solutions with which they have chemically reacted. The greater part of vein deposits is associated with intrusive igneous rocks.
- **Pegmatitic veins** are intrusive, coarse-grained rocks, consisting primarily of quartz, potassium feldspar (orthoclase) and muscovite mica. These are richer in silica than granites, from which they constitute a differentiation.
- **Hydrothermal veins** are formed during the cooling process of fluids when the temperature drops below 374 °C (the critical temperature of water) and they remain superheated aqueous solutions, which infiltrate into every crevice of the surrounding rock or along the planes of stratification. With progressive reduction in temperature (until ambient temperature), various associations of minerals separate from the solutions, encrusting and filling the cracks, giving rise to a whole "procession" of hydrothermal veins that run in every direction from the margins of the intrusive mass with which they are associated. At higher temperatures, minerals of gold, silver, iron, arsenic and uranium, accompanied by quartz, are formed; at lower temperatures, minerals of zinc, copper, lead, silver and mercury are deposited, usually in the form of sulphides accompanied by quartz, fluorite and calcite.
- • Amongst **diffuse hydrothermal deposits**, two cases can be distinguished.
- - **Impregnation deposits**: the veins are generally associated in systems and are variously spaced, but cases are known in which the minerals are disseminated in volumes of rock much larger than those occupied by the veins, such that they constitute impregnation deposits.
- - **Hydrothermal deposits on the ocean floor**: sea water, which infiltrates into cracks on the seabed of a rift valley, heats up to a few hundred degrees Celsius, and water at high temperature, which is released from the magma rising up under the ridge, dissolve minerals from hot rocks and form hydrothermal solutions that are rich in compounds. When these solutions rise up to the colder surface crust and are released on the ocean floor, at temperatures close to 0 °C, they precipitate sulphides of copper, iron and zinc due to their abrupt cooling.

### Mineral deposits of metamorphic origin

- The minerals that make up a rock are stable within a certain range of values of pressure and temperature within which they were formed. **Outside of these** values, the minerals "react" in search of a new equilibrium and this occurs with **solid-state transformations**: i.e. without any melting of the material.
- According to the intensity of a transformation, they are described as **low, medium and high-grade metamor-**

**phisms.** The set of these **neo-formation minerals** constitutes those rocks produced by **regional metamorphism**, from which the majority of the continental crust is formed. Among the **native elements**, *graphite* (C) is formed by high-grade metamorphism, as a final product of the process of carbonisation of organic substances.

Noteworthy among the **oxides** are: corundum ( $\text{Al}_2\text{O}_3$ ) – also present in pegmatitic veins – which is widely used as an abrasive and as a gemstone (ruby and sapphire); and two minerals encountered in hydrothermal veins, rutile ( $\text{TiO}_2$ ) and ilmenite ( $\text{FeTiO}_3$ ), which are important in the mining of titanium.

The **carbonates** are represented by magnesite ( $\text{MgCO}_3$ ) which is important in the mining of magnesium.

The **silicates** are present as muscovite and lepidolite micas (the latter being a silicate of lithium and potassium which is used industrially for the extraction of lithium), as sillimanite and kyanite (a silicate of aluminium, used for ceramic

products that are resistant to high temperatures and to high quality electrical insulators).

- Other rocks undergo a different kind of transformation if they come into contact with a mass of red-hot magma, as in the case of magmatic intrusions. **Contact metamorphism** can lead, in fact, to the generation of specific minerals, depending on the nature of the rock that undergoes the transformation and the temperature and composition of the magma, some of which are interesting in jewellery, such as grossularite (a garnet that is also called grossular). The rock known as *skarn* instead is derived from the contact between granitic and limestone magmas which undergo a metasomatic process: a reaction between the elements present in the hot fluids (typically iron, magnesium, manganese and silicon) and the rock that is invested. Copper, iron, manganese and molybdenum are formed in this mineralization mechanism, and they are all useful from an industrial point of view.

## Mineral deposits of sedimentary origin

- The **sedimentary process** is the part of the rock cycle that takes place on the Earth's surface, at modest temperatures and pressures, and that involves, with specific characteristics, continental, coastal and marine environments. The process of alteration and disintegration of outcropping rocks produces a **detritic mantle** that undergoes a more or less long transport which finally gives rise to a sedimentary accumulation. In this way, specific minerals concentrations can form. These are proper deposits that are distinguished as: alluvial; of chemical origin; associated with residual rocks; and associated with rocks of biochemical origin.
- **Alluvial deposits**, the most diffuse and extensive, are of detritic origin. They typically consist of minerals of high chemical stability and remarkable hardness, that have been transported in river or marine environments. They accumulate by decantation from aqueous suspension; this is the origin of many important deposits of gold and platinum.
- Amongst the **deposits of chemical origin**, the important ones are:
  - chemical transformation deposits, often associated with the overburden of mineral deposits, i.e. the part that rises to the surface of a deposit that undergoes oxidation (more superficial) or reduction (deeper) processes;
  - deposits formed by precipitation from solutions produced by chemical reactions, which include the largest iron ore deposits in the world – “banded formation” deposits – whose existence is tied to processes of oxygen release from cyanobacteria, which over 3 billion years ago had begun to build stromatolites;
  - deposits formed by precipitation from aqueous solutions produced by evaporation, which comprise:
    - salt water lakes: desert lakes with a poor supply from tributaries, that carry in solution the leaching products from the surrounding hills; their waters evaporate continuously and increases the concentration of salts in solution, such that diverse types of evaporite minerals, such as carbonates, sulphates and halides, are steadily accumulated at the bottom of the lake.
    - *particular marine environments*: ocean water contains in solution 84 of the 92 natural elements, although many only in very low quantities. Under appropriate conditions, they can precipitate through evaporation in concentrations such as to constitute a resource, as is the case with *halite* (common salt) and *gypsum* (calcium sulfate dihydrate). Deposits of evaporitic rocks are present and industrially exploited in different regions of the globe, including Germany, France, Texas, Eritrea and even in our own country (especially in the Romagnolo Apennines and in Sicily).
- **Deposits associated with residual rocks** (defined as rocks that are derived from accumulation in place (or in-situ), i.e. without transport, of materials that remain after the weathering of crystalline or sedimentary outcropping rock) include the laterites and bauxites; deposits of great industrial interest.
- **Deposits associated with rocks of biochemical origin** include phosphorites, also known as phosphate rocks, a resource of great economic interest because of their importance as fertilizers. At present, accumulations of phosphorites are in formation almost exclusively in areas of the continental shelf, in shallow water, where there is very high biological activity due to the availability of large amounts of nutrients.

