14 La crosta terrestre: minerali e rocce

Summing-up

Constituents of the Earth's crust

The **Earth's crust** is the outermost solid shell of the Earth and has a thickness of several tens of kilometres.

Numerous chemical, physical and biological processes which govern the continuous transformations of the «integrated Earth system» take place on the crust.

The crust is composed of **rocks**, which in turn are formed by **minerals**.

The study of rocks has shown that many were formed at depth and this has enabled the reconstruction of the Earth's internal processes that are not directly observable.

Minerals

A **mineral** is a naturally occurring solid substance with a well-defined chemical composition, and a crystalline structure: i.e. a regular spatial arrangement of the constituent atoms.

Each mineral exhibits a typical crystalline structure: a **crystal** is a geometric solid with faces, edges and vertices that arise from the progressive growth, atom by atom, of an elementary three-dimensional structure with infinitesimal dimensions (the **crystal lattice**).

Every mineral is characterised by a series of **physical properties,** such as hardness, cleavage, luster, colour and density.

Around 2,000 different **mineral species** are known, but only 20 of which are important constituents of the Earth's crust.

The most common minerals are **silicates**, which have a basic tetrahedron structure, formed by silicon and oxygen; **non-silicate minerals**, such as native elements, sulphides, sulphates, oxides and carbonates, are less abundant.

Minerals are formed by the crystallisation of molten magma, by precipitation from hot aqueous solutions, by sublimation from hot vapour, evaporation of aqueous solutions, biological activity, and by transformations in the solid state.

Rocks

A **rock** is, in the majority of cases, a natural aggregate of several minerals, sometimes even non-crystalline substances, usually in a very compact form. The majority of rocks are heterogeneous, that is they are made up of many mineral species.

There are three processes that lead to the formation of rocks (**lithogenic processes**):

- The magmatic process commences with high temperature molten material (magma) and leads to the formation of **magmatic** or **igneous rocks**;
- The sedimentary process, which takes place on the Earth's surface at low temperatures and pressures, leads to the formation of **sedimentary rocks**;
- The metamorphic process, that occurs within the Earth's crust at varying temperatures and pressures, leads to the transformation of pre-existing rocks into **metamorphic rocks**.

If the surface of the Earth were to be cleared of vegetation and soil, its composition would be: 55-60% metamorphic rocks; 35-40% magmatic rocks; and up to 5% sedimentary rocks.

Magmatic or igneous rocks

Magmatic rocks are all derived from magma, that is molten rock. Magmatic rocks are divided into two groups:

- **Intrusive** (or **plutonic**) rocks are formed when magma solidifies deep down in the Earth, surrounded by other rocks. Under these conditions the cooling takes place slowly over a long period and the rocks exibit a holocrystalline granular structure;

- **Extrusive** (or **volcanic**) rocks are formed when the magma overflows onto the surface (*lava*) and quickly cools in the open air. These rocks have a *porphyry texture*, in which crystals with a size in the order of several millimetres are present in a fine crystalline matrix.

Magmatic rocks are classified according to the silica content of the constituent minerals:

- **Acidic rocks** (or **felsic**), rich in silica, such as granite, granodiorite, and rhyolite;
- **Neutral** (or **intermediate**) **rocks** such as diorite and andesite;
- **Basic rocks** (or **mafic**) with low silica content, such as gabbro and basalt;
- **Ultrabasic rocks** (or **ultramafic**), with very low silica content, such as peridotite.

The origins of magmas

The various types of igneous rocks are due to the different origins of magmas:

- **Primary magmas** rise up from the mantle, from depths exceeding 35 kilometres. Their composition is close to that of basalt and are described as basic magmas.
- **Anatectic magmas** are formed by the anatexis process, i.e. melting of continental crust at a depth of several tens of kilometres. These acidic magmas, rich in silica, have high viscosity. In fact, under the same conditions (pressure, temperature), acidic magmas are more viscous than basic magmas.

The problem of how the melting of the rocks in the crust or in the mantle takes place is complex. The conditions necessary for the melting of rock to occur, at least in part, can be:

- A local increase in temperature for "mixing" the material at depth;
- The arrival of fluid that "dampens" the rock and thereby lowers the melting point.

Sedimentary rocks

Sedimentary rocks are the result of the continual "recycling" of each rock that comes to the surface through the processes of aggradation, erosion, transport and accumulation, all operated by **exogenous agents**.

Sedimentary rocks are classified according to the environment and way of formation:

- **Clastic rocks,** such as conglomerate, sandstone and clay, are formed by the accumulation of material removed by erosion and transported by water, wind or ice;
- **Organogenic rocks**, such as limestone, flint, coal and hydrocarbons, are made of substances produced by biological activity and usually occur as clusters of shells, of skeletal remains, etc., or by variously transformed organic matter;
- **Chemical rocks**, which are formed by chemical precipitation processes (evaporitic rocks, such as gypsum and rock salt) or alteration (residual rocks, such as bauxite).

Metamorphic rocks

Metamorphic rocks are derived from the transformation of any kind of rock that is subjected to a rise in temperature and/or pressure due to the continuous movements of the crust.

Contact metamorphism occurs in rocks that are in contact with magma that rises in the crust.

Regional metamorphism occurs in rocks that descend into the crust and its effects are intensified with depth.

By varying the intensity of the metamorphic transformation new minerals are formed. These **index minerals** enable the metamorphic facies to be identified: that is, the depth of the crust at which the transformation occurred that led to the metamorphic rock.

Ultrametamorphism (**Ultra-high-temperature metamorphism**) occurs when a further increase in temperature causes the complete melting of the rocks and gives rise to a regenerated or anatectic magma.

The lithogenic cycle

Various lithological processes form a lithogenic cycle, in which the materials of the Earth's crust are constantly being reworked and recycled.

The lithogenic cycle is not perfectly closed, but is subject to contributions of molten material from the mantle. In addition, the cycle is also not closed to external losses: the atmosphere and the hydrosphere, in fact, have accumulated material and are continually being "fed" by volcanic processes.