Rocks and minerals

What are minerals?

Minerals are solid substances that are present in nature and can be made of one element or more elements combined together (chemical compounds).
Gold, Silver and carbon are elements that form minerals on their own. They are called native elements. Instead, ordinary kitchen salt is a chemical compound that is called rock salt, which is a mineral formed of sodium and chlorine ions. Atoms, ions and molecules that form a mineral are present in the space in a tidy way and according to well-defined geometrical shapes, which are called crystal lattices. The structure of the crystal lattice defines the shape of the crystal as we see it. For example, rock salt or kitchen salt is a mineral formed of cubic-shaped crystals. Its crystal lattice has the same shape and consists of sodium and chlorine ions that are present in the space in alternate order.
The order of atoms in the space and the way they combine with each other determine the way a mineral can laminate or exfoliate. Lamination is the property that some materials have to break according to their geometrical shape.
Its chemical composition also determines the colour of the crystal, such as the yellow colour for the topaz, red for ruby, purple for amethyst quartz.
Another characteristic of minerals is their hardness, which is their resistance to scratches. Hardness is classified by numbers (from 1 to 10), according to the Moh's scale. At the beginning of the scale there are very soft minerals that can be scratched with a nail, such as talc, chalk and calcite. At the end of the scale there is the diamond, which is the hardest mineral in nature.

How many minerals do we know?

In nature there are many minerals: around 2000 species are known. Some of them are very rare, while some others are very popular. But only around thirty of them compose the Earth's crust rocks.
These minerals are made up of several chemical elements that distinguish them. According to their chemical composition, minerals are classified into the following groups:

- **silicates** are very important: only 8% of the minerals that compose the Earth do not belong to this group. These minerals are always made of silicon and oxygen, which can bind with aluminium, iron, calcium, magnesium, sodium and potassium. A very important mineral that is present in the deepest layers of the Earth is olivine, which has a very compact and dense structure, as is made of silicon, magnesium and iron. Asbestos, mica, clay minerals, quartz, feldspars (like orthoclase and plagioclase) belong to this group
- the group of **carbonates** is made up of two important minerals: calcite, a calcium carbonate that forms calcareous rocks and dolomite, a calcium and magnesium carbonate that forms dolomite rocks. These minerals and their corresponding rocks melt in water, and form karstic landscapes and dolomitic mountain landscapes
- in particular environmental conditions, the evaporation of sea or lake water leads to the creation of chalk or rock salt (kitchen salt). This is the group of **sulphates and salts**
- when oxygen binds to other elements such as iron, oxides and **hydroxides** are formed. Some examples are magnetite, limonite, haematite, which form rocks with a yellow-red colour, and represent the main iron source of the mining industry
- other important mineral deposits are represented by **sulphides**, minerals containing sulphur and iron, like pyrite. Sulphur together with iron and copper leads to chalcopyrite. Sulphur together with lead originates galena, while sulphur and mercury results in cinnabar

- gold,silver and copper are **deposits made** of only one element. This is why they are called native elements. Both diamond and graphite are exclusively made of carbon, but they differ from the commercial and crystal structure point of view, as explained in the corresponding paragraph.

Diamond and graphite

Carbon is a native element that, on its own, forms two very different minerals: the diamond (precious stone) and graphite. The diamond is the hardest mineral in nature, as it is made up only of carbon atoms with very strong chemical bonds (covalent bonds) that are present in the space forming a tree-dimensional crystal lattice. Also graphite is a mineral that is only made up of carbon atoms, but their bonds create horizontal layers, as if they were building floors. The different floors are linked by weak chemical bonds and form a mineral whose layers easily break.The environmental conditions during mineral formation and in particular the different temperatures and pressures determine the way carbon binds to other carbon atoms.

Rocks

The 2000 known minerals can form an endless number of combinations and give life to an extremely high number of rocks. The processes that lead to the creation of a rock do not separate the different minerals the rock consists of. As a consequence, it is difficult to find rocks consisting of one single mineral. We will see that rocks are a mixture of different minerals; only those minerals that are present in a higher quantity identify the type of rock. For example granite is a magmatic rock that consists of many minerals, but especially quartz, feldspars and mica are always present in a large quantity.
The process that leads to rock formation is fundamentally important, therefore rocks are classified according to how they were formed:

- magmatic or igneous rocks derive from the cooling of a mass of minerals in melted state (magma). Those minerals are mixed with gas substances during a process called magmatic process
- sedimentary rocks consist of rock fragments that have been accumulated during a process called sedimentary process
- metamorphic rocks are rocks that underwent modifications during geologic ages. The process that describes these changes is called metamorphic process.

The oldest rocks on Earth

Planet Earth was formed 4.7 billion years ago, and at the beginning of its history it only consisted of material in melted state. Melted state materials are distributed at different distances from the centre of the Earth according to their density: the lightest materials occupy a layer that is close to the surface; they cool down and transform into solid compounds. These solid compounds are the oldest rocks on the Earth.

Magmatic rocks

2/3 the Earth's Crust are made up of magmatic rocks that derive from the cooling of a mineral mass in melted state, mixed with gaseous substances. The mixture is called magma: it consists of different minerals that belong to the group of silicates. The gradual cooling of the magmatic mass leads to the crystallization of minerals and rock formation.
Crystal structures form more easily when the magma contains gaseous substances, which are retained more easily when the rock originates inside the Earth. In this case the cooling process is slow and gradual and leads to the creation of intrusive magmatic rocks. An example of it is granite, a rock whose crystals (belonging to different minerals) can be seen very clearly. Another example is diorite. When the cooling process occurs on the surface, it is characterized by a sudden temperature drop. The gases contained in the magma disperse into the atmosphere; their change into solid state takes place all of a sudden and the rock is made up of very small crystals. These rocks are called magmatic effusive rocks.

Examples are basalt, rhyolite, andesite, which are used in the building sector for road flooring and railway ballasts as they have a uniform colour. The colour depends on their structure where the mineral crystals are not visible.

The rock that derives from the most rapid cooling of magma is called obsidian as it has a “vitreous structure”, while another very particular rock is pumice. This rock derives from a magma that has lots of gases and that hardens before the gases can disperse. Its structure is porous and the various pores, due to gas bubbles, make the rock so light that it floats on the water.

The first magma mineral that hardens at very high temperatures is olivine, that is present in large quantities in the internal layers of the Earth. Closer to the Earth’s surface, magma temperature diminishes and minerals with lots of silica are formed: amphiboles, biotite, feldspars, muscovite and quartz: these minerals form magmatic rocks that are located close to the Earth’s surface.

***Can we see intrusive magmatic rocks*?**

Deposits of intrusive rocks originated deep underground and are surrounded by other types of rocks that can be altered by erosive phenomena occurring on the Earth’s surface. As a consequence, intrusive magmatic rocks are located on the Earth’s surface. The same thing happens when a mountain chain is formed, and tectonic movements lift deposits of intrusive rocks. Those deposits of intrusive magmatic rocks that are visible on the Earth’s surface are called plutons or batholithes.

Where does the magma form?

The magma originates on the mantle, at a depth of 100 kilometres, at a particular temperature and pressure conditions. After it is formed, the magmatic deposit can keep still for long periods of time, and only with temperature rises or pressure reductions it moves towards the Earth’s surface. This deposit feeds the volcanoes. During eruptions the magmatic material is expelled outside and acquires the name of lava. **Lava**

When it is very fluid, lava is expelled from the volcano without any explosive phenomena. It reaches a temperature of 1200°C and moves on the ground with a speed of up to 100 kilometres an hour. The presence of gas and silicon favours the volcano explosive activity: the magma is broken into pieces and the surrounding rocks are fragmented and violently launched into the air. The fragments are called pyroclasts and according to their size, it is possible to distinguish between: dusts (very fine), ashes, lapilli, bombs and blocks (big dimensions). Lava blocks are launched even at 10 km of distance, where they accumulate and form pyroclastic deposits, which are sedimentary rocks.

Sedimentary rocks

The action of water and air tends to transform and demolish the minerals that are contained in the rocks, by causing their disintegration and forming fragments of different size that are called debris. Debris are transported by rivers, sea water, wind and glaciers and then accumulate on the Earth’s surface depressions to form melted deposits. With time passing, transported sediments accumulate and compress the already-existing sediments underneath. Compressed debris are subject to a pressure that provokes the loss of water contained in the fragments. As a consequence, the material progressively becomes more compact. Some mineral substances melt in the water and deposit in the space between the debris, creating a “cement” that keeps them together. It takes millions of years to form a hard and compact rock through the so-called compaction and cementification of melted sediments. Physical and chemical processes are called diagenesis, which is more active in some specific periods. This leads to the creation of deposits made up of layers that can be easily seen on canyon walls or on the Dolomites.

Where are they located?

Stones of different dimensions are located at the bottom of the mountains. The sand, clay, gravel and round stones that are located along the rivers are **clastic sedimentary rocks**. In particular, when gravels are kept together by fine sand, they is called conglomerates.

Pyroclastic rocks are sedimentary rocks formed of lava fragments produced by explosive volcanic eruptions and then deposited on layers.

Organogenic rocks are very important and originate from the shells of sea molluscs. Ocean floors are covered by mud formed of planktonic organism shells such as foraminifers, radiolarians and diatoms. Other types of organogenic rocks

are created by the activity of sea organisms: polyps of madreporaria build their calcareous skeletons to form coral reefs. The Dolomites are a spectacular example of coral reefs, once submerged into the ocean and now huge mountains. Some blue algae, instead, are able to extract calcium carbonate from the water and deposit it, building dome-shaped structures made up of many layers: stromatolites. Remember that the accumulation of plant material forms fossil coal.
Inside karstic caves, close to water springs or waterfalls, calcium carbonate deposits and forms stalactites, stalagmites, travertine, alabaster, while deposits of water-insoluble minerals like iron and aluminium form laterites and bauxites.
These are chemical sedimentary rocks that derive from a depositing process originated by chemical reactions. Also minerals like calcite, rock salt and chalk deposit in the sea or in a lake after water evaporation, as it happens in the Red Sea, in the eastern part of the Mediterranean and in the Dead Sea, forming evaporites. Evaporite rocks can be found in Emilia Romagna, Sicily and Marche region. They were formed 6-7 million years ago, when Europe got closer to Africa and the Strait of Gibraltar (that guaranteed water exchange between the seas) closed. The Mediterranean water evaporated, new evaporite deposits were created and new lands emerged.
Flint and its varieties like opal (valuable decorative stone) are siliceous decorative stones, made of microscopic quartz crystals. They originate from the accumulation of both marine and fresh water organism-shells. Those shells, like radiolarians and diatoms, are made of silicon.

Metamorphic rocks

Sedimentary and magmatic rocks, when tectonic movements occur, can be dragged to high depths and find themselves at extreme temperature and pressure conditions, which transform their crystal structure. This process is called metamorphic process and transforms sedimentary and magmatic rocks into metamorphic ones. For example, carbonate rocks that are subject to the metamorphic process form marble. Sandstones and clay transform into gneiss rocks.

Can rocks transform?

The Earth's crust continuously evolves because rock transformation processes are constantly active. Superficial rocks (sedimentary and magmatic) are transported into soil depth and transformed into metamorphic rocks. If high temperatures are reached, rocks melt and transform into magma. When the magma cools down and goes back into solid state, magmatic rocks are formed. Deep rocks can be brought back to the surface, eroded and form fragments that will represent the deposits of sedimentary rocks.

Internal part of the Earth

The Earth is a spherical body that is made up of several internal layers, with a different thickness (crust, mantle, external nucleus, and internal nucleus). The passage from one layer to another is characterized by discontinuities:

- at 30-40 km of depth, the crust is divided from the mantle by Mohorovicic or Moho discontinuity
- at around 2900 km of depth the mantle is separated from the external nucleus by the Gutenberg discontinuity
- at around 5100 km of depth the external nucleus is separated from the internal nucleus by Lehman discontinuity.

The crust

The crust is the most external layer of the Earth. It is divided into earth and ocean crust. Continental crust has an average thickness of 40 km and is made of magmatic rocks (granites) and metamorphic rocks. The superficial layer of continents is mainly covered by sedimentary rocks. The ocean crust is less thick, as it measures around 6-8 km thickness and is made of different types of igneus rocks. In fact the first layer is made of basalts and then, underneath it, there are gabbro and metamorphic rocks. The surface of the ocean crust is also covered by sediments.

The mantle

The mantle is a layer that mainly consists of magmatic rocks (peridotites), which are denser than the gabbro and basalts that form the crust. The minerals that compose these rocks are fundamentally olivine and pyroxenes. The speed and direction of seismic waves through the mantle experience sudden changes showing that rocks are not always solid. Let us remember that magma originates at a depth of around 100 kilometres. In fact, between 70 and 200 kilometres of depth (immediately under the crust) there might be melted rocky material.

The nucleus

The behaviour of seismic waves brings up the hypothesis that the external nucleus could be composed of melted rocks, since it has the same characteristics as a liquid material. Researchers think that it is full of iron mixed with silicon and other metals like nickel. The internal nucleus, instead, behaves as a solid material, as it is rigid and elastic: it seems to be made of solid rocks.