Appendix 1 - The properties of minerals and rocks

Properties of minerals and rocks are very important to better understand the rock key of the RockCheck application.

What is a mineral and what are mineral grains?

A mineral is a naturally occurring, homogeneous solid that is usually formed during inorganic precipitation processes. It has a constant but not fixed chemical composition, an ordered crystal structure, certain morphological shapes and properties. Minerals are the basic building blocks of rocks, therefore, the determination of minerals is very important for the identification of rocks. It is important to understand that minerals are not rocks, but rocks are made up of minerals. The target group has little or no knowledge of this subject, so the questions in the rock key are only related to the basic properties of minerals that the general public can understand, like color and hardness.

ROCKCHECK	IMPORTANT CHARACTERISTICS	COLOR	RELATIVE HARDNESS	OCCURRENCE IN ROCKS
MUSKOVITE and BIOTITE	Minerals with thin sheets shape. Muskovite is transparent and is generally silver colored, while biotite is dark and opaque.		1 10	
CALCITE and DOLOMITE	Calcite reacts rapidly with diluted 10% HCL, dolomite does not.		1 10	
AMPHIBOLE and PYROXENE	These two minerals are hard to distinguished. They have prismatic shape and build many igneous and metamorphic rocks.		1 10	
FELDSPAR	Mineral with rectangular angles and pearly glow that makes up some of the most common rocks.		1 10	
OLIVINE	Transparent to translucent mineral with a glassy glow.		1 10	
GARNET	Mineral with spherical to cubic shape.		1 10	
QUARTZ	One of the most common minerals. It is usually seen in rocks as transparent to translucent minerals, with a glassy glow.		1 10	

Figure 1: A table of rock-forming minerals and their main properties.

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Mineral grains in rocks are visible as shiny surfaces that reflect light like small mirrors. They vary in size, large ones are visible to the naked eye while small ones are only visible under a microscope. Therefore, we can see all the mineral grains or only some of them in the rock. The mineral grains may be the same or a different color, and within the same rock we may observe mineral grains of the same or different sizes. Igneous, metamorphic, and some sedimentary rocks are composed of mineral grains. They are usually formed during rock formation; however, some metamorphic rocks contain mineral grains that are older and have not changed during metamorphism. Some mineral grains can be identified macroscopically. They are identified by their properties such as hardness, shape, cleavage, color, etc.

How to describe and recognize minerals in rocks?

Minerals in rocks are recognised indirectly by the user with the RockCheck learning aid by observing and testing their properties and testing their properties with the questions in the rock key. When observing minerals, one must be careful and watch for small differences. The rock key requires the user to determine the shape, size, colour, hardness and reaction of the minerals. The user compares the observed sample with the pictures and graphics in the application. The colour of the mineral is described in one or more words, although it is often not a decisive factor for the mineral recognition, it does limit the selection of possible rocks. By describing the hardness of minerals, we mean their relative hardness compared to the hardness of everyday objects. The user can also see in the application the professional display of basic experiments, for example, how we drop a hydrochloric acid (HCl) on the mineral.

Such a way of describing and recognising minerals has its limitations. Geologists classify minerals by their chemical composition and crystallographic form. This means that just by observing the properties, without detailed geological studies, we cannot determine the mineral with certainty. However, in favour of the method used, there are only about 30 minerals that are common enough to form rocks, and only ten of them make up 90% of the mass of the Earth's crust. The recognition of these minerals may be based on the principle we have presented. It is possible to distinguish these minerals using only basic examination techniques and by observing their properties.

What is rock?

Rocks are solid substances of more or less constant mineral and chemical composition. They form the continents and the bottom of the oceans. The entire crust of the earth (lithosphere) is made up of different types of rocks. Rocks may be composed entirely of one or different types of mineral grains or of various fragments of different rocks and/or fossils called sedimentary grains. Due to differences in rock formation and composition, rocks have different properties, such as color, hardness, chemical composition, etc. Rocks are classified into three main groups according to their formation processes: Igneous rocks, Sedimentary rocks and Metamorphic rocks.

Rocks are not eternal. External factors such as the sun, water, wind and ice are constantly transforming them. Rocks of one group may later form the rocks of the other two groups. We can sum up all these changes in a rock cycle.

What is the Rock cycle?

The rock cycle is an overview of the formation and change of rocks on and below the Earth's surface. The changes take place in the three main groups of rocks: Igneous rocks, Metamorphic rocks, and Sedimentary rocks. The rock cycle describes how one group of rocks changes into another through various processes.

Magma is the main source of minerals and rocks. Igneous rocks are formed when magma cools and crystallizes. When igneous rocks sink deep below the Earth's surface, metamorphosis (change) occurs, and igneous rocks are transformed into metamorphic rocks due to increased temperature and pressure. Igneous and metamorphic rocks can be lifted to the surface, where weathering and subsequent transport of the grains causes sedimentary grains to form from these rocks. Sedimentary grains can also form in the oceans from the skeletons of deceased organisms. The deposition of sedimentary grains and their lithification results in formation of sedimentary rocks (link to sedimentary rocks). Sedimentary rocks can also sink deep below the Earth's surface, where they transform into metamorphic rocks; however, if they sink even deeper, they melt into magma. This is the complete rock cycle.

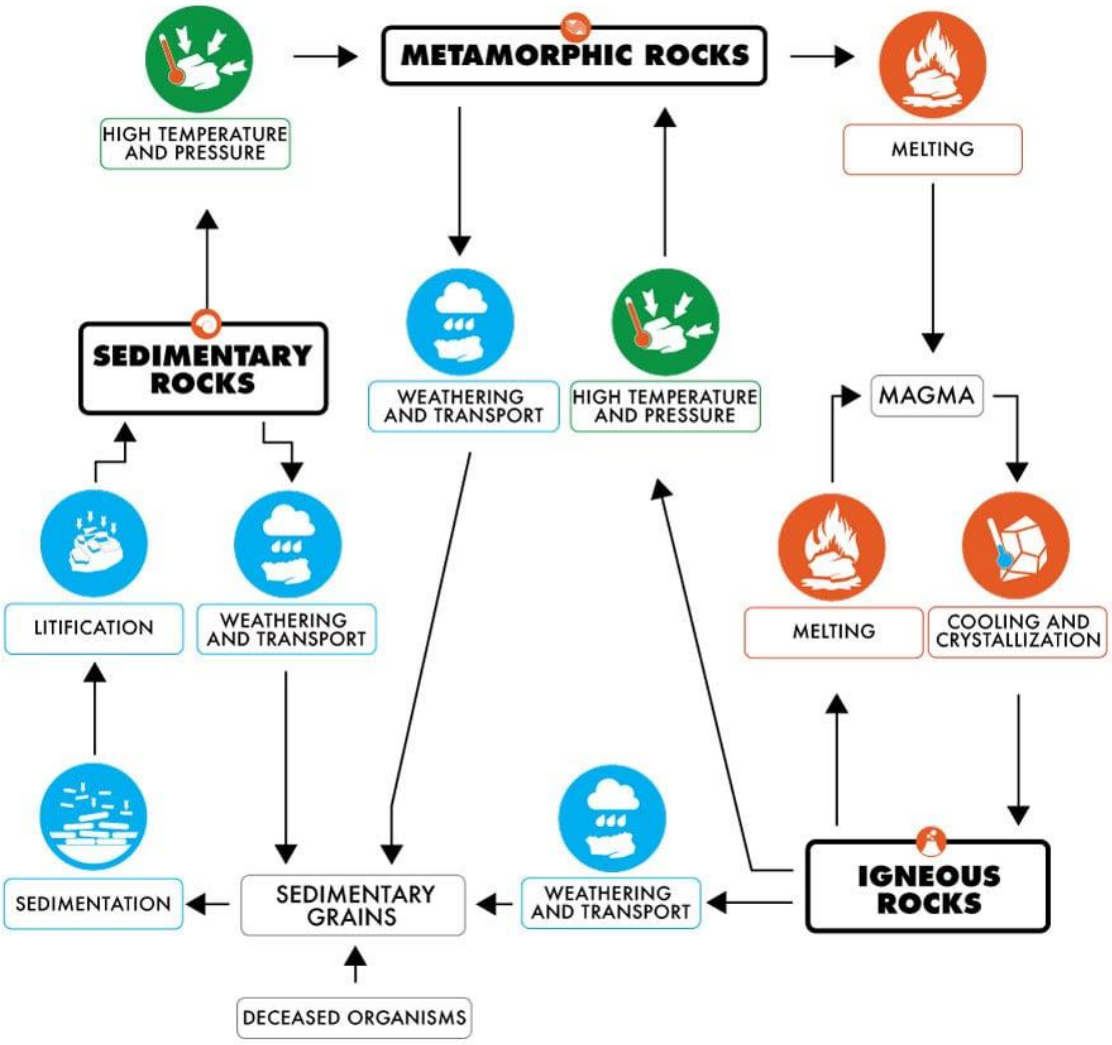

Figure 2: Schematic presentation of Rock cycle from the application.

IGNEOUS ROCKS

Igneous or magmatic rocks are formed through the cooling and crystallization of magma under or lava on the Earth's surface. Igneous rocks are divided into intrusive and extrusive igneous rocks.

Intrusive igneous rocks are formed from magma deep below the earth's surface. Because of the slow cooling of the magma, the minerals have time to crystallize. As a result, these rocks have approximately the same size mineral grains. This type of rock has a phaneritic texture.

Extrusive igneous rocks are igneous rocks formed from magma at shallow depths below the earth's surface or from lava at the surface. Because of the rapid drop in pressure and temperature, cooling and solidification of magma or lava occurs rapidly. Only individual mineral grains are visible (those with higher melting points), the rest of the rock forms what is called a matrix. This type of rock has a porphyritic texture.

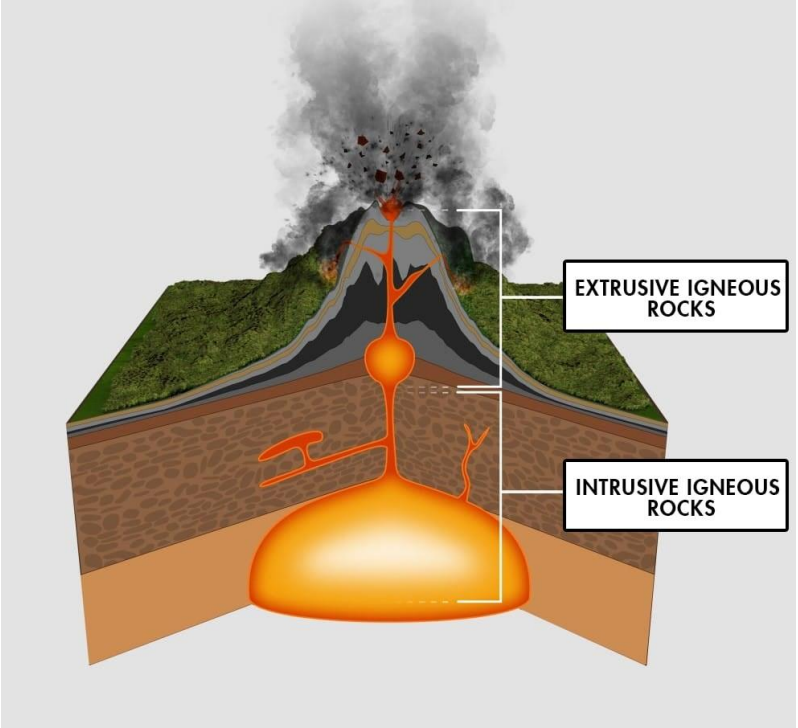

Figure 3: Graphical display of extrusive and intrusive rocks from the application.

Chemical composition of magma and lava

Magma is hot molten or semi-molten material in the Earth's mantle. When magma erupts at the surface, it is called lava. Igneous Rocks are formed with crystallization of mineral grains. The type of mineral grains and crystallized rock depends on the chemical composition of the magma or lava. The chemical composition of the melt (magma or lava) varies and depends on its origin in the Earth's mantle and crust. The melt consists of different elements such as silicon, oxygen, aluminum, sodium, potassium, calcium, magnesium and iron in different ratios. Consequently, different igneous rocks are formed. If the magma contains a lot of silicon and oxygen (felsic magma), rhyolite may form, while basalt may form from magma with a high magnesium and iron content (mafic magma). Magma with mixed chemical composition can form andesite. In the Earth's mantle, magma can contain high levels of magnesium and iron (ultramafic magma).

Figure 4: Display of chemical composition of magma and lava from the application.

What are phaneritic, porphyritic and vitreous textures?

Igneous rock with phaneritic texture is composed from mineral grains of roughly equal size and visible to the naked eye that are in contact with each other. Texture is typical for extrusive rocks and is formed by gradual crystallization of mineral grains from magma deep below the earth's surface.

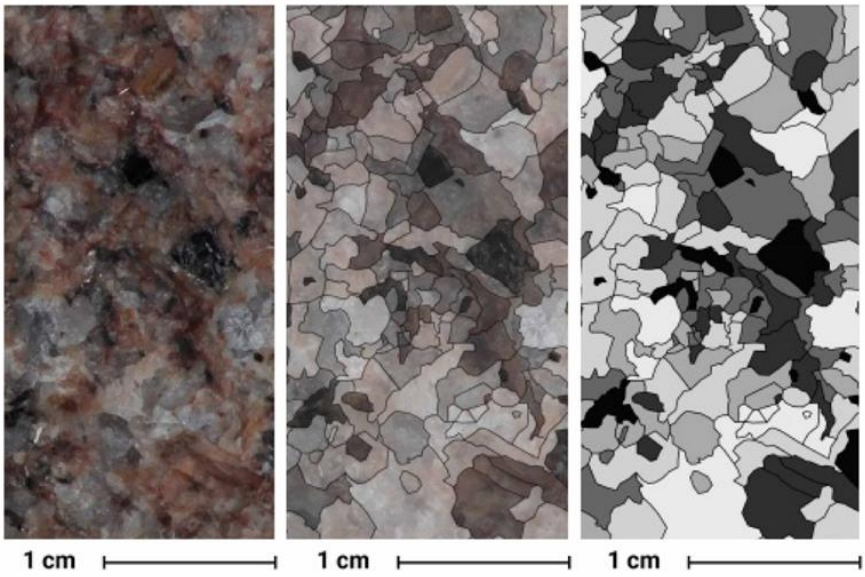

Figure 5: Graphical display of phaneritic texture from the application.

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Igneous rocks with porphyritic texture consist of individual large mineral grains that are known as phenocrysts. These minerals are first crystallized from the magma, while the remaining mineral grains are too small to be seen and are known as matrix. Intrusive rocks usually have a porphyritic texture. This texture indicates that the magma started to crystallize at a shallow depth below the Earth's surface, allowing time for the larger mineral grains (minerals that are visible in the rock) to crystallize. Because of the rapid drop of pressure and temperature near or at the surface, the magma cooled and solidified very quickly, and a matrix formed. There are two types of matrix: If it is fine-grained, it is an aphanitic (microcrystalline) matrix; if no mineral grains are visible, it is a vitreous matrix.

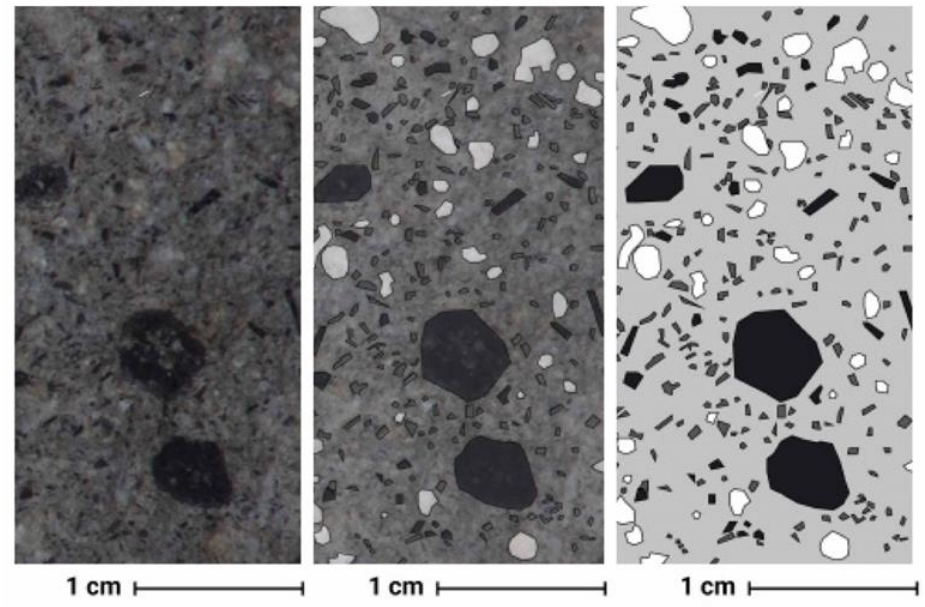

Figure 6: Graphical display of porphyritic texture from the application.

Vitreous texture is also known as glassy texture and occurs in extrusive igneous rocks (link to igneous rocks). Due to the rapid cooling of the lava, the minerals cannot crystallize and no mineral grains are visible in the rock. This creates a natural amorphous glass with virtually no visible minerals. The rock then breaks like a glass, with a conchoidal fracture. Sometimes the air bubbles are trapped in the rock. Examples of this are obsidian and pumice.

METAMORPHIC ROCK

Metamorphic rocks are formed from igneous, sedimentary, or pre-existing metamorphic rocks by the procces of metamorphism (change) at high temperatures and pressures, as well in the presence of gasses and fluids. Metamorphism changes the mineral composition and structure of the rock. Metamorphism occurs deep below the Earth's surface, usually at the tectonic contact between two plates when one plate slides under the other (subduction) or by the intrusion of hot molten magma into the solid crust of the Earth. Metamorphic rocks consist of mineral grains. Their composition depends on the source rock, while their characteristic structure depends on the temperature and the orientation of the pressure. Metamorphic rocks have different types of structures, such as schistose structure and granulose structure.

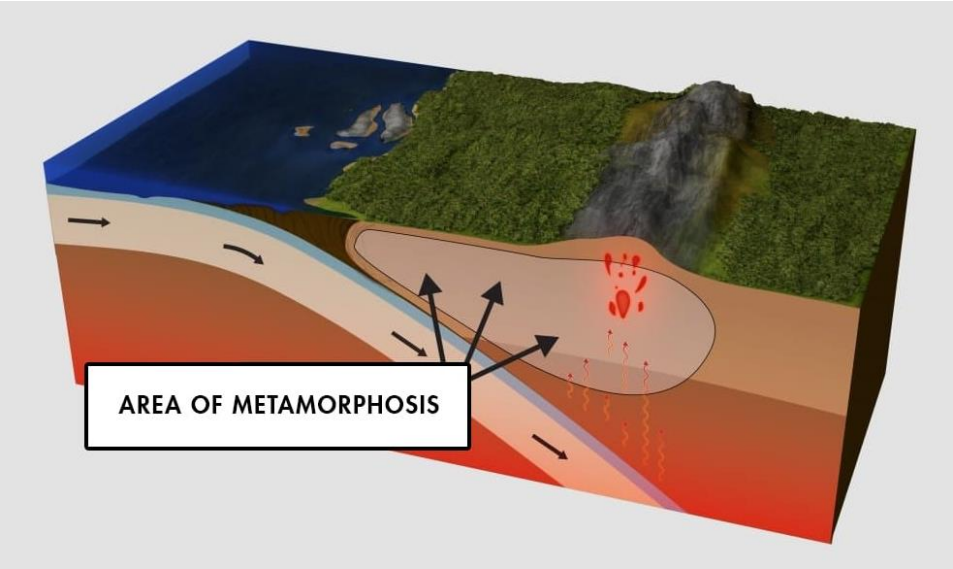

Figure 7: Display of areas of metamorphosis from the application.

What are granulose, schistose and gneissose structures?

Granulose structures are metamorphic rocks composed of mineral grains of similar size that have the same or different colors and are not aligned as in schistose structures. The granulose structure looks like an igneous phaneritic texture. Granulose structures form during metamorphism when the pressure is approximately equal in all directions and at high temperatures.

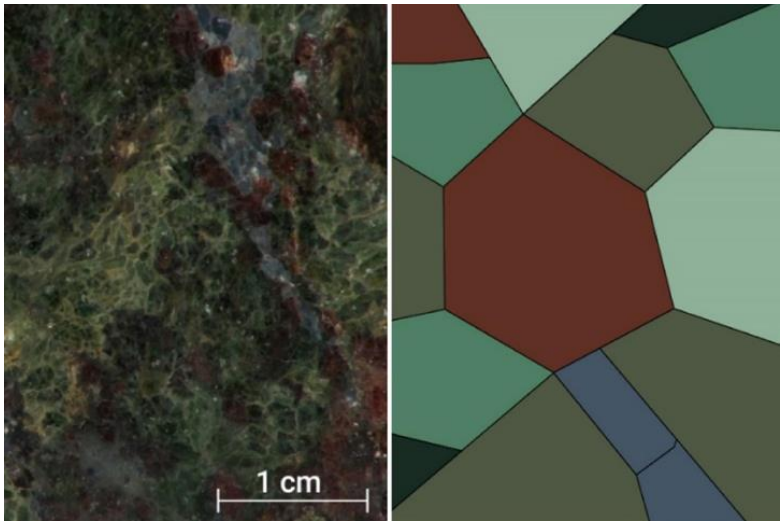

Figure 8: Graphical display of granulose structure from the application.

Thin, horizontal layers a few millimeters or a few centimeters thick characterize the schistose structure. Rock with this type of structure is often easily broken into slabs. Because of micaceous mineral grains, the rock layers may have a slight sheen. Schistose structure can be mistaken for laminas. Schistose structure is formed during metamorphism under oriented pressure, where the mineral grains are redistributed perpendicular to the direction of maximum pressure.

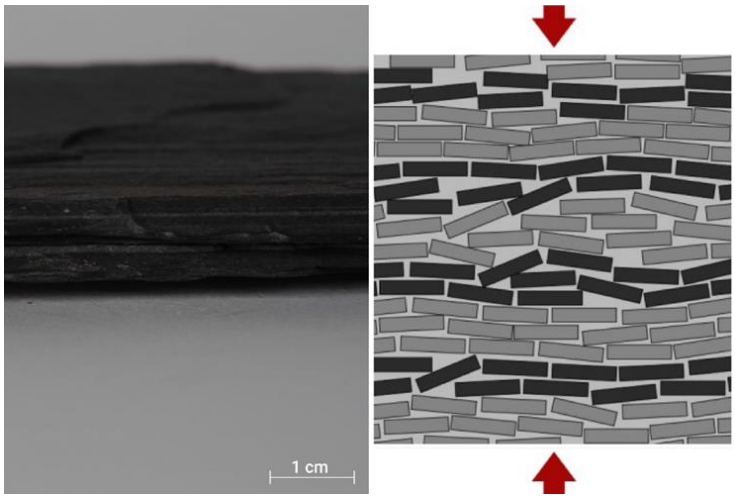

Figure 9: Graphical display of schistose structure from the application.

The alternation of light and dark mineral bands is characteristic of the gneissose structure. Sometimes larger, lighter minerals (feldspars) remain within the bands and have a shape resembling an eye. Rocks with gneissose structure are subjected to extremely high pressures and temperatures during the metamorphism that forms the gneissic structure. During such metamorphism, separation of minerals according to their melting point may occur, and the result of this process is dark and light mineral bands.

SEDIMENTARY ROCK

Sedimentary rocks are formed at the earth's surface during the processes of sedimentation and lithification of sedimentary grains or by precipitation of minerals from aqueous solutions. Sedimentary rocks can be divided into clastic, chemical, and biochemical sedimentary rocks.

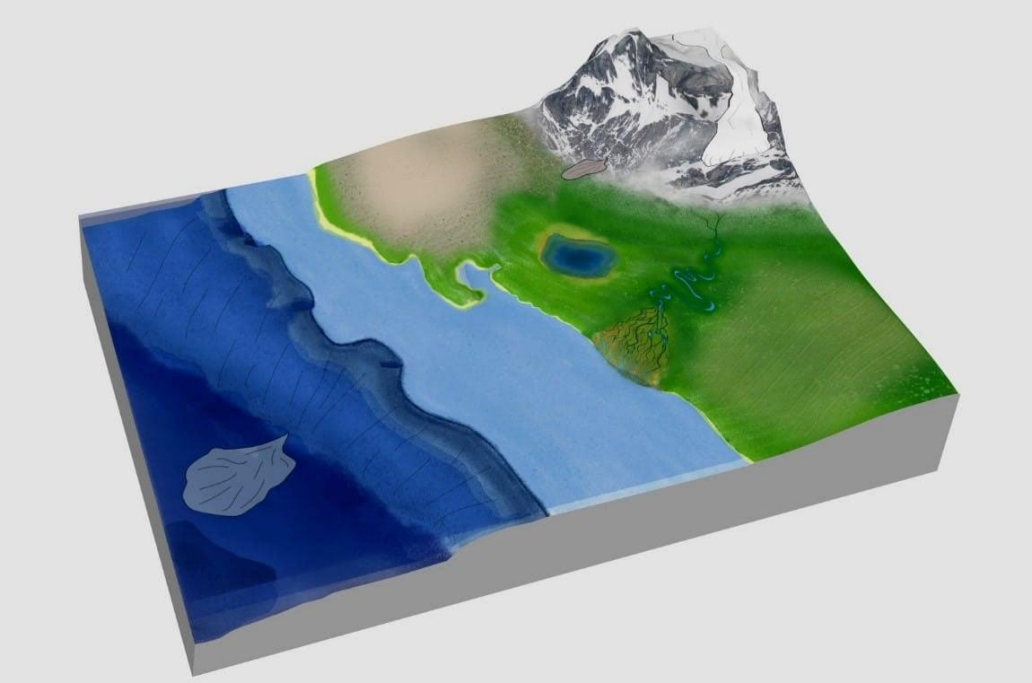

Figure 10: Display of environments of sedimentary rock formation from the application.

Clastic sedimentary rocks consist of sedimentary grains that are manly result of weathering of other (older) rocks. These grains are later transported (by water, wind, etc.) and deposited in a different location, e.g., river channel, floodplain, lake and seashore. Clastic sedimentary rocks may contain remains of organisms. Subsequently, compaction and cementation processes (lithification) occur, i.e. the sedimentary grains become solid rock. Clastic sedimentary rocks differ in size and shape of sedimentary grains.

Chemical sedimentary rocks are formed in oceans, lakes, or on land by the precipitation of minerals from an oversaturated aqueous solution as a result of changes in conditions. They are distinguished based on composing minerals.

Biochemical sedimentary rocks are formed with the help of living organisms. The organisms can be involved in two ways: Through their activity, they may enhance the precipitation of minerals from aqueous solution, or they may form the rock from the mineral skeletons. The latter can be crushed into fine sediments or remain in the rock as fossils. Biochemical rocks are distinguished based on mineral composition.

What are sedimentary grains?

Sedimentary grains are loose, solid particles of mineral grains, fossils and/or various rocks. The grains can have different shapes and sizes. Before they become solid rock, they are made up of pebbles, boulders, sand, silt, clay and are found along coasts, rivers, slopes, etc. Only grains of sand and larger grains are visible to the naked eye.

CLASTIC SEDIMENTARY ROCKS		
SEDIMENTARY GRAINS	GRAIN SIZE	SEDIMENTARY ROCKS
Gravel (angular sedimentary grains)	> 2 mm	Breccia
Gravel (rounded sedimentary grains)	> 2 mm	Conglomerate
Sand	2 mm - 0,063 mm	Sandstone
Silt	0,063 mm - 0,002 mm	Siltstone
Clay	< 0,002 mm	Claystone

Figure 11: Table of clastic sedimentary grains and rocks from the application.

Grain shape (rounded or unrounded) and size depend on the length of transportation and the hardness of the grain. The longer the transport, the rounder and smaller the grains become. For the same transport distance, softer grains become round, in contrast to harder grains, which can still remain angular (quartz).

What are layers and laminas?

Layers and laminas are sedimentary textures that form when sedimentary grains are deposited. The grains are deposited in successive layers and may vary in color and size. Layers and laminas can vary in thickness, on that basis we can also distinguish them. Individual layers can be at least 1 cm to several meters thick, while laminas are thinner than 1 cm. The latter are like schistose structure which is characteristic of metamorphic rocks. The difference between the two is that we cannot usually break up the rock along the laminas.

What are fossils?

Fossils are remains of organisms or their traces from past geologic ages preserved in sedimentary rocks. There are several types of fossils. The most common is the preservation of solid and resistant skeletons and traces of their activity, such as crawl marks, footprints, etc. A fossil is formed when the skeleton of an organism settles in a quiet environment where it is buried, and the physicochemical process of fossilization takes place. Fossils can be found in a variety of shapes and sizes. Some are so small that they can only be seen under a microscope, while others, such as dinosaurs, can fill entire museum halls.

What is incrustation of plants?

When carbonate minerals precipitate, calcium carbonate forms and covers the plants (leaves, twigs, etc.). In this way, the plants in the rock are covered with a thin crust (incrustation). The footprints of the plants can be seen in the broken part of the crust. Carbonate crust forms in calcium carbonate rich waters near waterfalls or springs where calcium carbonate precipitates from the saturated water due to pressure changes and reduced solubility and covers the plants (leaves, branches). When the plants are completely covered by the crust, tufa is formed.