6. ROCKS AND MINERALS

Types of Rocks

Minerals are naturally occurring inorganic substances, often with a crystalline structure. They are composed largely of the most abundant elements in the Earth's crust oxygen & silicon, coupled with metals or the metallic elements of iron, calcium, sodium, potassium, and magnesium.

Rocks are usually composed of two or more minerals. Often, many different minerals are present, but a few rock varieties are made almost entirely of one mineral. Most rock in the Earth's crust is extremely old, dating back many millions of years, but rock is also being formed at this very hour as active volcanoes emit lava that solidifies on contact with the atmosphere or ocean.

The Great Oxygenation Event or oxygen catastrophe which happened 2400 million years ago in the Proterozoic eon triggered an explosive growth in the diversity of minerals on Earth. The three types of Rocks are Sedimentary, Igneous and Metamorphic.

- **Igneous rocks**

These rocks have crystallized from magma which is made up of various components of pre-existing rocks and has been subjected to melting either at subduction zones or within the Earth's mantle.

- **Sedimentary rocks**

These rocks are formed through the gradual accumulation of sediment, such as sand on a beach or mud on a river bed. The sediment is buried and then it is compacted as more and more material is deposited on top. In several thousand to Lakhs of years , the sediment becomes so dense that it becomes a rock. This process is known as lithification.

- **Metamorphic rocks**

These rocks once existed as igneous or sedimentary rocks but have been subjected to varying degrees of pressure and heat within the Earth's crust. The processes involved changes the composition and fabric of the rock and their original nature is often hard to distinguish. Metamorphic rocks are typically found in areas of mountain building.

The above three classes of rocks are constantly being transformed from one to another in a continuous process through which the crustal minerals have been recycled during many millions of years of geologic time. The adjacent diagram shows these transformations.

Igneous Rocks

The upper 16 kilometers of the Earth's crust is made up of 95% Igneous rock, with a thin covering of sedimentary and metamorphic rocks. Igneous rocks are formed when molten rock cools, forming silicate mineral crystals. Felsic minerals are light colored and less dense, and mafic minerals are dark colored and more dense. The igneous rocks are generally hard and water percolates in them not so easily.

The most important characteristics of Igneous rocks are as follows:

- They usually do not occur in distinct beds or strata like sedimentary rocks.
- Igneous rocks are generally not having any fossils S They are generally granular and crystalline.
- They are less affected by chemical weathering as the water does not percolate in them easily.

Magma as source of Igneous Rocks

The mixture of the Molten Rocks which makes the Igneous rocks is called Magma. Magma in fact is a mixture of molten rocks, volatiles (gas) and other solids. It originated from the partial melting of the lower crust and the upper mantle, mainly at depths of 15-200 kilometers. Most magma is as hot as 700 °C to 1300 °C and is silicate mixtures mostly. The chambers under a volcano where Magma collects are called magma chambers. The magma chambers feed a volcano. Bulks of the igneous rocks are result of the cooling and solidifying of Magma. There are two processes by which Magma cools and solidifies. These are called "plutonic" and "Volcanic Eruption". When the Molten Magma goes down deep within the earth and gets solidified, it is called Plutonism. On the contrary, the molten Magma can also come out on the surface of earth via a volcanic eruption.

Intrusive and Extrusive Igneous Rocks

Magma that solidifies below the Earth's surface and remains surrounded by older, pre-existing rock is called intrusive igneous rock. Because intrusive rocks cool slowly, they develop large mineral crystals that are visible to the eye. They are further classified into Plutonic, Hypabyssal, Batholiths and Laccoliths as follows:

Types of Igneous Rocks

Intrusive	Plutonic	Generally very large crystal and they were formed due to cooling of magma very deep inside the Earth
	Hypabyssal	Consolidated in a zone above the base of Earth's crust and hence has distinct structural characteristics.
	Batholiths	They extend to greater depths and larger areas
	Laccoliths	A sheet intrusion that has been injected between two layers of sedimentary rock
Extrusive		Formed at the crust's surface as a result of the partial melting of rocks within the mantle and crust

If the magma reaches the surface and emerges as lava, it forms extrusive igneous rock. Extrusive igneous rocks cool very rapidly on the land surface or ocean bottom and thus show crystals of only microscopic size. Please note that Granite typically accumulates in batholiths. A single batholith sometimes extends down several kilometers and may occupy an area of several thousand square kilometers.

Felsic Rocks and Mafic Rocks

Whatever may be the process of cooling and solidifying, the magma while converting into a rock, undergoes numerous chemical and physical changes. Accordingly, there are two major types of Igneous rocks are produced viz. Felsic Rocks and Mafic Rocks. Felsic rocks are rich in silicon, oxygen, aluminium, sodium, and potassium, while the mafic rocks are rich in magnesium and iron. If the rock is highly dominated by Magnesium and Iron, it is called Ultramafic.

Examples of Igneous Rocks

- Granite: Intrusive (batholith generally), Felsic, igneous rock. Worldwide average chemical composition of Igneous Rocks has SiO2 — 72.04% & Al2O3 — 14.42%
- Diorite: intermediate intrusive igneous rock
- Gabbro: Mafic igneous rocks equivalent to basalt.
- Peridotite
- Rhyolite
- Andesite
- Basalt
- Komatiite
- Diabase

Sedimentary Rocks

Sedimentary rocks are made from layers, or strata, of mineral particles found in other rocks that have been weathered and from newly formed organic matter.

Sedimentary rocks form at Earth's surface by the hydrologic system. Their origin involves the weathering of pre-existing rock, transportation of the material away from the original site, deposition of the eroded material in the sea or in some other sedimentary environment, followed by compaction and cementation. Some common features are:

- They contain strata or layers. The layers are rarely horizontal and generally tilted due to lateral compressive and tensile forces. They are formed of sediments derived from the older rocks, plants and animals remain.
- Most part (around 75 percent] of the surface area of the globe is covered by Sedimentary Rocks.
- Most of the sedimentary rocks are permeable and porous.
- Sedimentary rocks are generally characterized by different sizes of joints, generally perpendicular to the bedding plains.

When rock minerals are weathered, their chemical composition is changed, weakening the solid rock. The rock breaks up into particles of many sizes. When these particles are transported in a fluid such as air, water, or glacial ice, we call them sediment. There are three major classes of sediment: clastic sediment, chemically precipitated sediment, and organic sediment. On this basis, three main types of sedimentary rocks are recognized viz. clastic rocks, organic rocks and chemically precipitated rocks.

Types of Sedimentary Rocks

Clastic	Made up of discrete fragments or clasts of materials derived from other minerals, largely of quartz and others such as feldspar, amphiboles, clay minerals.
Organic	They contain the materials which are generated by living organisms such as corals, mollucks, and foraminifera, which cover the ocean floor with layers of calcium carbonate, which can later form limestone.
Chemical	Formed by the Chemical & Biological Processes like limestone, rock salt, gypsum and dolostone.

Clastic Sedimentary Rocks

Clastic sediment is made up of inorganic rock and mineral fragments, called clasts. These can come from igneous, sedimentary, or metamorphic rocks, and so they can include a very wide range of minerals. Quartz and feldspar usually dominate clastic sediment.

When layers of clastic sediment build up, the lower strata are pushed down by the weight of the sediments above them. This pressure compacts the sediments, squeezing out excess water. Dissolved minerals recrystallize in the spaces between mineral particles in a process called cementation, thus giving rise to the Clastic Sedimentary Rocks. Due to the mechanical process, the clastic sedimentary rocks are also sometimes called mechanically formed Sedimentary Rocks. Sandstone, a rock made of sand, and shale, a rock made of clay particles, are typical examples of Clastic Sedimentary Rocks. Shale is a clastic sedimentary rock composed of very fine grains of clay or mud.

Chemically Precipitated and Organic Sedimentary Rocks

Chemically precipitated sediment is made of solid inorganic mineral compounds that precipitate from water solutions or are formed by organisms living in water. One of the most common sedimentary rocks formed by chemical precipitation is limestone. The third class of sediment is organic sediment. This is made up of the tissues of plants and animals. Peat is an example of organic sediment. This soft, fibrous, brown or black substance accumulates in bogs and marshes where the water stops the plant or animal remains from decaying.

Limestone

Limestone is by far the most abundant chemically precipitated rock. It is composed principally of calcium carbonate (CaC03 or calcite] and originates by both inorganic chemical and biochemical processes. Limestones have a great variety of rock textures such as skeletal limestone, oolitic limestone, and microcrystalline limestone.

Marine sediments form largely by biochemical precipitation. Carbonate sediments dominate at shallow depths and in warm near-shore waters. Elsewhere, siliceous sediment, which eventually forms chert, is typical in deeper water.

Skeletal Limestone

Some marine invertebrate animals construct their shells or hard parts by extracting calcium and carbonate ions from seawater. Corals, clams, algae, snails, and many other marine organisms construct their skeletons of calcium carbonate. After the organisms die, the shells accumulate on the seafloor. Over a long period of time, they build up a deposit of limestone with a texture consisting of shells and shell fragments. These particles may then be cemented together as more calcite precipitates between the grains. This type of limestone, composed mostly of skeletal debris, can be several hundred meters thick and can extend over thousands of square kilometers.

- Chalk is a skeletal limestone in which the skeletal fragments are remains of microscopic plants and animals. Oolitic Limestone

Other limestones are composed of small semi spherical grains of calcium carbonate known as oolites. Oolites form where small fragments of shells or other tiny grains become coated with successive thin layers of CaC03 as they are rolled along the seafloor by waves and currents.

Microcrystalline limestone

A third important type of limestone forms in quiet waters where calcium carbonate is precipitated by algae as tiny, needle like crystals that accumulate on the seafloor as limy mud. Soon after deposition, the grains commonly are modified by compaction and recrystallization.

- Some kinds of algae produce calcium carbonate particles that accumulate to form limestone.These are found near the Kuril Islands of the north Pacific.
- Diatoms are the shells of tiny single-celled algae that are made of silica. Some deepmarine sediments are dominated by diatoms. Some accumulations convert to chert.

Dolostone / Dolomite

Dolostone or dolomite rock is a sedimentary carbonate rock that contains a high percentage of the mineral dolomite. Dolomite is a carbonate mineral composed of calcium magnesium carbonate CaMg(C03]2. It is similar to limestone in general appearance, but reacts with acid only when powdered. Dolostone is commonly dull brownish yellow or light gray.

Chert

Chert is a common rock composed of microcrystalline quartz. In a hand specimen, it is hard, dense, and typically breaks like glass, but under a high-power microscope, it has a fibrous or granular texture. A distinctive type of deep-marine chert develops from deposits of siliceous shells of microscopic organisms, such as radiolaria and diatoms.

Rock salt

Rock salt is made of the mineral halite (NaCl], It crystallizes when evaporation concentrates sodium and chlorine ions to the point that salt is stable in the residual brine. Strong evaporation creates saline lakes in closed desert basins (for example, the Great Salt Lake and the Dead Sea], Enhanced evaporation also occurs in restricted bays along the shore of the ocean.

Gypsum

Gypsum, CaS04, 2H20 too originates from evaporation. It collects in layers as calcium sulphate is precipitated from water.

Hydrocarbons

Coal is an important biochemical precipitate. It forms by the decomposition of organic material buried within sedimentary rocks. Lush vegetation may form in an ancient swamp and then be converted by burial into coal. The coal beds on the left are interlayered with sandstone.

The accumulation of partially decayed vegetation is called Peat. Peat is a compound of hydrogen, carbon, and oxygen. They formed from plant remains that built up over millions of years and were compacted under thick layers of inorganic clastic sediment. Hydrocarbons can be solid (peat and coal], liquid (petroleum], or gas (natural gas). Coal is the only hydrocarbon that is a rock. We often find natural gas and petroleum in open interconnected pores in a thick sedimentary rock layer, such as in porous sandstone.

Metamorphic Rocks

The mountain-building processes of the Earth's crust involve tremendous pressures and high temperatures. These extreme conditions alter igneous or sedimentary rocks, transforming them into metamorphic rock. Thus, metamorphic rocks are formed from the pre-existing rocks within the Earth's crust by changes in temperature and pressure and by chemical action of fluid. This means that Both the Igneous and Sedimentary socks undergo profound physical and chemical changes under the increased pressure and temperature. The process is called "metamorphism". Some metamorphic Rocks are Schist, Gneiss, Slate, Quartzite, Marble and Granite. There are two basic types of metamorphic rocks:

1. Foliated metamorphic rocks such as gneiss, phyllite, schist and slate which have a layered or banded appearance that is produced by exposure to heat and directed pressure. This is called Foliation.
2. Non-foliated metamorphic rocks such as marble and quartzite which do not have a layered or banded appearance.

In the surface environment, rocks weather into sediment. In the deep environment, heat and pressure transform sediment into rock that is eventually exposed at the surface.