ENVIRONMENTAL GEOSCIENCES

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Lecture-29

Description of Common Metamorphic Rocks

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the module 5. In the module 5, we have already discussed concepts of rocks, magma, its composition and constitution, description of some common igneous rocks, description of some common sedimentary rocks, and today we will discuss the lecture 5, that is description of common metamorphic rocks. So, in this lecture, the important concepts will be covered like metamorphic rocks, metamorphism, structure of metamorphic rocks, mineralogical composition of metamorphic rocks, classification of metamorphic rocks, and description of common metamorphic rocks. So, in the previous lecture, we have seen that the three important types of rocks we are getting in the earth's crust, that is igneous, sedimentary and metamorphic rocks.

We have already discussed the igneous rocks in greater detail, then the sedimentary rocks. Today we will start to discuss about the metamorphic rocks. What is metamorphic rocks? These are rocks formed by alteration of pre-existing rocks by the action of temperature, pressure aided by sub-terranean fluids like magnetic or non-magnetic sources. Now today we will discuss the metamorphic rocks. Metamorphic rocks, these are formed by the alteration of pre-existing rocks by the action of temperature, pressure added by sub-terranean fluids that is magnetic or non-magnetic. Some of the common example of metamorphic rocks are slate, marble, schist, gneiss, quartzite, etc.

So important features of metamorphic rocks, generally the metamorphic rocks are hard, interlocking grains and bedded, if derived from the stratified rocks, that is sedimentary rocks. Fossils are rarely preserved in rocks of sedimentary origin except in slates. Foliated, gneissose, schistose, granulose, slaty etc. are the common structures. Common minerals in metamorphic rocks are andalusite, sillimanite, kyanite, cordierite, garnet, graphite, etc. So these are the important features of the metamorphic rocks.

Now what is metamorphism? The word metamorphisms come from the Greek word meta means change and morph means form. So metamorphism means to change in form. In geology, this refers to the changes in mineral assemblages and texture that result from subjecting a rock to pressure and temperature difference from those under which the rock originally formed. Therefore, metamorphism is the response of the solid rocks to pronounce changes of temperature, pressure and chemical environment.

Now changes due to metamorphism. As rocks are subjected to great heat and pressure, they begin to undergo changes like: changes in the minerals compositions, folding and bending of the rocks causing change in its shape, recrystallization causes changes in minerals size and shape. Chemical reactions occur between the minerals to form new sets of minerals that are more stable at the pressure and temperature of the environment and new minerals form as a result of polymorphic phase transformations. So here you can see in the diagram also, if the temperature will increase, the first metamorphic rock is the shale. Then the shale, slate, then the phyllite, then the schist and then the gneiss.

So this is telling about the increasing metamorphism in the metamorphic rocks. Next is the agents of metamorphism. So, we have understood already that temperature, pressure and chemically active fluids, they are playing very very important role in bringing metamorphism in the pre-existing rocks. Now, similarly the agents which are mostly responsible for bringing about metamorphic current changes are, first is the temperature, second is the pressure, pressure two types, hydrostatic or uniform pressure and second is the direct pressure or stress and third is the chemically active fluids. Now, one by one we will discuss. Temperature, it may be supplied by geothermal gradient, magmatic heat, frictional heat, and by radioactive disintegration inside the Earth's surface. The temperature range within which metamorphic changes take place is from 200ºC to 700ºC.

However, in certain cases, a temperature of 1000ºC to 1200ºC may also be encountered. Now, on the basis of temperature, the different types of metamorphism are, first is the pyro-metamorphism. At 800ºC to 1000ºC in the immediate vicinity of the intrusive, the induration, baking, burning, and fritting effects of lava flows and intrusions on the neighboring rocks is known as caustic metamorphism or optalic metamorphism. Now, second is the contact metamorphism. It occurs around larger intrusive at comparatively low temperature.

It includes normal contact metamorphism where rocks are simply crystallized without new mineral formation. Pneumatolytic additive or metasomatic, the composition of the rocks is vastly modified depending on the addition of material from magnetic emanations. Injection metamorphism, here, with the intrusion of magma or its residual liquid may alter the intruded rock substantially. Next is the autometamorphism. It is the mineralogical readjustment of an igneous assemblage to the falling temperature as the body of the igneous rock cools.

It includes uralitisation and serpentinisation etc. Next is the retrograde metamorphism, also known as diaphthoresis, where mineralogical readjustment of high temperature to a low temperature one takes place. Second agent is pressure. Here, uniform pressure and directed pressure, two types of pressures are here. Uniform pressure, it is the hydrostatic pressure which increases with depth.

Uniform pressure and temperature can both dominate together at greater depths. There is a reduction in the volume of the rock and change in the meteorological composition. It is known as plutonic metamorphism. Example is granulites, eclogites. These are the metamorphic rocks.

Next is the directed pressure, it is produced mostly by orogenic movements. It dominates at or near the surface. It results in crushing and granulation of minerals without the formation of any new mineral. It is also known as dynamic metamorphism or cataclastic metamorphism. An example is mylonites.

Third agent is the chemically active fluids. These are from the following sources. First, the meteoric water, juvenile water. Water carries minerals in some cases in solution and also serves as medium in which chemical changes take place. Chemical activity is more pronounced in the vicinity of the igneous intrusions.

So, these are about the agents, three important agents, which are bringing metamorphism to the pre-existing rocks. Now, grades of metamorphism. The degree of metamorphism or grades depend upon the extent to which the agents were in operation during the processes. According to the temperature, pressure, condition, there are usually three grades of metamorphism and accordingly there are three zones also. First zone is the epizone.

It is the zone of low-grade metamorphism where temperature ranges from 100 ºC to 300°C. Pressure is low to moderate. It is characterized by the presence of hydrous minerals like sericite, muscovite, chloride, biotite, talc, actinolite, epidote, andalusite, etc. Important rocks in this category are slates, phyllites, chlorite-schists, muscovite-schists, biotite schists, etc. Second zone is the mesozone. This is the zone of medium grade metamorphism, where the temperature ranges from 300ºC to 500ºC. Pressure is moderately high.

It occurs at an intermediate depth that is between 5 to 10 miles. Important minerals are remaining present in this zone rocks are cordierite, quartz, hypersthene, almandine, orthoclase, ilmenite, etc. And the important metamorphic rocks are phyllites and mica-schists. Next is the Katazone. It is a zone of high-grade metamorphism where the temperature ranges from 500ºC to 650ºC, pressure is high. It occurs at a depth of 9 to 13 miles.

It is characterized by anhydrous and anti-stress minerals. Important minerals are alkali feldspar, plagioclase, quartz, garnet, sillimanite, kyanite, etc. And the important metamorphic rocks are gneisses of various types, hornfels, etc. So, these are about the grades of metamorphism. Now structure of metamorphic rocks.

Five major types of metamorphic rocks have been recognized. First is the cataclastic structure, second is the maculose structure, third is the schistose structure, fourth is the granulose structure and fifth is the gneissose structure. Now one by one we will discuss the different types of metamorphic structures. Cataclastic structure, it is produced under stress and in absence of high temperature, whereby rocks are subjected to shearing and fragmentation. Only the durable mineral partly survive the crushing force and the less durable ones are powdered.

Second type of structure is maculose structure. It is produced by thermal metamorphism of argillaceous rocks like shales. Here, larger crystals of andulosite, cordierite, and biotite are sometimes well-developed, giving a spotted appearance to the rocks. The well-developed crystals porphyroblasts with increasing degree in metamorphism, the spotted slates pass into extremely fine-grained granular rock known as hornfels. Next type of structure is schistose.

Here the platy or flaky minerals like the micas and other inequidimensional minerals show a preferred orientation along the parallel planes under the effect of stress dominating during metamorphism. The longer durations are parallel to the direction of maximum stress. Schistosity is the property or tendency of foliated rock whereby it can be readily split along foliation plane. Next type of structure is the granulose structure. This is found in the rocks composed of equidimensional minerals like quartz, feldspar, and pyroxenes.

They are formed by recrystallization of pre-existing rocks under uniform pressure and great heat. The typical texture is coarsely granoblastic. The structures also known as sacchroidal. Quartzites and marbles are typical examples of this structure. Fifth structure is the gneissose structure, it is banded structure due to alteration of schistose, dark colored and granulose light colored bands and is produced by highest grade of metamorphism typically by regional metamorphism. So these are about the structures of the metamorphic rocks. Now mineralogical composition of metamorphic rocks, In it, we are getting stress and anti-stress minerals.

Stress minerals are produced as a result of stress and have a stable existence only under stress conditions. Kyanite, garnet, chloritoid, staurolite, epidote, zoisite, glaucophane, anthophyllite, etc. are the common stress minerals. The anti-stress minerals are those which are formed conveniently under the uniform pressure. These minerals are incapable of withstanding high shearing stresses. Such minerals, therefore, do not occur in highly deformed rocks. They may include sillimanite, cordierite, anorthite, felspathoids, andalusites, alkali feldspars, etc.

Now anti-stress minerals are of low density while stress minerals generally are denser. So these are about the stress and anti-stress minerals which are remaining present in the metamorphic rocks. The following are the typical metamorphic rocks. Following are the typical metamorphic minerals. Aluminosilicates like andalusite, kyanite, sillimanite, staurolite, cordierite, epidote, tourmaline, talc, chlorite, zeolites, graphite, pyrite and pyrrohtite, etc, are the common typical metamorphic minerals.

Now, metamorphic classification. If the parent rocks are of igneous origin, subjected to metamorphic changes, then the resultant rock is called as orthometamorphic rock or meta-igneous rock. And examples are orthogneiss, meta-basalt, eclogite, etc. But if the parent rocks are of sedimentary origin subjected to metamorphic changes, then the resultant rock, para-metamorphic rock or meta-sedimentary rock. Examples are slate, phyllite, marble, quartzite, etc.

Now we will discuss some common metamorphic rocks. Common metamorphic rocks are slate, schist, gneiss, quartzite, marble and phyllite. So one by one we will discuss this thing. First is the slate. Slate is a fine grained metamorphic rock.

It is fine grained characterized by a perfect cleavage that is a tendency to split easily yielding smooth surface. This slaty cleavage is due to the parallel arrangement of platy or flaky minerals, arrangement will be parallel of platy or flaky minerals, under the influence of metamorphism. The composition of slate, mineralogically, slate is composed of very fine grains of micas, chlorite, quartz, feldspars, oxides of iron, and many other minerals, all of which cannot be identified even under the microscope because of their extreme fine nature. Origin of Slate, Slate is the product of low-grade regional metamorphism on argillaceous rocks like shale. When slate is subjected to further action of dynamo thermal metamorphism, recrystallization may lead to the development in number and size of micas.

Such metamorphic rocks with conspicuous mica layers and slaty appearance are generally termed as phyllites, which on further metamorphism changes into megascopically crystalline schists. Now Use of Slate, Slate is locally used where available as a roofing material. You can see in the diagram also, slate is used as roofing material. It cannot be used as building stone or road stone because of its low crushing strength and slaty cleavage. Next type of metamorphic rock is the schist.

Schists are megascopically crystalline metamorphic rocks characterized by a schistose structure. The constituent flaky and platy minerals are mostly arranged in irregularly parallel layer or bands. Composition of schists. Platy and rod-like minerals, that is acicular minerals, form the bulk of most of the schists. Among these, micas, muscovite, biotite and a fine-grained variety, sericite, chloride, talc, hornblende, tremolite, actinolite and kyanite are very common; quartz and feldspars are comparatively rare but not absent.

Porphyroblasts of Sterolite, Garnet, Andalusite etc. are also present in some schists. Now varieties of schists. Specific names are generally given to the schists on the basis of predominance of any particular mineral or minerals. Some common types of schists are muscovite schists, biotite schists, sericite schists, tourmaline schists, etc. Sometimes schists are grouped into two divisions on the basis of degree of metamorphism as indicated by their mineralogical composition.

First is the low-grade schists formed under conditions of regional metamorphism at low temperatures. These are rich in minerals like albite, muscovite, chlorite, which are unstable at high temperatures. Examples are mica-schists, chlorite-schists, and talc-schists. Now, high-grade schists, high-grade schists are formed at high temperatures under conditions of regional metamorphism. In comparison to low grade schists, these are rich in minerals that are easily stable under conditions of high temperatures.

Example, andulosite, cordierite, garnet, staurolite and sillimanite etc. Example of high grade schists are cordierite-schists, garnet-schists etc. These are some of the good examples of high grade schists. Now texture and structure of schists. Schists show quite a wide variation in textures and structures.

Most varieties are typically schistose, whereas others may be lineated or may show porphyroblastic fabric. Origin of schists, schists are generally the product of dynamo-thermal metamorphism of argillaceous rocks like shales. Some types like clorite-schists, talc-schists may be formed from basic and ultra-basic igneous rocks, respectively. Usage of schists. Schists are inherently weak rocks and normally they cannot be put to any engineering use.

Next is the gneiss. It is also one of the important metamorphic rocks. A gneiss is a megascopically crystalline metamorphic rock characterized by segregation of constituent minerals into layers or bands of contrasting color, texture and composition. A typical gneiss will show bands of mica and other flaky minerals alternating with layers of equidimensional minerals like feldspar and quartz etc. Composition of gneiss, gneisses are generally rich in minerals of the parent rocks.

Feldspar and quartz are more common than in schists and this forms an important distinguishing character of these two rock types. Dark minerals of amphipole and pyroxene groups are also common as are the typical metamorphic minerals like staurolite, sillimanite, garnet, kyanite, epidote etc. Now the structure of gneiss, gneiss may show a variety of structures and textures but the most common is the gneissose structure. The augen-gneiss shows cataclastic structures. Variety of gneisses.

Specific names of gneisses are generally based on the mode of origin and structure rather than on mineralogical composition. Important types are orthogneisses-formed as a result of metamorphism of granites and other igneous rocks. Paragneisses which are formed from the sedimentary rock. Banded gneisses, in which the tabular and flaky minerals are segregated in very conspicuous bands. Augen gneisses, a gneissose rock formed as a result of dynamic metamorphism of granites and characterized by cataclastic structure.

The stronger minerals are elongated in lense-like forms. So these are about the gneisses. Origin of gneisses, origins are generally the products of advanced stages of regional metamorphism of a variety of parent rocks, chiefly among which are the sandstones, conglomerates, granitic rocks, etc. Presently, it is broadly agreed that gneisses may be divided into two categories, paragneisses and orthogneisses, signifying their undoubted origin from sedimentary and igneous parent rocks, respectively. Usage of gneisses when sufficiently strong may be used as road stones or for common buildings.

Now next type of metamorphic rock is quartzite. Quartzites are fine-grained metamorphic rock composed chiefly of grains of quartz. The name orthoquartzite is used for a sedimentary rock of similar composition with siliceous cement. Metamorphic quartzite is a granular rock characterized by a tendency of fracturing through the grains under the heavy loads. Now composition of quartzite.

Besides quartz, the rock generally contains subordinate amount of micas, feldspar, garnet and some amphiboles which result from the impurities of the original sandstone during metamorphism. Origin of quartzite, quartzite results from the recrystallization of the sandstone under the influence of contact and dynamic metamorphism. Usage of quartzite, it is used to cover walls as roofing tiles, as flooring and stair steps. Next important type of metamorphic rock is marble. Marble is essentially a metamorphic rock composed chiefly of recrystallized calcite.

It is characterized by a granulose structure, but the grain size shows extreme variations from finely sacharoidal to highly coarse grain. They may often show banded structure. Coarse types may exhibit a variety of structures. Composition. The rock is composed mostly of calcite,

Small amounts of olivine, serpentine, garnet and some amphiboles may also be present in many of the marbles. These minerals are formed from the impurities in the original limestones. Various colors of the marbles are also explained by the presence of impurities in the parent rock. Varieties of Marble. Various types of marbles are distinguished on the basis of color, composition or structure of the rock.

A few types are pink marble, dolomitic marble and schistose marble. Origins Marbles may result from recrystallization of limestones or dolomites under the influence of contact and regional metamorphism. Usage of marble, the rock is used extensively as building stones especially for the decoration purpose. It occurs in a variety of colors and gets very brilliant polish. Next important type of metamorphic rock is Phyllite.

It is mostly a fine grained metamorphic rock and represents an intermediate stage in the metamorphism of slate to schist. The individual minerals are not recognized by unaided eye, but presence of muscovite is easily indicated by the shining cleavage surface. The rock shows a foliated structure. Composition of Phyllite, it consists chiefly of chlorine, muscovite, and quartz grains, all of which are fine in state. Origin, as mentioned above, phyllites are formed as a result of dynamothermal metamorphism of argillaceous rocks like shales.

Here also you can see the foliated metamorphic rocks are there. Shale to gneiss, increasing metamorphism is there. Now, engineering importance of the metamorphic rocks. Gneiss, schists and quartzites are widely used in construction due to their high compressive strength and resistance to the weathering. Metamorphic rocks like gneisses are generally strong compact and relatively impervious making them reliable as foundation materials for dams bridges and other heavy structures. Slate, due to its fine-grained and fissile nature, is extensively used for roofing tiles, paving stones, and wall claddings.

Marble, due to its aesthetic appeal, is used in monumental architecture and interior decoration. Metamorphic rocks can also serve as hosts for valuable mineral deposits such as garnet, graphite, mica, which are of industrial significance. Just summarizing the chapter, we have discussed the metamorphic rocks. So first, we have discussed that metamorphic rocks are formed by the alteration of the existing rocks by the action of temperature, pressure, aided by subterranean fluids. Some of the examples of metamorphic rocks are slate, marble, schist, gneiss, quartzite, etc.

Secondly, we have discussed about the classification of metamorphic rocks in which we have seen that orthometamorphic rock or metaigneous rock are the parent rocks are of igneous origin. Example is ortho-gneiss, meta-basalt, eclogite etc. Para metamorphic rocks are metasedimentary rock. The parent rocks will remain of sedimentary origin. Examples are Slate, Phyllite, Marble, quartzite, etc.

Third is the structure of metamorphic rocks. Five major types of metamorphic structures have been recognized as cataclastic structure, maculose structure, schistose structure, granulose structure, and gneissose structure. Lastly, we have discussed about the common metamorphic rocks that is slate, schist, gneiss, quartzite, marble, phyllite. Now, conclusion of the module, we will discuss. In the module 5, we have discussed about the rocks.

Rocks are the fundamental building blocks of the earth crust, classified into three primary types, that is igneous, sedimentary and metamorphic. Each type forms through distinct geological processes that shape the earth's structure and surface. We have also discussed magma. Magma, a molten mixture of minerals, gases and volatiles, plays a crucial role in the formation of igneous rocks. Next we have discussed the sedimentary rocks.

Sedimentary rocks are formed through weathering, erosion, deposition and lithification of the sediments. They serve as vital records of earth past environments and often contain fossils offering insights into ancient ecosystems. Metamorphic rocks are products of pre-existing rocks exposed to high temperatures, pressures and chemical processes. The formation and transformation of rocks are interconnected through the rock cycle. These dynamic processes illustrate Earth's continuous evolution, highlighting the interaction between internal and surface forces shaping the planet.

Now the references. I have taken the references for preparation of the module five from these books. Thank you very much to all.