Availability and Management of Groundwater Resources

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Lecture - 06
Geological Formation as Aquifer

Welcome you all in the second lecture of the subject availability and management of groundwater resources. The second part of the subject is based on the geological formation that is an aquifer. So, in the first lecture we have already discussed about the hydrological cycle, the water cycle. Another name of hydrological cycle is the water cycle. In which we have seen that the precipitation is the only recharge source which generally replenish the underlying rock formation that is the aquifer.

So, in the first lecture also we have discussed about the water budget equation. We have seen that the important components of the hydrological cycle where the precipitation, evaporation transpiration, runoff and subsurface runoff that is groundwater runoff. So, in this way in the first lecture we have just formed the concept that the precipitated water that is the rain water generally comes near to the surface infiltrates inside the earth's surface percolates within or among the different layers of the soil layers.

And then it reaches to the rock formations which are having the capacity to hold the water. So, those water is generally called as the groundwater. So, in the very first lecture we have seen this detailed about the different activities because of the hydrological cycle. Now in this lecture in the second lecture we will learn just; what are the different rocks which are responsible for holding the groundwater.

So, in this lecture briefly we will go through it step by step the different information's which are very much important for knowing the understanding of the groundwater reservoir inside the earth's surface.

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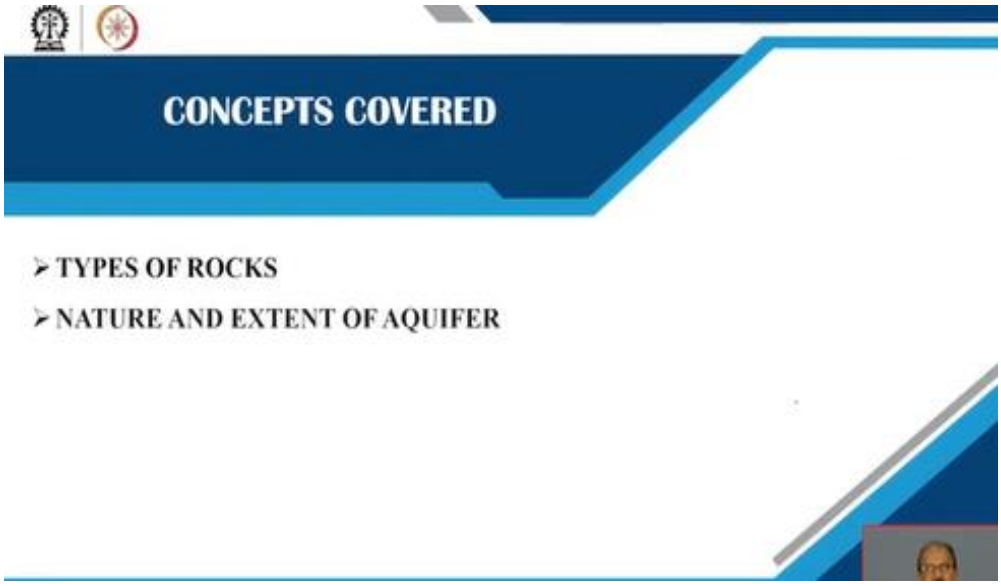

So, we will start the lecture with the two important concepts. The first concept is the rocks the types of the rocks and second concept is the nature and extent of aquifer. So, these two are the first part of the lecture will comprise of types of the rocks and the nature and state of aquifer.

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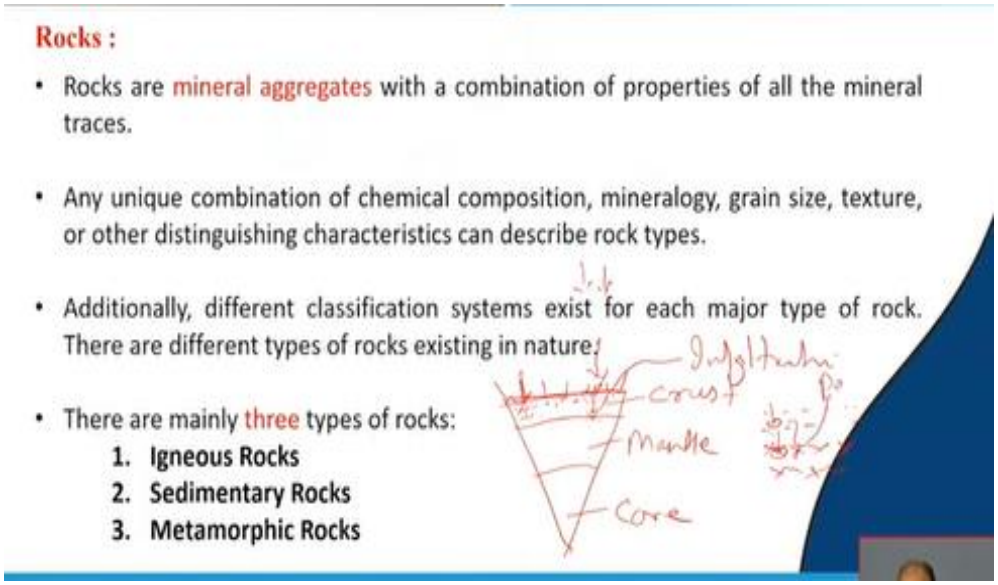

So, generally what we are seeing the earth's interior are made up of different types of rocks. We already know that inside the earth surface suppose this is the layer of the earth surface so inside just below it we get a layer which is called as crust. This is crust so this layer is composed of different variety of rocks we will see. And then the next inside layer is termed as mantle, this is mantle and below it is the core.

So, this we know already that earth interior comprises of three important layer crust, mantle and core. So, this crust this is just inside the layer we are getting different types of the different textures of the soil layer also. So, just inside the earth surface we get the soil layers. So, these soil layers again since we are moving coming down. So, the different layers of the soil is having the different textural characteristics, different types of the shapes so different physical chemical characters also.

So, this soil layers will allow the water to move inside the earth's surface because of the gravity. So, here we were getting the infiltration here just the rain water was falling down. So, it reaches to the surface then it tries to go inside the earth surface in the form of infiltration. So, this we were knowing from the first lecture that the term is infiltration if the rain water is coming just inside the first top layer of the soil.

So, this is infiltration. So, now we are having the different layer of the soil also inside the earth's surface. So, this water which infiltrated from the top to first layer of the soil will then move down because it tries to reach to the rock which has having the capacity to hold the water. So, this terminology here will change. It will not be infiltration it will be percolation. So, what we are seeing that infiltrated and percolated water is after all reaching to the reservoir rock that is the rock which is having the ability to store the water.

Which is called as generally aquifer. So, rain water converted into the infiltrated water infiltrated water to percolated water and then percolated water to ground water that is in the reservoir rock that is an aquifer but these all are made up of rocks. So, rocks are nothing but these are the mineral aggregates with that combination of properties of all the mineral traces. Rocks are the combination of different types of minerals.

And any unique combination of chemical composition mineralogy, grain size, texture or other distinguishing character can describe the different type of rock types also because the different rock will have the different types of minerals. And on this basis the different types of the rocks we are getting inside the surface. But primarily we are getting three important types of rocks. And the rocks names are igneous, sedimentary and metamorphic.

So, this earlier in the first lecture we have just developed the concept that the precipitation, infiltration, percolation, evapotranspiration these are some of the components of the hydrological cycle which plays very important role in the formation of the ground water. Now in the second part of the lecture of the subject we will know which type of rocks are mainly responsible for remaining as an aquifer or responsible for holding the water that is especially the groundwater inside the earth surface.

This concept we will develop in this lecture. So, now we have known that three important types of rocks are present inside the surface that is the igneous, sedimentary and metamorphic rocks.

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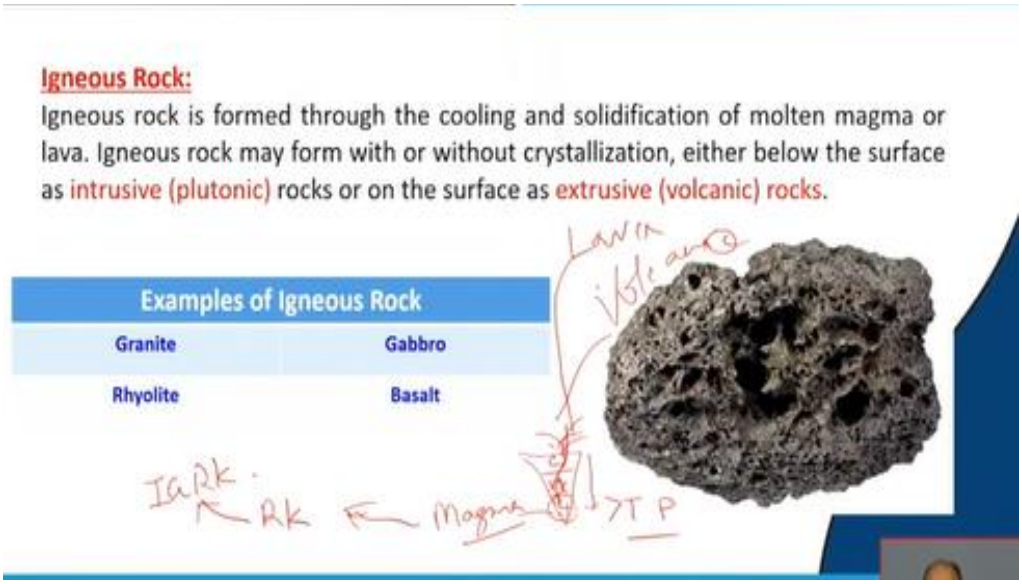

Now one by one we will discuss in very brief because we have to know about the types of the rocks which are very suitable for an aquifer. So, igneous rock the first rock is generally formed through the cooling and solidification of molten magma. So, what is happening? The igneous rock since I have just told you that the earth interior is made up of three important components the crust, mantle and core.

So, generally as we move down towards the earth, that increase in temperature and pressure are there. So, because of the high temperature the rocks at this place will remain in molten state which is called as magma. So, magma is nothing but this is just the molten rocks material inside

the core as well as the lower mantle. So, this is called as magma but when this magma will consolidate then it is forming a rock and this rock is known as the igneous rock.

So, when the molten magma why remaining molten? Because of the high temperature and pressure. So, because of the high temperature and pressure at this stage the rocks remain in molten condition. But because of the change in the temperature and pressure condition it tries to form a rock. So, this rock which is being made by the magma is known as the igneous rock. It is termed as igneous rock. But what is happening?

This molten magma sometimes because of some weaker strength of the upper rocks it tends to move up the molten magma because of certain change in the temperature and pressure conditions it tries to move up. And all on a sudden it ejects from the earth's surface which generally is known as volcano. And the volcanic molten material is termed as not magma but it is termed as lava. The process is termed as volcano and the liquid material.

Here also the liquid material was there but it was inside the surface. So, it is called as magma but this magma if by certain means or by certain condition will move near to the surface and then erupts suddenly then it is termed as lava and the process is termed as volcanism. So, what is happening? In the volcanism process also, we are knowing that some of the molten magma material is coming out. But that is not molten magma that is termed as lava.

So, both magma and lava will try to consolidate because of the change in the temperature and pressure condition in the form of rocks. When the magma is forming rocks, it is known as intrusive or plutonic igneous rock. Since magma is consolidating which is remaining inside, so when it is forming a rock it is known as intrusive or plutonic rock. But when the lava which is similar to magma but only difference is it is just above the surface because of the volcanic eruption.

So, the lava will consolidate it will form the extrusive igneous rock which is known as volcanic rocks. So, in one place in the case of magma we are getting the plutonic rock. Since it is forming inside the earth whereas in other place, we are getting the volcanic rock which is forming just

above the surface of the earth. But both are having the same chemical compositions having the different, different types of the minerals inside it.

It is not necessary that plutonic rock and volcanic rocks will have the same types of the minerals never because both have consolidated at different conditions. So, this is basically termed as igneous rock. Now first we will know about the rock then we will see whether it is capable of storing the groundwater or not. So, first part we are just discussing some of the main examples of the igneous rocks are granite, rhyolite, gabbro, basalt.

So, these are some of the important types of the igneous rock. But we have understood already when the molten magma will consolidate to form a rock this type of rock is known as igneous rock. When it is forming because of the consolidation of the magma it is called as intrusive or plutonic rocks. When the igneous rock is forming because of the lava eruptions then it is called as the extrusive of volcanic rocks. So, this is about the igneous rock.

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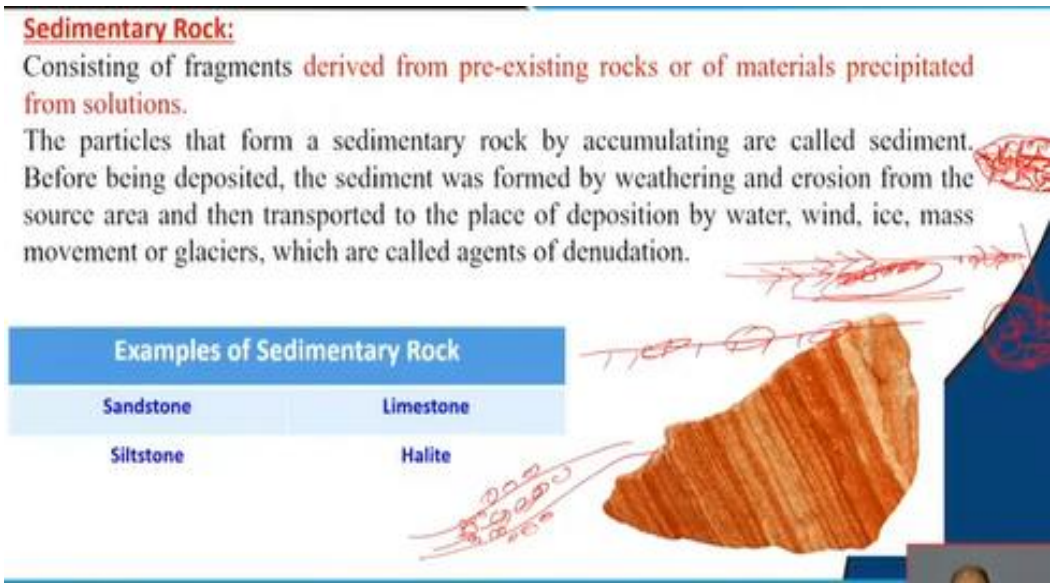

Now next is the sedimentary rocks because some rocks will hold the water some rocks will form an aquifer. So, first we should know what are the important types of rocks. However, there are several types of rocks but primarily we are having three important types of rocks in near sedimentary and metamorphic which we are discussing just now. So, second type is the

sedimentary rocks, which is consisting of fragments derived from the pre-existing rocks or material precipitated from some solutions.

So, it is forming a rock and the rock named is sedimentary rock because the particles that, form a sedimentary rock by accumulating small pieces which is called as sediment. So, here what we are noticing suppose this is the earth's surface. So, on the earth surface we are having some rocks inside the earth also it is remaining. So, when this rock this is pre-existing rock will just decompose small, small pieces, this rock will decompose small soft pieces.

And because of some natural agents see it is also very important because some natural suppose wind is blowing just. So, it will try to loosen the upper part which generally we are telling it as a weathering. In the science meaning it is weathering. So, just decomposition of the top part of any exposed rock. See this is the exposed rock, this is the top part. The top part has just decomposed thus disintegrated by means of some geological agents which is called as wind, river, glacier.

These are the geological agents. We are getting sand on the bank of the river only not near to the road, why? Because every river is having some rocks inside which is known as bedrock. And then at the top we are seeing the water. So, what is happening? Because of the current of the river water the bedrock the top portion of the bedrock is disintegrated just breaking down small-small pieces.

And these small-small pieces are nothing just they will accumulate near to the bank of the river which is called as sand. So, we are getting sand near to the bank of the river not near to the side of the road. The small pieces of the sand what we are getting is just known as dust which we are getting just at the side of the road. There we are getting dust here we are getting sand, why? Because of some natural agents, what are the natural agents? Wind, river, glaciers.

So, these are the natural agents which is generally just decomposition just making the top superficial part weaker. And then it disintegrates there by the action of the wind or the river, water or by glacier melt. Here it is just the broken material lying it is termed as weathering. But

if it moves to a certain distance and then by any means say either getting a tall building or getting a tall tree or by cessation of its own velocity own velocity has decreased.

Then this small particle which has just removed from the top of this rock will try to settle at some place. And when this sediment will just compact and make a rock then such type of rock is known as sedimentary rocks. So, this is the basic difference from the igneous rock. Whereas in igneous rock we have seen that the igneous rocks were forming by the consolation of either molten magma or by molten lava.

But here what we are seeing that the sedimentary rocks are forming by some sort of weathering and erosion phenomena. What is weathering? Just the; loosening of the top portion of the exposed rock on the earth's surface by some natural agents. What are the natural agents? The water, wind, glaciers etcetera. So, these natural agents generally decomposing the top part; then after disintegration of small, small particle known as sediment.

By the action of the natural agents, it will move to a certain direction then it will try to settle at some place. And at some place if it is settling then by compaction if it is forming a rock such type of rocks are known as sedimentary rocks. So, sedimentary rocks in total are very good aquifer and it is a good rock because it is having the pore spaces in between. This is the very good point with the sedimentary rocks.

Why pore spaces? Because suppose the first disintegrated layer deposited here second disintegrated layer will try and settle here. Third will try and settle here so fourth will try and settle here. So, what we are seeing that in between we are getting the space. In between the grains because these are the sediments, we are having the space. And these spaces are nothing but these are the pore space.

So, within this pore space the groundwater will remain in a greater quantity. So, in sedimentary rocks we are getting very good amount of groundwater also. The important type of sedimentary rocks are sandstone, limestone, silt stone, halite. Some of the important sedimentary rocks which

generally we are getting in the sedimentary rock. So, the two types of rocks we have seen first the igneous second the sedimentary.

In the sedimentary we have seen that it is having good number of pore spaces. Why good number of pore spaces? Because the sediments are depositing at certain place one by one so not all on a sudden. In the case of igneous rock, we have seen that the molten magma has suddenly consolidated. So, in igneous rock we are not having any pore spaces. But in sedimentary rock we are having the pore spaces.

So, if there will be pore spaces definitely it will have the minerals it will have the water bodies etcetera. So, sedimentary rocks are a very good form of aquifer also. Now third is the metamorphic rock.

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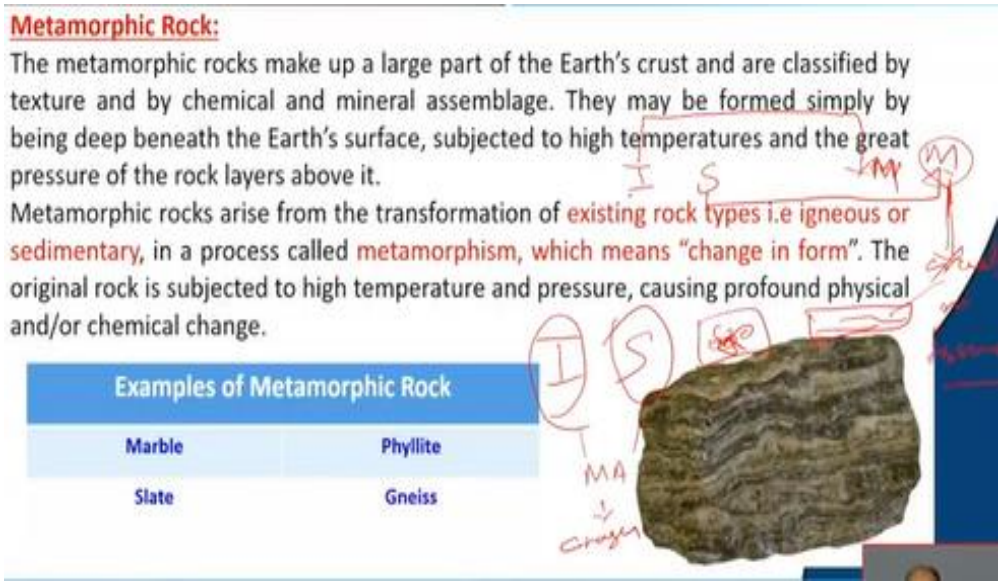

So, in this case what we have seen metamorphic rock? Metamorphic rocks make up of a large part of earth crust. We will see the total earth crust metamorphic rocks are remaining in dominance and are classified by texture and by chemical and mineral assemblages. So, we have seen in the case of igneous and sedimentary that the formation was something because of its natural consolidation of the one place the molten magma or lava.

Other place the types of the sediments which have disintegrated because of the certain natural agents. Here what is happening? Their metamorphic rocks are forming by means of the change in the high temperature and pressure inside the surface because of the change of the high temperature and pressure. The pre-existing rocks we are having now two pre-existing rock, first is the igneous rock second is the sedimentary rock.

So, we are having only two pre-existing rocks. So, every rock igneous and sedimentary rocks will have certain set of mineral assemblages. So, certain mineral assemblages will be there. Now because of the change of the high temperature and pressure these are called as metamorphic agent. So, these are agent high temperature, high pressure some chemically active fluids etcetera. If they are just changing the set of the mineral assemblages.

Then that type of rocks which are forming because of the transformation of the existing rock types. Existing rock types is the igneous rock or sedimentary rock. Then this process is termed as metamorphism. Metamorphism means just the change in form and the rock which is forming because of the high temperature and pressure is called as the metamorphic rock. So, generally these rocks are also having some spaces in it.

But it is near to your igneous rock very less spaces within it. Yes, in this rock we are not getting the pore spaces rather we are getting some sort of small cracks or fissures. So, here the groundwater may remain stored. But quantity wise we are getting much more groundwater in the sedimentary rocks compared to the metamorphic rocks. This is one point second point is also here.

If the pre-existing rock say we are having the two pre-existing rock one is the igneous rock other is the sedimentary rock. If the pre-existing rocks say igneous rock is transforming and making the metamorphic rock then this will have the similar characteristics just like the igneous rock. Means igneous rock is a very compact rock so no pore spaces within it nothing in it. It is not a repository of the groundwater even minerals also.

But if the pre-existing rock is the sedimentary rock so it will also form one metamorphic rock. But here in this very metamorphic rock it will have certain characteristics of sedimentary rocks.

And those characteristics are what I have discussed the cracks and fissures which we are getting. So, in the hard rock areas generally metamorphic rocks remains. We are also getting the groundwater. But the groundwater is remaining at a greater depth in some cracks and fissures.

But where we are having the abundance of the sedimentary rock formation there, we are getting good amount of groundwater in the area. So, that is why we are discussing about the different types of rocks also here because the subject name is availability and management of groundwater resources. So, first we should consider what are the concepts? What are the basics? Which are very important for the subject availability and management of groundwater resources.

First where the groundwater will remain available? We have seen the hydrological cycle phenomenon that is the only responsible source for the recharging of the surface. It is all right but in this type of rocks that is also very important this type of formation that is also very important. So, that is why we have discussed just now that three important types of rocks igneous, sedimentary and metamorphic rocks.

Metamorphic rocks and igneous rocks are having small space in which metamorphic rocks are having very small cracks like fissures in which the groundwater remains. Whereas in sedimentary rocks the large number of pore spaces remains in which the groundwater remains. So, these two types of rocks one the sedimentary rocks and second the metamorphic rock whose parent is of sedimentary origin.

So, if the any sedimentary rocks will metamorphose it will also convert a metamorphic rock. And in this metamorphic rock we may have the chances of getting cracks and fissures or we may have the chances for getting groundwater. So, this is the concept. Some of the important examples of metamorphic rocks are marble, phyllite, slate, Gneiss etcetera. So, these are some of the important examples of metamorphic rock.

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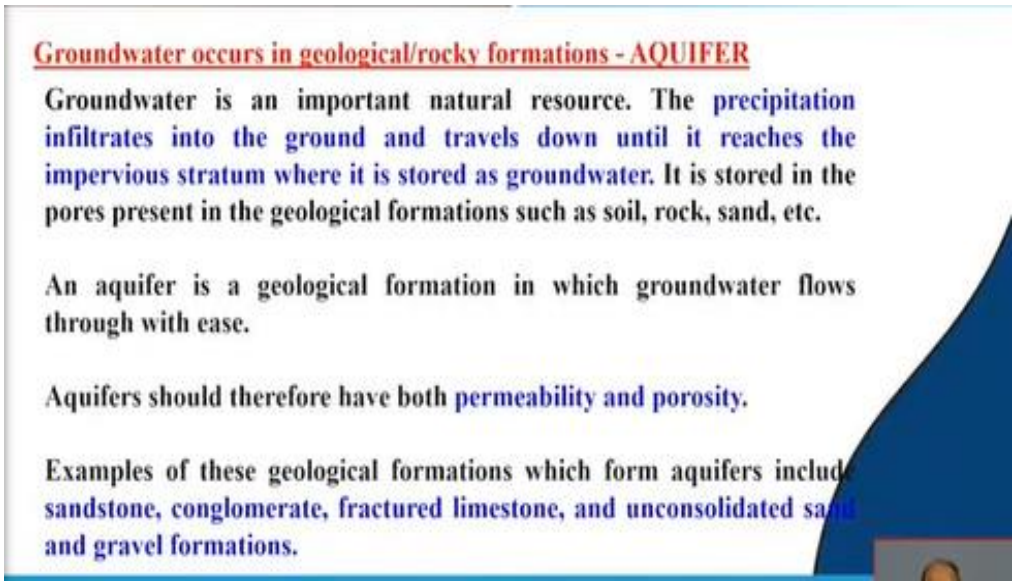

So, now this we have seen. Now just groundwater occurs in this type of rocky formation which is termed as aquifer. So, this groundwater what we are discussing will remain in some rocky formation and it is generally called as an aquifer. So, we know that it is very important natural resource. The precipitation infiltrates into the ground. This we have seen in the first lecture also infiltrates first into the ground.

Then percolates and then travels down until it reaches the impervious stratum where it is stored as groundwater. Impervious stratum is very important because if it will be pervious stratum so what will happen? Again, it will move down. So, it will not hold the water. The formation will not hold the water. So, this rain water is coming down and it is storing in the pores present in the geological formations such as soil, rock etcetera.

So, when it is getting the suitable types of rocks or soil layer then this precipitated, infiltrated, percolated water will rest here and it will remain stored there and this type of the rocky formation which is holding the ground water is known as an aquifer. So, in an aquifer which is a geological formation the groundwater flow will become ease. So, inside also what we have seen also at some places the groundwater is in good amount.

At different places groundwater is not in good amount so what is the reason? Because inside the earth's surface also we; are having the different aquifer, aquifer 1, aquifer 2, aquifer 3. So, if the

storage capacity of the aquifers will remain good or the aquifer means the rock these all are rocks or nothing else. If this rocky formation will store good amount of water, then the area is flooded with groundwater.

Or in second wave we can understand it that if the availability to transmit the water this is also very important for an aquifer. If the aquifer is not having availability to transmit the water it means what? It will store the water. Storage of water is not important because suppose you just have seen perhaps also a well which is having good amount of water. But when you are extracting the water again it is not coming to its actual point where it was.

This point is termed as water table. So, if it is not reaching to the actual depth of the water table then this well is not good enough although it is having the good capacity to store the water. So, capacity to store the water is very important for any rocky formation or for any aquifer. But the aquifer should have also the ability to transmit the water from one aquifer to another aquifer. Otherwise, the aquifer is not good. It may store the water.

Clay, we have heard the name clay which is a very good repository of water. But whenever we people are getting clay in the soil layer generally, they are avoiding for digging a well. Why it is having a good capacity to store the water that is good. But the well will require further water after extraction. So, from where it will come? Because it is having no ability to either receive or to transmit the water inside the aquifers.

So, that is why any aquifer any rocky formation should have two important properties. First the having the good number of pore spaces which are termed as porosity and second the availability to transmit the water that is permeability. Then only any aquifer will be a very good aquifer. And if there will be very good aquifer definitely there will be no shortage of groundwater. So, this is a very important characteristic of any rock formations.

Because those rock formations will only hold the water which is having a very good porosity and the good permeability. We will discuss the terms later on in the different parts of the lectures. But here we should at least understand that we have seen the different types of rocks are

remaining inside the surface. We have also seen all the rocks are not responsible for holding the water.

Few rocks are very important say sedimentary rocks or metamorphic rocks which have been derived from the sedimentary rocks. These rocks are generally holding the water inside the surface. Inside the earth's surface formation which is holding the water is termed as aquifer. And this aquifer is also, having two important characteristics first the permeability and second the porosity. Porosity means having the good number of pore spaces to hold the water groundwater.

And permeability means having the ability to receive the water or to transmit the water from one aquifer to another aquifer inside the earth's surface also. So, this is generally very important terminology for aquifer. Some of the good geological formations which are a very good aquifer are sandstone, conglomerate, then fractured limestone, then unconsolidated sandstone and gravels. So, these are very good geological formation which is holding the groundwater.

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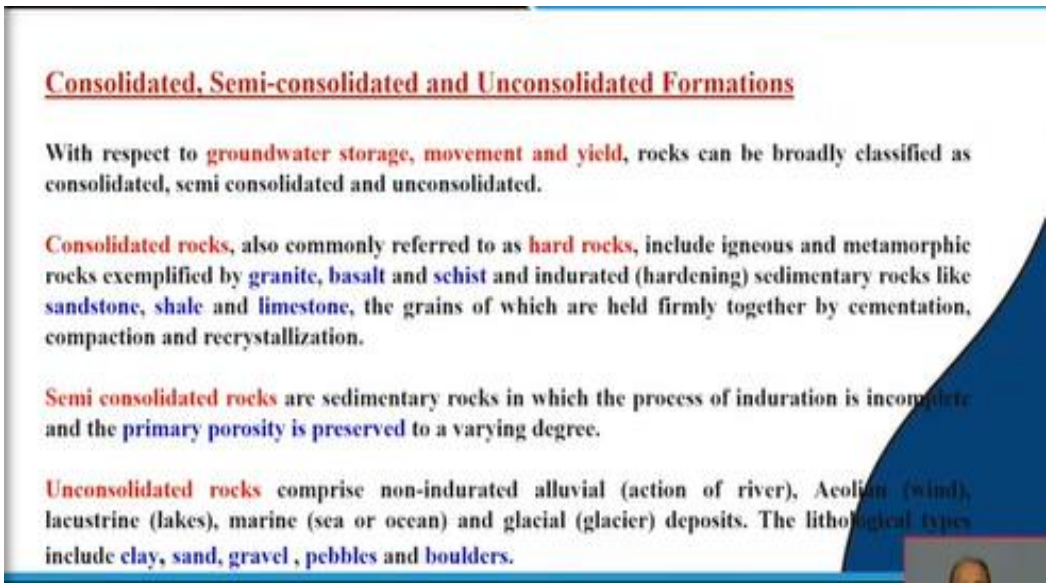

Now these consolidated, semi consolidated, unconsolidated formations these are generally responsible for holding the water. So, this is on the basis of groundwater storage how much having the capacity to store the groundwater, its movement and yield. Basically, these important factors groundwater storage, movement and yield generally classify the different types of geological formation in terms of consolidated, semi consolidated and unconsolidated.

So, consolidated rocks generally called as hard rocks and I have told you just now that igneous and metamorphic rocks are generally consolidated hard rocks. Example also granite, basalts these are the examples. And this hardening is because of some of the chemical and physical factors which are responsible for making the rocks. We have seen in the case of igneous rock, molten magma were just consolidated by the change of the temperature and pressure.

So, this granite, basalt then schist the example of the igneous sedimentary rocks and some of the hard sedimentary rocks also like sandstone, shale, limestone so these are generally the consolidated rocks. The grains of which are held firmly together by process of cementation then compaction, recrystallization. So, these are generally termed as consolidated rocks. Semi consolidated rocks are sedimentary rocks in which the process of induration is incomplete.

If the process of induration will remain incomplete then what will happen? Primary procedure preserved to a certain degree. So, semi consolidated rocks generally sedimentary rocks here in the example of igneous and metamorphic is not coming is having the incomplete hardening inside it. So, the primary porosity means its own porosity will remain preserved to a certain degree. And unconsolidated rocks comprise of those alluvial, then Aeolian, lacustrine.

Aeolian means the deposits made by the wind. Then lacustrine the deposits made by the lakes. Then the deposits made by the sea or ocean marine. So, generally clay, sand, gravel, pebbles, boulders these are called as unconsolidated rocks. So, generally because of the factors of the groundwater storage, movement and yield three important types of classifications are there. Consolidated rocks, semi consolidated rocks and unconsolidated rocks.

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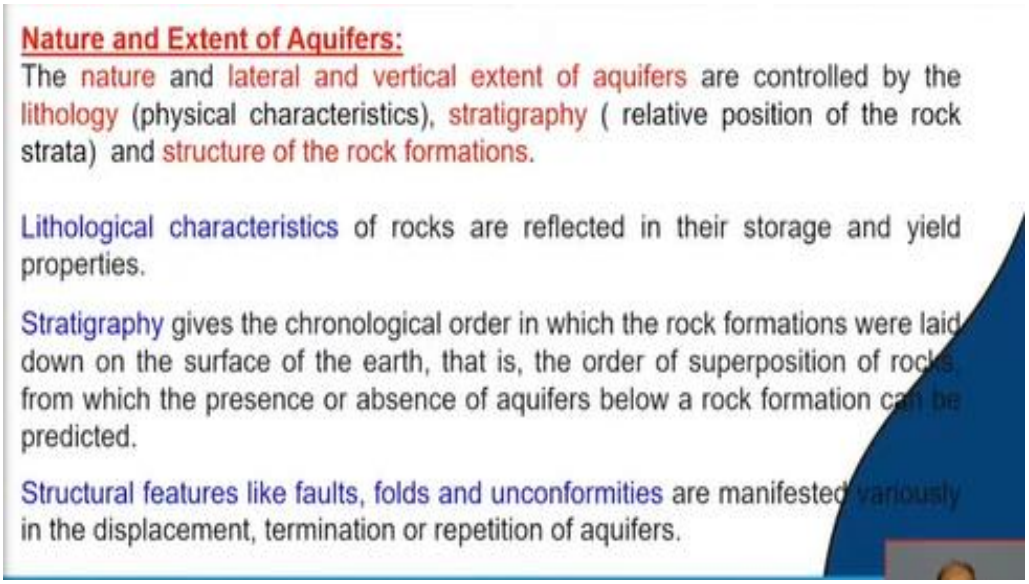

So, what we have seen that the rocks will form the aquifer and the aquifer will have nothing but these are the different types of rocks. And these rocks are remaining in different forms also consolidated, semi consolidated, unconsolidated. And these aquifers are having certain nature and extent of aquifer also. So, aquifer which is lying inside the surface will have certain extent also. So, what is happening?

That these nature and extent of aquifer because inside also we should know. What are the types of aquifer? What is the extent of aquifer? What is the depth or length of the aquifer inside the surface? So, generally the factors like lithology which is called as physical characteristic, stratigraphy which is called as the relative position of the rock strata and structure of the rock formations. So, inside the surface we have seen the rocks.

So, its physical characteristics, its relative position of the rock strata and the structure of the rock formation generally decides the nature and extent of the rock of the aquifer inside the surface. So, what we have seen that lithological characteristics of rocks are reflected in their storage and yield properties. If we have seen that in the case of sedimentary rocks, we are getting good amount of pores.

So, pores will remain in higher amount then definitely the more volume of water will store there. So, lithological characteristics generally decide about the storage and yield behaviour of any

aquifer. Second the stratigraphy which gives the chronological order in which the rock formations were laid down on the surface of the earth. It is also very important because order of superposition of the rocks from which the presence or absence of aquifers below a rock formation can be predicted.

So, if we are knowing that the different sets of rocks, assemblage as rock formations are going on then only because inside the earth, we are having the different layers of the rock. So, all the rocks will not have the ability to store the water or to transmit the water. So, they may not become an aquifer. So, which rock is a very good aquifer they can be decided if we are having the idea of the stratigraphy?

The types of the rock formation which are laying just inside the surface. And third which is a very important type structure of the rock formation. Some of the structural features like faults, folds and unconformities these are nothing but just the structural component of earth's rock inside it. So, these are manifested in terms of displacement, termination or repetition of aquifers. So, suppose see what it fold?

This is a rock which is subjected gentle pressure so it will just crumble in the form of this one. So, this is generally called as crest. And this is called as trough. So, if this trough will have good amount of groundwater if it is a rock sedimentary formation. So, if these are just the consideration how much will be the extent of an aquifer. So, this can be decided by some of the important characteristics.

The first characteristic is the lithology, second is the stratigraphy and third is the structure of the rocks. Whether the rocks is having some folded strata, faulted strata or some unconformity. So, in this way we can see about the different types of formations which will hold the water inside it. So, this was about the first part of the lecture about the geological formation as an aquifer. Thank you.