

# **ENVIRONMENTAL GEOSCIENCES**

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**Lecture-7**

## **Types of Weathering**

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. Today, I am going to start Module Two, which comprises types of weathering, erosion, transportation, and the geological work of wind, rivers, and glaciers. So today, within Module Two, I will start the first lecture, which is about the types of weathering. In this very first lecture on the types of weathering, the main concepts covered will be an introduction to weathering, factors affecting weathering, and types of weathering. As we have learned in Module One, there are three important types of rocks: igneous rock, metamorphic rock, and sedimentary rock, which is soft rock.

Metamorphic rock is just the metamorphosed rock that is generated from pre-existing rocks. So these three rocks generally break and undergo decay under the influence of atmospheric agencies like wind, sun, frost, water, and organisms. So this phenomenon is generally called weathering. The breaking or decaying of the rock material is generally termed as weathering because it is due to the influence of atmospheric agents like wind, river water, organisms, and glaciers. So weathering occurs where rocks and minerals are exposed to surface conditions. So including air, water, and biological activity, which are common at the Earth's surface, we are very much familiar that on the Earth's surface, suppose this is the Earth's surface on which some rocks are just lying, so these are the rocks. Because of the geological agents, we generally have the wind.

Wind is nothing but moving air called wind. So this is just decaying the top portion of this rock or breaking the top portion of this rock. So this phenomenon is generally called weathering. So this weathering process includes two processes mainly: disintegration, meaning first it is breaking, called disintegration, and second, sometimes it also decays, so decomposition. So disintegration is generally physical breaking, and decomposition is chemical decay. Now, this weathering process takes place in different ways. In-situ

process is generally where weathering affects rocks in place, and here the weathering is affecting the top portion of the rock.

This is just telling that the top portion which is exposed to the surface is just breaking, meaning the rock portions are not transporting to any places. They are simply broken down or altered where they originally formed. So it remains at the same place, but here it is just breaking or decaying. So this type is known as in situ process. Again, there is a definition: weathering versus erosion. So weathering helps to prepare rocks for erosion, but they are separate processes.

Weathering can occur without erosion, and erosion cannot happen without weathering. So this is very important. Weathering can take place without the help of erosion, but erosion cannot happen without weathering. So this is the general idea about weathering. Now, denudation is another word.

Denudation, that is the combined effect of weathering and erosion, is called denudation. So the combination of weathering and erosion processes is called denudation. It involves the general wearing down of the Earth's surface. You can see in the adjacent figure also, just the material has worn out. These processes result in the lowering, flattening, and removal of surface features such as mountains, valleys, and plateaus.

Now, what are the key components of denudation? Generally, weathering, erosion, and transportation are the key components. Weathering, the breakdown of rocks in place, as we have learned, physically or chemically. Erosion, the removal and transport of weathered material by agents like wind, water, or ice. And third, transportation, the movement of eroded material to a new location, as rivers carry sediment to the sea.

So that's why we get sand at the bank of the river because the weathered part, the broken part of the rock, is generally settled near the bank of the river. That's why we get sand at the bank of the river, not at the bank of the road. So weathering is simply the physical or chemical breaking down of the rock portion; then it is called weathering. But if the broken portions of the rock, because of weathering, are removed and transported to some other place and then settle at any location, then this is generally called erosion. And collectively, weathering and erosion are called denudation.

Denudation plays a crucial role in shaping the landscape and affects the geological features over long periods of time. The question is, what are the factors which affect

weathering? So, there are some factors. We will start with the first factor, which is the rock structure. The rock we have learned about is the hard part which remains in the crust.

Within the rocks, the minerals remain. So, the mineral composition of the rock determines its susceptibility to weathering. Softer minerals weather more, whereas harder minerals will weather less. So, this is one of the very important factors of weathering. Bedding planes, faults, and fractures.

Suppose this is the rock; there are certain joints within the rock. Bedding planes, just like the different types of succession of beds, are known as bedding planes. Faults and fractures we will learn about in later lectures. These are some of the weaker zones, which provide pathways for weathering agents to penetrate the rock within these weaker zones. Generally, the geological agents which remain in our atmosphere enter into these portions, penetrate the rock, and then speed up the weathering processes.

Again, next is the porosity and hardness. Rocks which have more pores or a weaker structure are more easily weathered than dense or hard rocks, which have fewer pores or no pores, will weather less. So, these are some of the factors related to the rock structure. In the rock, if the minerals are very soft, definitely the weathering will be more. In the rocks, if there are many more joints, bedding planes, faults, and fractures, definitely it will weather more.

And within the rocks, if you have more pore spaces, then it is definitely weaker, and more weathering will take place. So, this is related to the rock structure. Now, climate. Climate plays a significant role in weathering processes. It includes elements like temperature, moisture, humidity, precipitation, wind, and evaporation. So, temperature and moisture are key in determining whether physical or chemical weathering dominates. So, this is very important because wherever physical or chemical weathering is dominating, definitely the role of temperature and moisture is there.

A hot and wet climate tends to favor chemical weathering, while a cold or dry climate may lead to more physical weathering. So, whenever the climate is hot and wet, it favors chemical weathering. And when it is cold or dry, it favors physical weathering. So, this is about the climate. The next factor is related to the topography. Topography is nothing but the surficial features of the land. Whatever features we are getting on the land surface, say, this land surface, on the land surface we are getting basins, we are getting plateaus, we are getting hills. So, whatever features we are getting on the earth's surface, somewhere we are getting plain land. So, these are called topography. The shape and

slope of the land affect the weathering processes by influencing how rocks are exposed to weathering agents.

Steeper slopes may experience more erosion, while flatter areas might retain weathered material longer. Topography also influences precipitation levels and temperature variations, which can impact the type and speed of weathering. Now, after this, the next factor is the vegetation. Vegetation acts as a protective cover for the soil and rocks, reducing the impact of weathering processes. It helps shield rocks from direct exposure to the elements, especially in areas with heavy rainfall.

But bare spaces, the spaces which are without vegetation, are very much prone to weathering as they are directly exposed to wind, water, and temperature fluctuations. The roots of plants can also contribute to mechanical weathering by growing into cracks in rocks, further breaking them apart. Suppose this is a rock, and within the rock, some plants have grown, and these are the roots. So, after a later period, you can see that a crack has developed. Why has it developed? Because this crack has developed due to the roots within it, and these roots have initiated this process, and cracks have developed because of mechanical weathering.

So, these roots of the plants are also contributing to the mechanical weathering processes and ultimately cracking or breaking the rock surface. Next are the agents of weathering. What are the different agents of weathering? After understanding the factors affecting weathering, now what are the different agents which are essential for the weathering processes? The principal agents of transformation of rocks in the mantle of waste are river water, which is very prone to weathering the bedrock, oxygen, CO<sub>2</sub>, which are gases, acids remaining in the atmosphere, organic matter, organisms, and temperature.

These are some of the agents through which we observe the weathering processes. These agents affect both physical and chemical processes of weathering equally. Now, what are the types of weathering? There are three main types of weathering: physical weathering, chemical weathering, and biological weathering. So, one by one, we will understand these three types of weathering.

First, physical weathering. This process refers to the mechanical disintegration of rocks. So, if the rock is breaking mechanically, then this process is termed physical weathering. What is happening in this mechanical weathering? In this process, the mineralogical composition is not changing.

Only the rocks are disintegrating, but the minerals within the rocks are not changing. This happens mainly through mechanical forces like temperature changes, thermal expansion, and contraction. So, this is due to thermal expansion and contraction within the rocks, ultimately breaking the rock surface. Some important processes of physical weathering are exfoliation, crystal growth, freezing of water, and differential expansion. So, if a rock is breaking mechanically, this process is known as physical weathering. In this process, the minerals of the rocks are not changing; they remain as usual. Okay. Now, exfoliation, crystal growth, freezing of water, and differential expansion are some types of physical weathering. We will discuss them one by one.

Exfoliation occurs when rocks peel off in thin layers due to temperature changes. Some of the rocks you will see are just part of the Earth's surface, and these are the exposed rocks. Some of the rocks you will notice that the top surface of the rock has just peeled off in thin layers because of the temperature changes. During the day, rocks heat up. Here, you can see that during the day, rocks heat up and expand, and at night, they cool and contract. This expansion and contraction cause the outer layers to crack and flake off. So, this outer layer is just cracking and flaking off.

It can also happen when overlying rocks are removed, reducing pressure on the rocks underneath, which then expand and crack. Here, you can see a good example of granite. During the daytime, because of the sunlight, cracks are seen in this figure. And then, this portion has just peeled off, and the weathered exfoliation dome is created. This is a good example of exfoliation. This is a type of physical weathering.

The next type of physical weathering is crystal growth. In the picture, you can see that when water evaporates from the rocks, suppose in a rock, if water remains between the cracks and the water remains in it, it will evaporate during the daytime. And what will happen? Evaporation leaves salt crystals behind. Some of the water will move to the atmosphere, but the salt crystals will remain in the cracks where the water was earlier. So, what will happen eventually? Eventually, you can see the rocks, and again, because of the salt content, you can see some cracks have developed, and ultimately, the rocks have separated from the main body.

These crystals grow, create pressure, and then cause the rock to crack and break apart. This is a good example of physical weathering due to crystal growth. The next example of physical weathering is the freezing of water, also termed as frost action. Here, you can

see side by side in the picture that water that infiltrates rocks can freeze and expand, exerting pressure on the surrounding rock. This causes cracks to widen.

So in the first figure. Water collects in the crack. Then it freezes and expands. Forcing them to widen. Just widen. And then what happens? Ice thaws. Contracts.

Water gets deeper into the cracks again, and in the end, you can see repeated expansion and contraction causes further cracks until the rock breaks apart. So when the ice melts, the process repeats, gradually breaking the rock apart. This is most common in areas with freezing and thawing cycles. So this is also a very good example of physical weathering. Now, the next example of physical weathering is differential expansion. Rocks are made of different minerals, and each mineral expands and contracts at different rates when heated or cooled. In areas with extreme temperature changes, like deserts, this difference in expansion can cause the rocks to fracture and break apart over time.

The intense heat of forest and bushfires is known to cause rapid flaking and scaling of exposed rock surfaces. So, these are some of the examples of physical weathering. The next type of weathering is chemical weathering. Chemical weathering is a process that occurs when the minerals in rocks are changed by chemicals in rainwater, causing the rocks to break down and disintegrate. In the picture, you can also see that it affects not only igneous rock but also sedimentary and metamorphic rocks.

Chemical weathering is more significant than mechanical weathering in most climates. The main reactive agents in the atmosphere are water, carbon dioxide, and oxygen. Three processes are generally responsible for chemical weathering: oxidation, hydration, and carbonation. In the picture, you can also see this is just a statue, and in the statue, you can see that weathering has taken place and eroded the earlier shape or color of the statue because of chemical weathering. Next is oxidation. That is, you are seeing that three processes are causing chemical weathering.

First is oxidation, second is hydration, and third is carbonation. So, oxidation, the presence of dissolved oxygen in water in contact with mineral surfaces leads to oxidation, which is the chemical union of oxygen atoms with atoms of other metallic elements. See, in iron compounds, they are most commonly oxidized because we get rust in iron-bearing minerals. It weakens where the rusting will take place; definitely, that area will weaken and alter the mineral, contributing ultimately to rock breakdown. So, in the picture, if you see, in every place, you will find some sort of disintegration at the top portion because of the oxidation processes.

The next process is hydration. Hydration is the chemical union of water with minerals, causing them to expand and break down over time. Aluminium-bearing minerals like feldspar are particularly susceptible to hydration, leading to their alteration. In the pillars also, you can see at the bottom some of the materials have just remained at the bottom of the pillar. Earlier, it was not so, but because of the hydration, since it is inside the water, the pillar's shape at the bottom has changed because of the weathering processes.

Next is carbonation. Carbon dioxide, which remains in the atmosphere, dissolves in rainwater, forming carbonic acid, which acts as a solvent, resulting in crusting. Carbonation is especially effective on carbonate rocks like limestone. Our Taj Mahal is a very famous example, causing them to dissolve. In the diagram also, you can see before it was white in color.

Limestone is white in color. But now, at the present day, you can see the yellowish color has generated because of the carbonation process. So, chemical weathering has taken place, and the color of the Taj Mahal has changed. So, this is because of this process. So, these are the processes.

The next type of weathering is biological weathering. Biological weathering refers to the breakdown of rocks and minerals due to the activities of living organisms. You can see in several places on the rocks where some plants have just grown. Why? Because of biological weathering, which is driven by both the physical and chemical actions of organisms, and it plays a significant role in breaking down rocks and transforming the landscapes.

This process is crucial in shaping soil formation and promoting further weathering. These organisms, primarily plants and bacteria, contribute to the weathering of rocks at the surface in two ways: biophysical processes and biochemical processes. What are biophysical processes? Plant roots are responsible. Plant roots grow between rock joints or fractures.

In this figure, you can see within the fractures of the rock or some joints in the rocks where some plant roots have grown. Exerting, after growing, what they are doing is just exerting pressure that widens these openings and creates new fractures, accelerating the weathering of the rock. Insects and animals, organisms like earthworms, snails, and other burrowing animals, loosen the soil cover, exposing rocks to external weathering agents like wind, water, and temperature changes, which ultimately contribute to rock

breakdown. So, this is about the biophysical processes. Biochemical processes involve microbial weathering taking place.

Certain bacteria, algae, and mosses break down rock-forming silicates to obtain essential nutrients like silicon, potassium, phosphorus, calcium, and magnesium, and these are just transforming the rocks in the processes. Decay of organic matter. When plants and animals die and decay, they release chemically active substances like humic acid, which can chemically alter and weather the rocks, accelerating the processes. So, this is about the biochemical processes. Now, rates of weathering.

We have understood the factors, then the types, and now the rates of weathering. The rate at which a rock weathers depends on certain factors. The first factor is the particle size. The particle size influences the rate of weathering. The smaller the particle, the greater the surface area for chemical attack.

The second factor is the mineralogical composition. The mineral composition of a rock is also very important. Slate, which is mainly composed of clay minerals, is very resistant to weathering, while this is not true for marble. The order in which the silicate minerals weather is the same as their order of crystallization. From the Bowen reaction series, it is clear that olivine crystallizes first and is the least resistant to weathering, while the last to crystallize is the most resistant.

So, this Bowen reaction series we will understand in a later module. But this is just in brief I am telling you here that the Bowen reaction series is just like the electrochemical series which we have learned in our earlier studies. So, some of the processes are there through which the different crystals are crystallizing. So here, an example has been given that the silicate mineral weathering is the same as their order of crystallization, and this we are finding from the Bowen reaction series. The rates of weathering are also affected by climatic factors. Chemical weathering is most active in warm, humid regions and least active in cold or arid regions. The role of weathering on the environment: Weathering is very important because we are getting different types of soil at different places on the Earth's surface.

So, soil formation breaks down rocks into soil, supporting plant growth. Even the color of the soil is different at different places because of the different types of minerals present in the rocks. Landform shaping creates features like valleys, cliffs, and caves. The carbon cycle absorbs CO<sub>2</sub>, helping in regulating the climate. Water quality releases minerals in water, affecting quality and the ecosystem.

So different water has different quality because of the release of minerals from the rocks. Ecosystems provide nutrients, influencing biodiversity. Agriculture enhances soil fertility but can lead to erosion if excessive. Natural hazards can also cause landslides, rockfalls, and erosion. They also play an important role in weathering the environment.

If we summarize lecture 1, the important factors we have learned about weathering are rock structure, climate, topography, vegetation, and other complex geological factors. Type-wise, physical weathering is caused by applied forces, chemical weathering by processes like carbonation, oxidation, and reduction, and biological weathering by plants, animals, and microorganisms. Thank you very much to all.