ENVIRONMENTAL GEOSCIENCES

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Lecture-15

Geological Hazards - Volcanoes

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are continuing Module Three in which we have already discussed Dip, Strike, Folds, and Faults, their environmental interpretation in Lecture One, and Geological Hazards - Earthquakes in Lecture Two. Today, I am going to discuss Lecture Three, which is about Geological Hazards related to Volcanoes. In this lecture, the important concepts will be covered, such as geological hazards, an introduction to volcanoes, types of volcanoes, how volcanoes are formed, volcanic products, the impact of volcanic eruptions, volcanic topography, features associated with the decaying phases of volcanism, and major active volcanoes around the world. Now, first of all, we should understand geological hazards.

We have already discussed earthquakes. Geological hazards are natural events caused by the Earth's dynamic processes, often posing risks to life, property, and the environment. They result from phenomena like tectonic plate movements, volcanic activity, slope instability, often exacerbated by human activities such as deforestation or mining. These include earthquakes, tsunamis, volcanic eruptions, landslides, floods, and sinkholes. These hazards can lead to loss of life, destruction of infrastructure, and environmental degradation. Understanding geological hazards is crucial for disaster preparedness, reducing risk, and protecting communities and ecosystems from potential devastation. Now, about volcanoes. Volcanoes are conical or dome-shaped structures built by the emission of lava and its contained gases from a restricted vent in the Earth's surface.

Volcanoes have truncated tops representing the crater that acts as the avenue for magma to rise. So, this portion is the crater. Volcanoes take many forms, and the activity associated with their eruption is highly varied. The activity of volcanoes differs in the amount and type of material ejected. The size, temperature, and composition of the material ejected determine the shape of the volcano.

Now, types of volcanoes. There are several types of volcanoes. So, we will see the first one is the active volcano. When it is erupting intermittently or continuously, then such a type of volcano is called an active volcano. A dormant volcano is a volcano that has not erupted for a longer period and is known as a dormant volcano. An extinct volcano is a volcano that has stopped erupting over a long time, and such a type of volcano is known as an extinct volcano. On the basis of the mode of eruption as well as on the basis of the nature of eruption, different types of volcanoes have been recognized. Besides the above, a number of other types of volcanoes have been identified according to their degree of explosive activity.

So, volcanoes have been classified on three important bases. First, on the basis of the mode of eruption. Second, on the basis of the nature of eruption. And third, on the basis of their degree of explosive activity. So, now one by one, we will understand the types of volcanoes.

So, the first is on the basis of the mode of eruption. Importantly, there are two types: the central type, where lava and other volcanic products escape through a single centralized pipe or vent. This leads to the formation of a cone-shaped volcano. And second, the fissure type, where the ejection of lava takes place from a long fissure or a group of parallel or closely spaced fissures. So, the point is that magma, which is just erupting out of the Earth's surface, is termed as lava, and this lava is coming out through a specified place, which is known as a crater, through some vent.

So when the lava erupts to the Earth's surface through a centralized pipe or vent, such a type of volcano is known as a central type volcano, whereas when it is ejected through some long fissure or a group of parallel or closed fissures, such a type of volcano is known as a fissure type volcano. On the basis of the nature of eruption, there are two types. The first one is the explosive type. In this case, the lava is acidic in nature, that is, felsic in nature, meaning it is rich in iron and silica. And because of its high degree of viscosity, it produces explosive eruptions.

Quiet type, in this case, the lava is of basic composition, mafic lava is present, which is highly fluid and holds little gas. As a result, the eruptions are quiet, and the lava can travel long distances to spread out in thin layers. So the explosive type and quiet type volcanoes are based on the nature of eruption. Based on the degree of explosive activity, some different types of volcanoes exist. Let us see: the first one is the Hawaiian type, where silent diffusion of lava occurs without any explosive activity, then it is a Hawaiian

type of volcano. Strombolian type involves periodic eruptions with a little explosive activity, so here the explosive activity begins. Vulcanian type: eruptions take place at longer intervals, and the viscous lava quickly solidifies, giving rise to explosions of volcanic ash.

Vesuvian type: here, highly explosive volcanic activity occurs, and eruptions happen after long intervals. Plinian type: the most violent type of Vesuvian eruption is sometimes described as the Plinian type. Here, huge quantities of fragmental products are given out with little or no discharge of lava. Plinian type: this is the most violent type of all eruptions. They are characterized by eruptions of nuees ardentes.

It is a product of a cloud of gas and volcanic ash. So these are based on the degree of explosive activity. Now the question is, how are volcanoes formed in nature? So before we learn about volcanoes in detail, we should know some terms related to volcanoes. Magma is the molten rock material inside the Earth's surface.

Lava is magma that has erupted onto the Earth's surface. When magma erupts from the Earth's surface, it becomes lava. The crater is the upper part of the vent, a cup-shaped depression. So this is the crater; this portion is the crater. A vent is an opening through which magma, gases, and volcanic materials are expelled.

So this is called the vent; this pipe is called the vent. Pyroclastic material is the fluidized mixture of solid to semi-solid fragments. Many fragments are ejected during the volcanic process. Volcano formation is driven by geological processes linked to tectonic plate interactions and heat dynamics within the Earth. When tectonic plates collide and undergo the process of subduction, it sets the foundation for a volcano.

Subduction leads to high temperatures and pressures, which contribute to the melting of rock into magma. Additional heat from radioactive decay, friction, and geothermal gradients further contributes to magma formation. Magma, being less dense, rises towards the Earth's surface, creating magma chambers beneath the crust. The buildup of high temperature and pressure in magma chambers causes magma to break through the crust, forming a volcano. Now, what are the volcanic products?

Volcanic eruptions comprise solid, liquid, and gaseous materials. So, about solid products. Fragments of rocks ejected during an explosive eruption are generally called pyroclastic materials. The pyroclastic materials of various size grades are known differently; first are

the volcanic blocks or bombs. The diameter of the fragments is always above thirty-two millimeters.

Second, cinders or lapilli; here, the diameter ranges between 4 mm to 32 mm. Ash particle size ranges between 0.25 mm to 4 mm. Fine ash consists of minute particles with a diameter less than 0.25 mm. Tuff rocks, made up of ash and fine ash, are known as tuffs. When the tuffs are welded, they are known as ignimbrite. Agglomerates are pyroclastic rocks consisting mainly of fragments larger than 20 mm in diameter.

These are about the solid products. Now, liquid products. Liquid emissions from a volcano are generally known as lava. Lava of acidic composition is more viscous and less mobile than highly fluid basic lava. Fluid lava results in calm eruptions as it allows the dissolved gases to escape freely.

In viscous lava, the gases do not escape freely. They frequently build up internal pressure to produce violent eruptions. Gaseous products, the most important constituent of volcanic gases is steam. It forms nearly ninety percent of the total gas content. The other chief gases, in order of abundance, are carbon dioxide, nitrogen, sulfur dioxide, and smaller amounts of hydrogen, carbon monoxide, sulfur, and chlorine.

The density of magma and molten lava is reduced by the presence of dissolved gases. So these are about the products: solid, liquid, and gaseous products during volcanic eruptions. Now, the impact of volcanic eruptions: the effects of volcanic eruptions can be divided into primary and secondary effects. The primary effects are immediate and result from the eruption itself. Volcanic gases, lava flows, and pyroclastic flows are some of the primary effects that can be observed.

Now, volcanic gases: all magma contains dissolved gases. These gases are mainly steam, carbon dioxide, and compounds of sulfur and chlorine. Lava flows are streams of molten rock. Pyroclastic flows are high-speed avalanches of hot ash, rock fragments, and gas that move down the sides of a volcano. These flows occur when the vent area or ash column collapses.

In the adjacent figure, you can see an example of pyroclastic flows. Secondary effects are lahars, which are mixtures of water, rock, ash, sand, and mud that originate from the slopes of a volcano. Lahars often happen because of heavy rainfall eroding volcanic deposits. Landslides: heat from cooling magma can cause hydrothermal alteration of the

rocks, turning sections of them into clay. This weakens the rocks and increases the risk of slope failures.

Now, flooding: explosive eruptions can change the surface areas around a volcano and disrupt the drainage patterns, leading to long-term flooding. So, these are the secondary effects of volcanic activity. Now, other secondary effects also include food and water supply interruptions due to volcanic activity, people becoming homeless, businesses being forced to close, the cost of insurance claims, unemployment, and long-term issues with the tourism industry. Now, volcanic topography includes both positive and negative relief features. The high or elevated relief features, comprising hills, mountains, cones, plateaus, or upland plains, are some examples of positive relief features, while the low-lying relief features, such as calderas and tectonic depressions, represent the negative relief features.

Now let us understand positive relief features. These features are formed due to both quiet and explosive volcanic types of activity. Some of these are hornitos, which are very small lava flows; driblet cones, which are formed from the most acidic lava and often give rise to quite small conelets. Cinder cones, these are volcanoes of the central type of eruption, steep-sided with uniform slopes of about 30-40°. A figure is given here. Shield volcanoes, these are made up of lava alone and due to the quiet type of eruption, whereby the piling up of flow after flow of fluid lava produces a rounded dome-like mass.

Such a type of structure is known as a shield volcano. Composite cones, these are made up alternately of pyroclastic material and lava. Due to their stratification, these are known as stratovolcanoes. Negative relief features, these are calderas. Sometimes, because of a violent volcanic eruption, the entire central portion of the volcano is destroyed, and only a great central depression named a caldera remains.

The calderas may also be formed due to erosion and enlargement of the crater. Lava tunnels, the more mobile lavas of basic composition, when erupted on the surface in the form of flows, quickly consolidate and form a solid crust while the interior may still remain fluid. Under such conditions, the enclosed fluid lava drains out through some weak spots lying at the periphery of the flow, forming what is known as a lava tunnel. Cone-in-cone topography. After an explosion destroys an existing crater, a new smaller cone with its own crater is built up.

This is known as cone-in-cone topography. Features associated with the decaying phases of volcanism. The first feature is fumaroles. These are fissures or vents through which volcanic gases are ejected. Fumaroles emitting sulphurous vapor are called sulfataras.

And those which emit carbon dioxide and boric acid vapor are known as moffetes and soffioni respectively. Hot springs, these are fissures through which hot water escapes. The water usually gets heated with increased temperature below, maybe magmatic or radioactive heat. Calcareous deposits formed from hot springs are known as travertine or tufa, and similarly, siliceous deposits are called siliceous sinters. Geysers, hot springs ejecting boiling water and steam at regular intervals, are known as geysers.

Siliceous deposits formed around geysers are known as geyserite. Pseudo-volcanic features, mud volcanoes, and meteor craters are of non-volcanic origin and are examples of pseudo-volcanic features. Major active volcanoes around the world, you can see, are concentrated in a narrow belt called the Circumpacific Ring of Fire, where the volcanoes are located on the high, young, folded mountains. Other volcanic areas include the scattered areas in the Pacific, particularly the Hawaiian Islands, a belt that includes Arabia, Madagascar, and the Rift Valleys of Africa, the Mediterranean Belt, Andaman Nicobar Islands, etc. So, now just concluding the lecture, first we have discussed the volcano.

Volcanoes are conical and dome-shaped structures formed by the emission of lava and gases from the Earth's surface, with activity varying in eruption type and material ejected. Causes of volcanism: volcanic activity results from tectonic plate movements, magma chamber pressure, radioactive heat, and the subduction of plates that cause magma to rise and erupt as lava. Types of volcanoes: volcanoes are classified by mode of eruption and nature of eruption, with specific types based on the degree of explosive activity. Fourth, volcanic products and impacts: volcanic eruptions release solid, liquid, and gaseous materials. Their impacts include primary effects like lava flows and pyroclastic flows, and secondary effects like lahars, landslides, and flooding, etc.

Thank you very much to all.