ENVIRONMENTAL GEOSCIENCES

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Lecture-18

Summary of Module 3

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We were discussing module three. Today, we will discuss lecture six, which is the summary of dip, strike, folds, and faults, their environmental interpretation, and geological hazards such as earthquakes, volcanoes, floods, and landslides. In this summary lecture, we will briefly discuss dip and strike, folds, types of folds, faults, types of faults, and geological hazards such as earthquakes, volcanoes, floods, and landslides. What we have seen in the last few lectures is that dip and strike represent the orientation of a plane in space.

It can be specified by measuring its dip and strike only. Dip is the amount of slope of the plane. It is determined by measuring the angle between the horizontal and the sloping plane. Dip is always measured in a vertical plane perpendicular to the strike in the direction of maximum inclination of the rock plane. Whereas strike is the direction of a line formed by the intersection of the plane and the horizontal.

We have already discussed folds in detail. Now, just summarizing, folds are produced by lateral compression of the rock. Under this type of stress, the crustal rocks are deformed into a series of wave-like forms oriented transverse to the direction of maximum stress. Folds are an indication that crustal shortening has taken place. Folds are most easily visible in sedimentary rock sequences because of the bedding in the rock strata.

There were several types of folds. Important ones are, anticlines are formed by the upward bending or buckling of the strata, so the fold has the shape of an arc. Here you can see this is the shape of the anticlinal fold. This is the shape of the anticlinal fold. Whereas the sides or limbs of an anticline dip downward and outward from the fold crest.

The opposite of an anticline, just opposite of this, is the syncline in which the central portion is bent downward to form a trough. The limbs of a syncline dip toward the center of the trough. So, this is the limb. Here you can see, and in the syncline, it is just dipping toward the center of the trough. Now, the line connecting the points of maximum curvature is called the axial plane or axis.

So, the axial plane contains the axis that divides the fold into two equal sections, which is dividing the fold into two equal sections. In an eroded anticline, the oldest rocks are exposed at the center of the structure, at the center of the structure. So, this is about the youngest and oldest. Here you can see the first one is the oldest. Then this is the second bed.

This is the third one. This one is the fourth one. So, in this way, we are getting the oldest to youngest with the presence of a syncline or anticline. Here, you can see this is the folded strata, and these are the limbs. This is the axial plane, which is dividing the fold into two equal halves.

So, this is about the parts of the fold. Fold types are differentiated by the geometry of the limbs and the orientation of the axial planes. In symmetrical folds, the limbs dip in opposite directions in about the same amount. Dips of opposing limbs are not equivalent in asymmetrical folds. If both limbs dip in the same direction, the folds are said to be overturned folds.

A step-like bend in strata without two well-defined limbs is known as a monocline. So, here you can see the different cases: this is the case of a monocline, then this is the case of a symmetrical fold, this is the case of an asymmetrical fold, this is the case of an overturned anticline, and this is the case of a recumbent anticline. So, these are some of the cross-sections of the fold types defined by geometry and the position of the axial plane. Now, faults. Faults are fractures along which relative displacement or movement of rock masses has occurred parallel to the fault plane.

Faults are classified according to the type of movement, or slip, that has taken place. The two categories established on this basis include dip-slip faults and strike-slip faults. Dip-slip faults, in which the relative movement of rock masses is in the direction of the dip of the fault plane, include normal faults, reverse faults, and thrust faults. Normal and reverse faults can be differentiated if the relative displacement of a bed or other lithological feature can be determined. The blocks on opposite sides of the fault plane are defined as the hanging wall and the footwall.

The hanging wall is always the block above the fault plane, and the footwall is always the block below the plane. So here, you can see the hanging wall, this one, and this is the footwall; this is the normal fault, then, in this case, this is the reverse fault, and this is the thrust fault. If the hanging wall has moved downward, this is moving downward with respect to the footwall. This one is the footwall.

The fault is a normal fault, and the relative movement in the opposite sense is characteristic of a reverse fault. Here, you can see just the opposite of the normal fault. It is known as a reverse fault. Thrust faults are very similar to reverse faults, except that the angle of the fault plane with respect to the horizontal is quite low. They involve intense crustal compression and can result in large displacements.

Now, you see a down-drop block bounded by two normal faults is generally called a graben. This is called a graben. Rift zones, in which the lithosphere is being pulled apart by plates moving away from each other, usually contain large grabens at the surface. The structure formed when the central block between two dip-slip faults is upthrown is known as a horst. Strike-slip faults are characterized by the lateral movement of the fault block along the strike of the fault plane.

So here, you can see the pair of normal faults forming. The first is forming the graben, and the second is forming the horst. So here, by the strike-slip faults, we are getting different types of structures: graben by the down-drop block, and when the central block between the two dip-slip faults is upthrown, we get the structure horst. Now, earthquakes—we have discussed geological hazards in detail, and here we are discussing them again. Earthquakes are caused primarily by the rupture of the rocks in the Earth's crust along the fault plane.

So, we have seen that our lithosphere is made up of so many plates. So, when movements take place within the plates at the plate boundary, then in some of the rocks, we may get some ruptures. And because of the rupture, we encounter earthquake disasters. Most earthquakes take place along the faults in the vicinity of the plate boundaries. So, earthquakes also occur far from plate boundaries.

The faults associated with these intra-plate earthquakes are deeply buried and not visible at the land surface. Now, the elastic rebound theory. We have discussed this theory when we were discussing earthquakes. Again, we will just revise it. According to Professor H.F. Reid, the materials of the earth are elastic in nature.

They can withstand a certain amount of stress without deforming permanently. Here, the materials of the earth are nothing but the rocks and lithospheric plates. But if the stress is continued for a longer period of time in the materials of the earth or if it is increased in magnitude, the rocks will first deform permanently and ultimately rupture. So, when the rupture occurs, the rocks on either side of the fault tend to return to their original shape because of their elastic nature, and an elastic rebound occurs. The rebound results in the release of an enormous amount of energy in the form of elastic waves, and these waves actually set up the seismic waves.

On the right side, you can see in the diagram that the stress is accumulating upon a rock bed. The stress is accumulating upon the rock bed, then the bed has been deformed to some extent, and a crack is developing. We can see the crack that has developed here. Along the crack, the two fractured blocks rebound to their original position of no strain. These are the pictorial representations of the elastic rebound theory.

Elastic strain that had been accumulating on either side of the fault is suddenly released. Elastic strain energy is released in the form of seismic waves, which radiate outward through the rocks in all directions from the hypocenter. The energy stored in the system through the decades is released instantaneously, causing underground dislocation of rocks and setting up vibrations that are either feeble or strong, as the case may be. The rupture and movement of the blocks may take only a fraction of a minute to be completed. This is the time of the major shock.

The final adjustment of the rock block to its original position may be completed over a long period of time with a number of minor shocks, which are known as aftershocks. The propagation of seismic waves during fault movement is a consequence of elastic rebound, and the hypothesis is known as the elastic rebound theory. Detection and recording during rupture at the hypocenter of an earthquake, the elastic strain energy stored in the rock is suddenly released in the form of seismic waves. These waves are propagated outward from the hypocenter through the rocks in all directions. This seismic energy causes rapid vibrations in the rocks in the subsurface as well as on the land surface itself.

The instrument designed to measure and record the characteristics of seismic waves is called a seismograph; it is called a seismograph. Measurement of an earthquake. The seismograph is the instrument used to measure seismic waves. The strength and effects of earthquakes are determined in two ways, either in magnitude. The effects of earthquakes are determined in two ways. Magnitude is a quantitative measure of the energy released by an earthquake as obtained from seismograph records.

A method for determining magnitude, developed by seismologist Charles F. Richter, defines magnitude as the logarithm of the largest seismic wave amplitude produced by the trace of a standard seismograph located at a distance of 100 km from the epicenter. Magnitudes obtained by this method are commonly referred to as magnitude on the Richter scale. The highest magnitude values measured have been approximately nine. Intensity is a subjective measure that is determined by observing the effects of an earthquake on structures and by interviewing people who experienced the event. The most commonly used intensity scale is the modified Mercalli scale, which has twelve divisions.

Each division describes a particular level of human response and building performance. Intensity generally decreases with distance from the epicenter and local geological conditions. It also influences the amount of ground shaking. So, magnitude and intensity are the two important factors through which we understand the intensity of an earthquake. Types of seismic waves.

Seismic waves generated during an earthquake fall into two types. Body waves travel through the earth's interior from the earthquake's hypocenter. And surface waves move along the earth's surface from the epicenter. Body waves can be divided into two parts: primary and secondary waves. Primary waves are known as compressional waves because they travel through the rocks as alternate compressions and expansions of the material.

P waves are the fastest-moving seismic waves. S waves are also known as shear waves because of their mode of travel. The travel of S waves is analogous to the movement of a rope anchored to a wall at one end and shaken up and down with your hand at the other end. S waves, or shear waves, cause particles to move perpendicular to the direction of wave propagation, creating a side-to-side motion. S waves are slower than P waves, traveling at speeds of three to five kilometers per second.

They arrive after P waves in a seismic event. Unlike P waves, S waves can only move through solids and cannot pass through liquids. The velocity of S waves is lower than that of P waves. Here, you can see in the diagram the motion of P waves and the transmission of S waves. Surface waves, which arise at a seismograph station after both P and S waves, include Love and Rayleigh waves.

The period measures the amount of time that elapses between the arrival of two successive wave crests, and the wavelength measures the distance separating identical points on successive waves. Love waves originate from S waves that reach the surface at the epicenter. As they move outward along the surface of the Earth, they produce only horizontal ground motion. Rayleigh waves resemble the motion of ocean waves, with predominantly vertical displacement. Now, the second disaster we have learned about is volcanoes.

So, I will summarize here about the volcanoes. Volcanoes are natural geological formations that occur when molten rock, gases, and ash from beneath the Earth's crust break through the surface. This process is a result of tectonic plate movement and the Earth's internal heat, which causes magma to rise from deep within the mantle. When magma reaches the surface, it erupts, cooling and solidifying to form lava and sometimes ash, which can build up over time to create various types of volcanic landforms. Volcanoes are often found at plate boundaries where tectonic plates are either colliding, moving apart, or sliding past each other.

However, they can also form in areas of the crust, such as the Hawaiian Islands, where magma rises from deep within the Earth's mantle to create volcanic activity in the middle of a tectonic plate. Types of volcanoes, based on mode of eruption, are two types: central type and fissure type. Central type: lava and other volcanic products escape through a single centralized pipe or vent. This leads to the formation of a cone-shaped volcano. Fissure type: lava is ejected from elongated cracks or fissures rather than a single vent.

These eruptions form plateaus or extensive lava flows. Based on the nature of eruption, there are quiet type and explosive type. Quiet type involves basic lava that is fluid and contains minimal gas. The lava flows quietly and spreads over large areas, forming thin layers. Explosive type is characterized by acidic felsic lava, which is highly viscous and traps gases, causing violent explosions.

Explosive type is associated with pyroclastic materials like ash and pumice. Volcanic eruptions can vary significantly. Some are explosive, throwing ash, gases, and debris high into the air, which can be hazardous to nearby communities and the environment. These eruptions can cause pyroclastic flows, fast-moving clouds of hot gas and volcanic matter, and lahars, mudflows. Other eruptions are more effusive, with lava flowing slowly from the volcano, allowing people to evacuate in time.

The flow of lava can destroy property, infrastructure, and even entire towns. Volcanic activity can have both positive and negative effects on the environment and human life. In summary, volcanoes are powerful natural features that play a major role in shaping our surface, influencing ecosystems, and even human history. While they present significant hazards, they also offer opportunities for scientific study and can bring benefits in the form of fertile land and geothermal energy. The third geological disaster is the flood.

Floods are natural events that occur when water overflows onto normally dry land, often due to heavy rainfall, rapid snowmelt, dam or levee failure, or coastal storm surges. Floods can happen anywhere and are influenced by factors such as topography, weather patterns, and human activities. There are several types of floods. The first is the river flood. These occur when rivers or streams overflow their banks due to excessive rainfall or melting snow, leading to the inundation of the surrounding areas.

Second is the coastal floods caused by storm surges, high tides, or rising sea levels. These floods affect coastal regions and can be intensified by hurricanes or tropical storms. Third is the flash floods. These are sudden, fast-moving floods that occur within six hours of heavy rainfall or other events like dam failure. They are typically dangerous because they develop quickly and can be life-threatening.

Urban floods. In cities with poor drainage systems, heavy rainfall can overwhelm infrastructure, causing localized flooding even without large rivers or bodies of water. Plains floods. These floods occur in low-lying areas that are prone to water accumulation, such as floodplains, after heavy rain or snowmelt. Flooding can cause significant damage to homes, infrastructure, agriculture, and ecosystems, leading to economic losses, displacement, and sometimes loss of life.

It can also disrupt transportation, communication, and utilities, making recovery efforts more difficult. The effects of flooding are influenced by factors like the volume of water, the duration of the flood, and the vulnerability of the area. Flood can also bring positive effects, such as replenishing soil fertility and supporting ecosystems. To mitigate the risk of floods, measures like flood forecasting, early warning systems, improved drainage, flood barriers, and land use planning are essential. Floodplain zoning and the construction of levees, dams, and reservoirs can help in protecting vulnerable areas, though these measures also have certain limitations.

In summary, floods are destructive natural disasters with various causes and types. While they can offer some ecological benefits, the damage they cause to human life, property, and the economy can be devastating. Effective flood measurement and preparedness are key to reducing the impact of flooding. Next is the landslides. Landslides are the movement of rock, soil, and debris down a slope due to gravity.

They can occur in a variety of environments, particularly in mountainous or hilly regions, and are often triggered by heavy rainfall, earthquakes, volcanic activity, or human activities such as construction or deforestation. Landslides can range from small localized slides to large catastrophic events that cause significant damage. There are several types of landslides. The first one is rockfalls, when large rocks or boulders fall from steep cliffs, often triggered by weathering or seismic activity. Mudslides or debris flows are fast-moving, water-saturated mixtures of soil, rocks, and vegetation that travel quickly down the slopes, often after heavy rain.

Slumps occur when a portion of a slope slides downward in a rotational manner, typically leaving a curved scar on the landscape. Earth flows are slow-moving landslides of wet soil that can travel downhill over weeks or months. Avalanches are a rapid downslope movement of snow and ice, often triggered by weather conditions or disturbances. Landslides can cause serious damage, including the destruction of homes, infrastructure, and transportation networks. They can also lead to loss of life and disrupt local ecosystems.

The impact of landslides depends on factors such as the size and speed of the slide, the type of material involved, and the population density in the affected area. Several factors contribute to the likelihood of landslides, such as heavy rainfall or rapid snowmelt. Water can saturate the ground, making it unstable and more likely to slide. Earthquakes or volcanic activity can shake loose material on slopes, triggering slides. Human activity, deforestation, construction, and road building can weaken slopes and make them more susceptible to landslides.

Soil erosion, loss of vegetation, and the degradation of soil structure can destabilize hillsides. To reduce landslide risk, prevention and mitigation strategies include careful land use planning, monitoring of slopes, the construction of retaining walls or drainage systems, and the stabilization of steep slopes with vegetation. Early warning systems and community preparedness can help save lives and reduce property damage. In summary, landslides are natural disasters that involve the movement of earth materials down a slope. They can be triggered by weather events, seismic activity, or human actions, and their consequences can be severe.

Understanding the causes and implementing preventive measures are key to minimizing the impact of landslides. Thank you very much to all.