D.B.F. Dayanand College of Arts and Science, Solapur

Department of Geology

B.Sc. III

2020-2021

Subject	**GEOLOGY**
Paper No. and Title	**Paper – X Landslides**
Module (Flipped classroom) Title	**Geom-2**
Module Tag	**DAYA.GEO.VMD6**
Key words	**Mass movements, causes and mitigation**

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Malin Landslide On 30 July 2014

Module No. 1

Title – Mass movements, causes and mitigation

- **Prerequisites –**
- Basic knowledge about weathering, erosion and deposition.
- Knowledge of structural geology such as, bedding plane and attitudes of beds.
- Knowledge of stresses on the rock due to gravity

- **Learning outcome:** Students will
  - Know various causes of mass movements.
  - Learn mode of rock mass failure and types of mass movement.
  - Process, analyze, and interpret data to identify and classify mass wasting sites and connect their development to environmental factors.
  - Synthesize susceptibility models with environmental, social, and political considerations to develop a comprehensive landslide risk assessment.

- **Objectives of the Module**
  Students should learn about the details of the meaning and concepts in remote sensing.

Content	Objectives (Learner should be able to)	Cognitive Level
Definition Classification, causes and mitigation.	Definition and classification of mass movements	Remembering
	Causes of mass movement. Roll of water and gravity in the mass movement	Remembering
	Mitigation and preventive measures.	Remembering
	Visualization method	Applying
	Proper thought process	Understanding
	Asking question and some simple concept	Evaluating

Table of Content:

1. INTRODUCTION

The earth is a dynamic system and it's environment has evolved during geologic past by continuous interaction amongst barysphere, asthenosphere, lithosphere, hydrosphere, biosphere and atmosphere. This uniformly operating multi sphere system is suddenly disturbed by the endogenous and exogenous forces. Both endogenous and exogenous forces are operating since the inception of the earth and will continue to operate in future, constantly changing physical, chemical and biological face of the earth and shall bring human beings to their toes by their sudden and swift action causing harm to them, their economic and social

institutions. These surprising actions are called as natural disasters. There are many natural and man-made disasters which inflict losses to human beings and their socio-economic gains. The natural disasters are all part of the earth's dynamic system and they cannot be prevented or stop for occurring. But humans can reduce their impact, severity, frequency and magnitude by analysing their past occurrences and probability of future occurrences with the help of awareness, preparedness and mitigation.

Large part of the India is susceptible to mass movements especially in the mountainous regions like Himalaya. This high magnitude of vulnerability is due to many factors such as, active tectonics, high seismicity, steep slopes, complex geological setting, heavy snow and rain fall. Landslide events are also reported from the Western Ghat mountains during monsoon due to heavy rains. Many of the mass movement events occurs because of anthropogenic activities such as rail and road network, settlements, flooding, dam construction etc.

Proper understanding of landslide phenomenon, controlled and planned, development of landslide prone areas and pertinent civil engineering measures can reduce the occurrence of landslides and minimize the losses.

2. DEFINITION AND GRAVITY

Definition: *Mass-wasting is the down-slope movement of* ***Regolith*** *(loose uncemented mixture of soil and rock particles that covers the Earth's surface) by the force of gravity without the aid of a transporting medium such as water, ice, or wind. Still, as we shall see, water plays a key role.* Such movements of the superficial masses have been termed in common language as *Landslides*.

3. CLASSIFICATION AND TERMINALOGY

Classification of landslides: The down-slope movement of material, whether it is bedrock, regolith, or a mixture of these, is commonly referred to as a ***landslide***. All of these processes generally grade into one another, so classification of mass-wasting processes is somewhat difficult.

<table>
<tr><th colspan="2">A. FLOWAGE</th><th colspan="2">B. SLIDING</th><th colspan="2">C. SUBSIDENCE</th></tr>
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1. Shallow creep
2. Deep creep</td><td>Earth flows</td><td>Rock slides</td><td>Single rock slips</td><td>Rock falls</td></tr>
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2. mass creep</td><td>Mud flows

Rock glaciers</td><td>Debris slides</td><td>Multiple rotational slip</td><td>Debris falls</td></tr>
<tr><td>Talus creep
Rock creep</td><td>Stone streams</td><td colspan="2">Sub-aqueous slides</td><td></td></tr>
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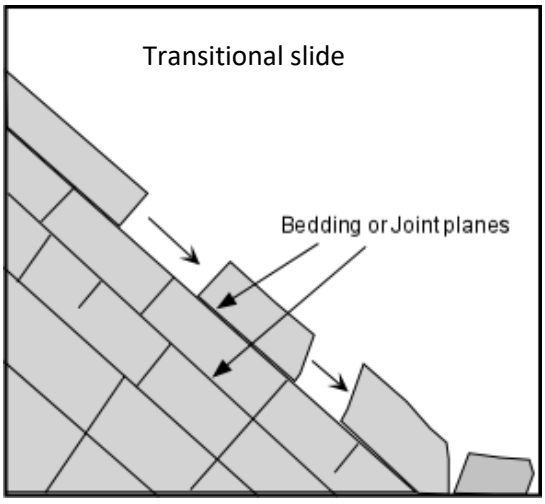
A. FLOWAGE: Flowage is a downgrade movement of mass along *no definite surface of failure*. Mass is unconsolidated, regolith or loosely packed. A sediment flow is a mixture of rock, and/or regolith with some water or air. In unconsolidated material each grain or unit of grains behaves as if it has its own shear failure surface. The result is that the movement

is distributed throughout the mass and in irregular manner. Flowage is further distinguished into slow and rapid flowage.

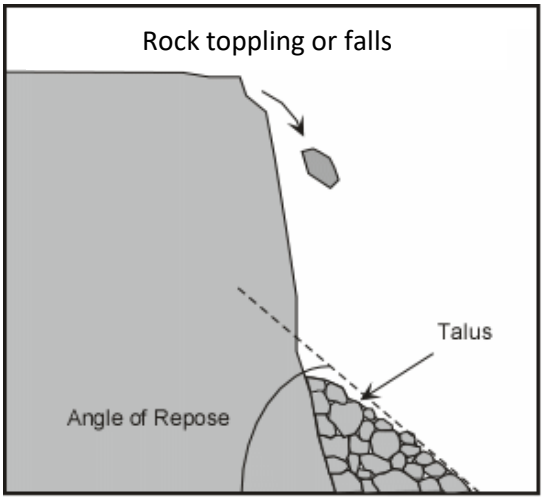
1. *Slow flowage*: In first case ground is moving down slope at very low rate as a few cm/year or even less. In slow flowage sediment flows that contain between 0 and 20% water. Note that granular flows are possible with little or no water. Fluid-like behavior is given these flows by mixing with air. Granular flows are not saturated with water. ***Creep*** - the very slow, usually continuous movement of regolith down slope. Creep occurs on almost all slopes, but the rates vary. Evidence for creep is often seen in bent trees, offsets in roads and fences, and inclined utility poles. ***Solifluction*** -flowage at rates measured on the order of centimeters per year of regolith containing water. Solifluction produces distinctive lobes on hill slopes. These occur in areas where the soil remains saturated with water for long periods of time.

2. *Rapid flowage*: In rapid flowage mass may travel few mts. per day or more. Rapid flowage is sediment flows that contain between about 20 and 40% water. As the water content increases above about 40% flows grade into streams. Flows are considered water-saturated flows. ***Earthflows*** - are usually associated with heavy rains and move at velocities between several cm/yr and 100s of m/day. They usually remain active for long periods of time. They generally tend to be narrow tongue-like features that begin at a scarp or small cliff. ***Mudflows*** - these are a highly fluid, high velocity mixture of sediment and water that has a consistency ranging between soup-like and wet concrete. They move at velocities greater than 1 km/hr and tend to travel along valley floors. These usually result from heavy rains in areas where there is an abundance of unconsolidated sediment that can be picked up by streams. Thus after a heavy rain streams can turn into mudflows as they pick up more and more loose sediment. Mudflows can travel for long distances over gently sloping stream beds. Because of their high velocity and long distance of travel they are potentially very dangerous. Mudflows can also result from volcanic eruptions that cause melting of snow or ice on the slopes of volcanoes, or draining of crater lakes on volcanoes. Volcanic mudflows are often referred to as ***lahars***.



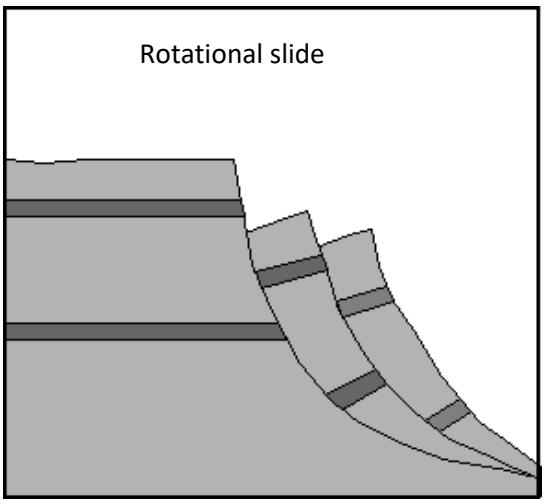
B. SLIDING: A true landslide is a type of mass failure in which a superficial mass fails by moving as a whole along a *definite surface of failure*. The surface of failure may be planar or semicircular. Sliding may involve materials of any composition, shape and varying degree of consolidation. In case of unconsolidated mass the sliding takes place along curved shear surface. When mass involved is hard and brittle the shear surface will be planar. Sliding is further divided in to transitional sliding and rotational sliding.

Transitional slides: The surface of failure is generally planar in character; speed is quite rapid and mass involved is rock blocks, rock slabs, debris and soil cover or even a mixture of all of them.



Rotational slides (Slumping): In such slides, the failing surface is curved and speed of failure is also quite rapid. Because of the nature of the failing surface, the movement of the mass takes the form of a sort of *rotation*, rather than translation. The material involved in failure tilts as the rear end and heaves up at the front or toe. There may be single surface of failure or a number of them adjoining to each other.

Rock toppling or falls: These are grouped along with sliding although there may be little or no sliding involved in their failure for a simple reason that they are commonly associated with or accompany the landslides and because they are essentially a slope failure phenomenon. In the falls, there is almost free, sudden and fast decent from a steep slope.



C. SUBSIDENCE: *Subsidence or sinking is defined as the failure of the ground in a vertically downward direction.* It may vary from a few cms. to many meters and may be due to natural or artificial causes. Subsidence hazards involve either the sudden collapse of the ground to form a depression or the slow subsidence or compaction of the sediments near the Earth's surface.

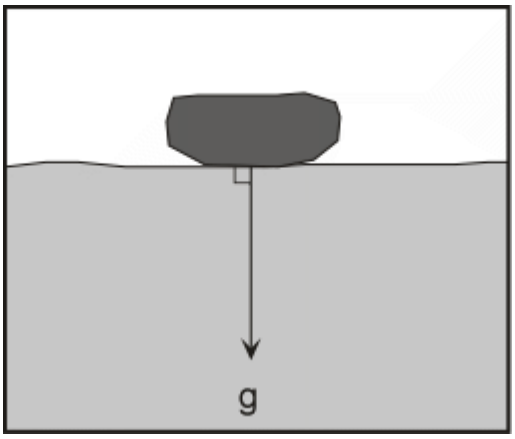
4. CAUSES OF MASS MOVEMENTS

Solution of subsurface rocks: Carbonate rocks such as limestone, composed mostly of the mineral calcite ($CaCO_3$) are very susceptible to dissolution by groundwater during the process of chemical weathering. Such dissolution can result in systems of caves, sinkholes, and eventually to karst topography

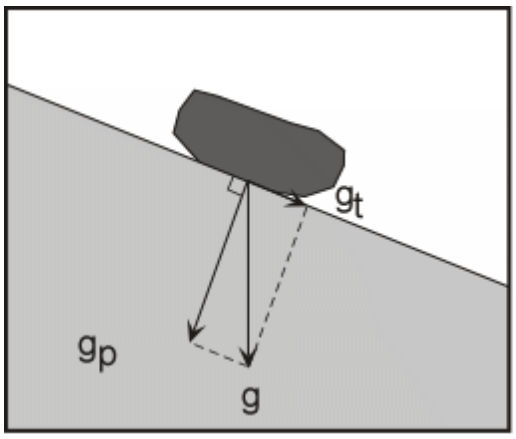
1. Removal of Solids and Mine Related Collapse**:** Humans can play a large role causing collapse of the surface. Mining activities that remove material from below the surface can result in collapse if precautions are not taken to ensure that the there is adequate support for the overlying rocks. Since mining often removes material from below the surface without dissolution, mining can create voids that may become unstable and collapse Coal occurs beneath the surface as extensive layers called coal seams. The technique used in coal mining is referred to as "room-and-pillar" mining. The rooms are where the coal has been removed, and the pillars are left to support the overlying rock.

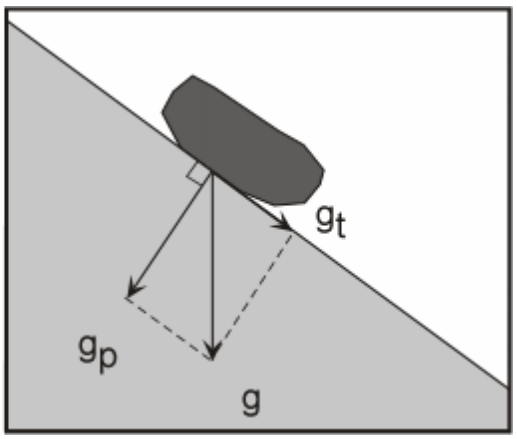
Sometimes, too few pillars are left, and the overlying rock collapses into the mine. This is not only dangerous to the miners, but can also cause hazards to areas on the surface where the collapse occurs

2. Removal of fluid: Any fluid that exists in the pore spaces or fractures of rock is under pressure due to the weight of the overlying rock. So long as the pressure of the fluid is enough to support the overlying rock, no subsidence at the surface will occur. But, if fluids are withdrawn from below the surface, a decrease in fluid pressure may occur resulting in the removal of support and possible collapse. The two most important fluids that occur beneath the surface are water (in the form of groundwater) and petroleum (in the form of oil and natural gas). Both of these fluids are often withdrawn for human use, and thus humans are often responsible for fluid withdrawal related subsidence. But, such withdrawal can also occur by natural processes.



Causes of landslides: Mass-wasting is part of a continuum of erosional processes between weathering and stream transport. Mass-wasting causes regolith to move down-slope where sooner or later the loose particles will be picked up by another transporting agent and eventually moved to a site of deposition





such as an ocean basin or lake bed. In order for regolith to move in a mass wasting process it must be on a slope, since gravity will only cause motion if the material is on a slope.

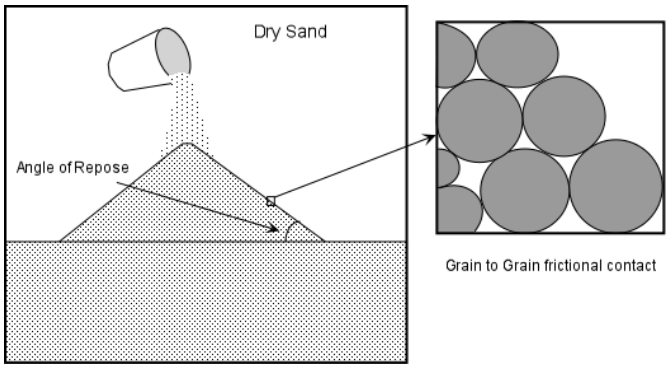
A. Gravity and nature of slope:

Gravity is a force that acts everywhere on the Earth's surface, pulling everything in a direction toward the center of the Earth. On a flat surface, parallel to the Earth's surface, the force of gravity acts downward. So long as the material remains on the flat surface it will not move under the force of gravity. On a slope, the force of gravity can be resolved into two components: a component acting perpendicular to the slope, and component acting tangential to the slope

- The perpendicular component of gravity, g_p, helps to hold the object in place on the slope.
- The tangential component of gravity, g_t, causes a ***shear stress*** parallel to the slope and helps to move the object in the down-slope direction.

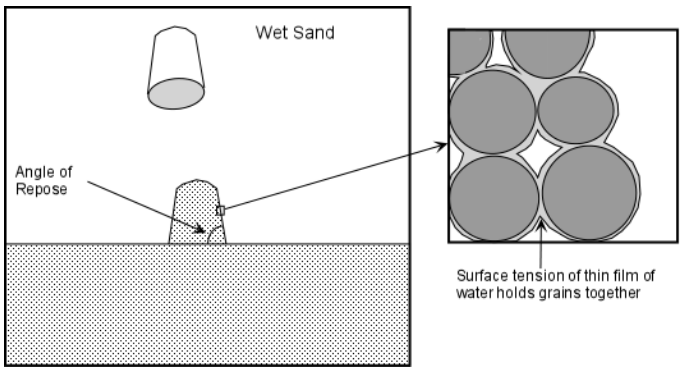
- On a steeper slope, the shear stress or tangential component of gravity, g_t, increases, and the perpendicular component of gravity, g_p, decreases.
- Another force resisting movement down the slope is grouped under the term ***shear strength*** and includes frictional resistance and cohesion among the particles that make up the object.
- When the sheer stress becomes greater than the combination of forces holding the object on the slope, the object will move down-slope.
- Thus, down-slope movement is favored by steeper slope angles (increasing the shear stress) and anything that reduces the shear strength (such as lowering the cohesion among the particles or lowering the frictional resistance.

B. The Role of Water

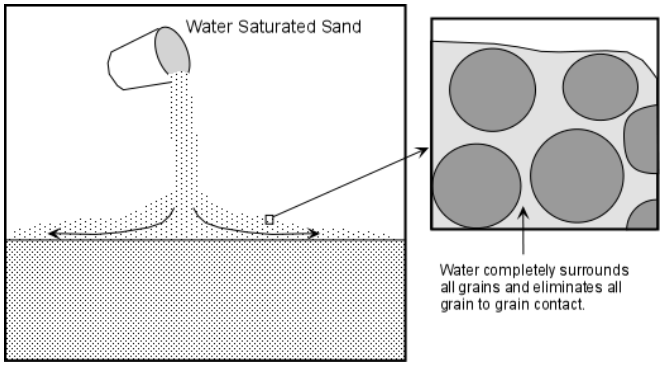


Although water is not directly involved as the transporting medium in mass-wasting processes, it does play an important role. Think about building a sandcastle on the beach. If the sand is totally dry, it is impossible to build a pile of sand with a steep face like a castle wall. If the sand is somewhat wet, however, one can build a vertical wall. If the sand is too wet, then it flows like a fluid and cannot remain in position as a wall.

Dry unconsolidated grains will form a pile with a slope angle determined by the ***angle of repose***. *The angle of repose is the steepest angle at which a pile of unconsolidated grains remains stable, and is controlled by the frictional contact between the grains.* In general, for dry materials the angle of repose increases with increasing grain size, but usually lies between about 30 ^{o} and 37^{o}.



- Slightly wet unconsolidated materials exhibit a very high angle of repose because surface tension between the water and the grains tends to hold the grains in place.
- When the material becomes saturated with water, the angle of repose is reduced to very small values and the material tends to flow like a fluid. This is because the water gets between the grains and eliminates grain to grain frictional contact.

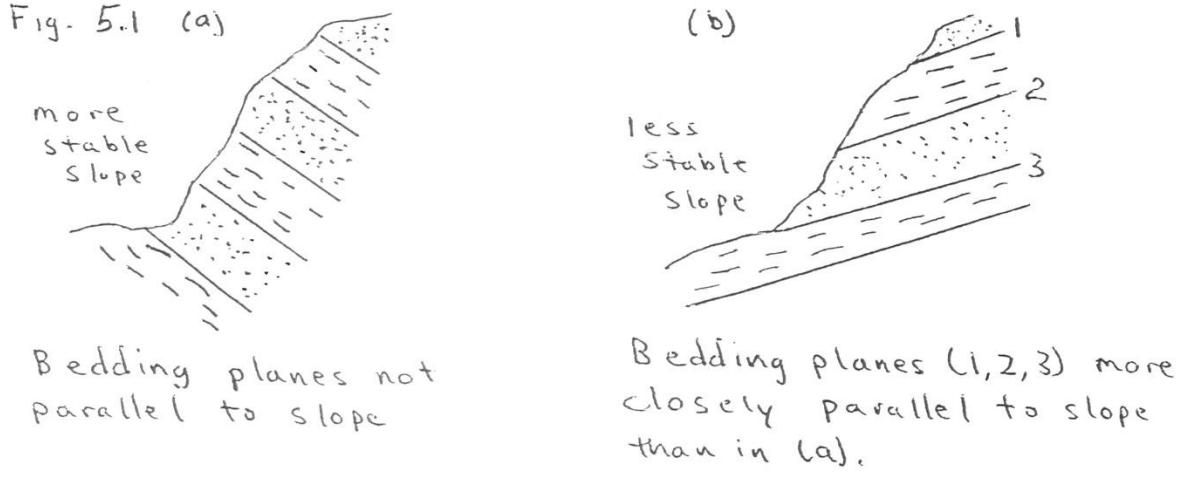


C. Composition of the Mass: Some materials are stable at given conditions of slope and water content while others are unstable under the same conditions. Crystalline igneous rocks like granites and gabbros and massive

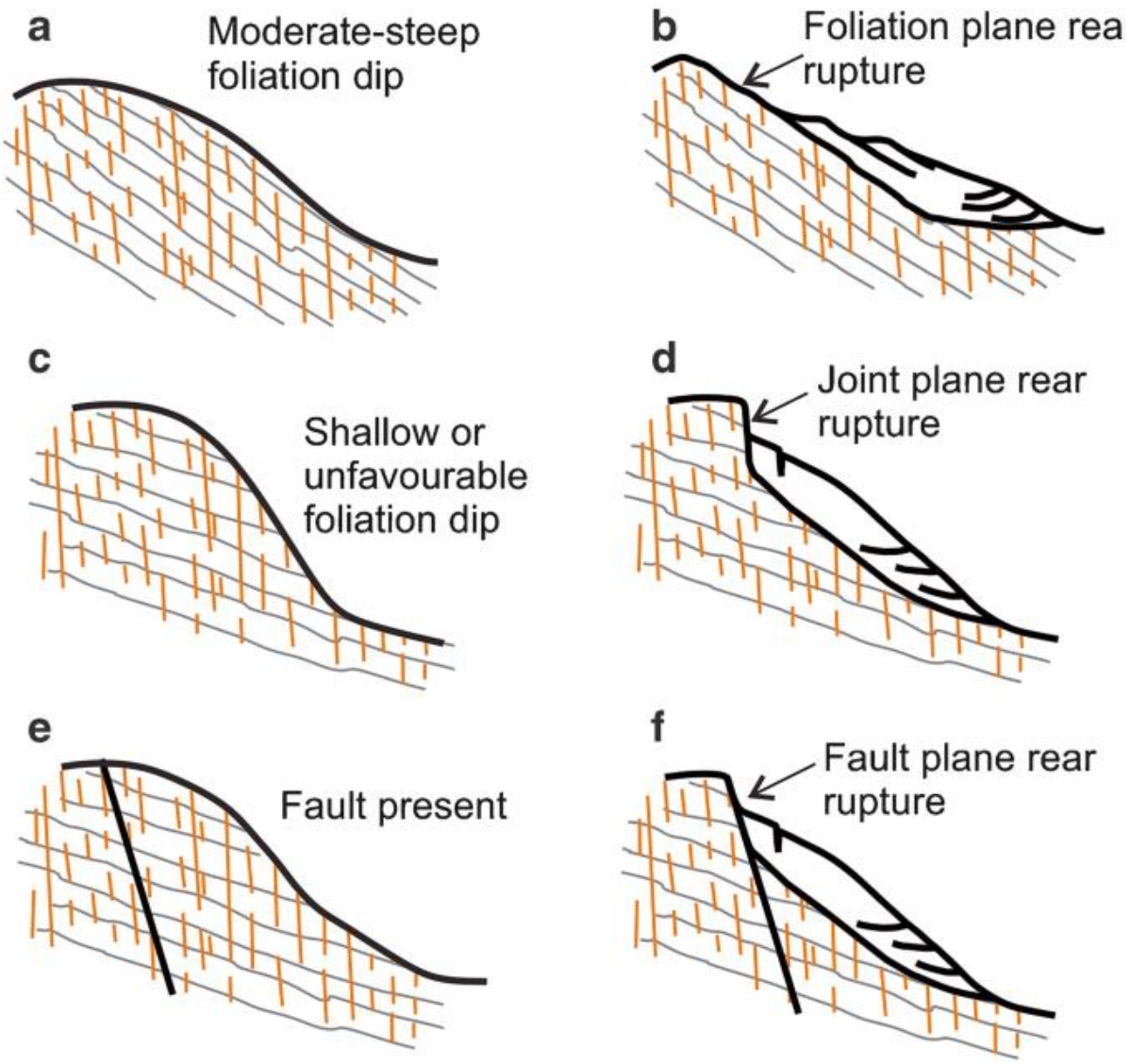
metamorphic rocks like marbles, quartzites and gneisses may be stable even with vertical slopes whereas the same cannot be said about *chalk* – a soft variety of limestone or shale or clay stone or soils. Here *composition* has both chemical and physical implications. *Composition* of mass means i) whether the mass is in the form of soil or rock. – If soil, whether it is cohesive or non-cohesive and also sandy, silty or clayey or a mixture of these components. – If rock, whether it is igneous, sedimentary or metamorphic with their detailed texture and composition. The role of composition is very important, for example sandstone, it occurs in great variety, if it is fine textured, dense and massive with silica cement, it is stable on vertical slopes, whereas the same rock with ferruginous, calcareous or clayey cements may become unstable at angles of 60^0 or even less. Along with composition, *texture* of rock is also important factor to consider the stability. Here, texture indicates size, degree and manner of packing of the constituent crystals or grains in a rock or soil. As such it controls and permeability of mass. Compact, dense and impervious rocks are more stable than loosely packed, porous and permeable masses under similar conditions.

D. Geological Structures: Geological structures are of great significance in defining stability of mass, especially in rocks. These structures are divided in to three categories. a) The bedding planes in stratified (sedimentary) rocks, b) The schistosity, foliation and cleavage in metamorphic rocks and c) The jointing structures, faults and shear zones in all types of rocks and fissures in clays.

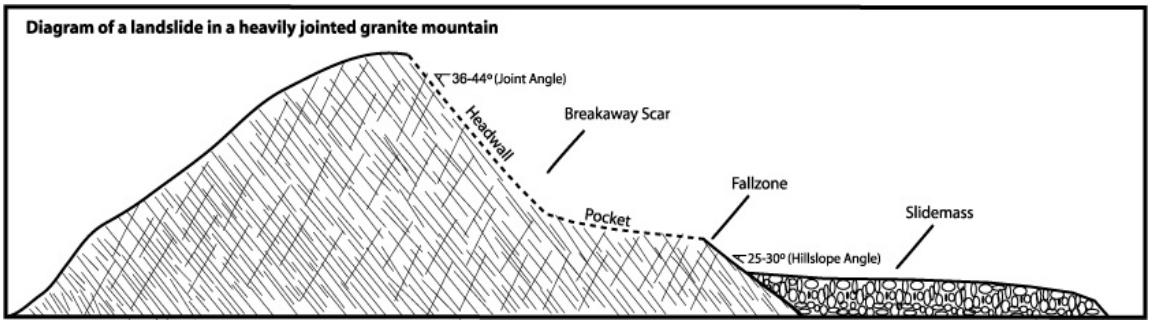
a) Bedding planes: The bedding plane is a plane of least cohesion in layered rocks masses. The bedding planes may be horizontal, inclined or even vertical. The dip of rock exerts influence on the stability of slopes. **1.** In fig. 1 bedding planes are horizontal, in such rocks slopes of valley or artificial cuts are stable up to 90^0. **2.** Fig. 2 indicate inclined layered rocks, in such situation, the stability of slope depends upon whether the layers are dipping *backward* in to the mountain or forward into the valley or the cut. *Dipping in to mountain* – slope is stable, *dipping in to valley* – slope is unstable, the layers may slide, the slope angle should be $<30^0$.



b) Schistosity & foliation: The schistosity and foliation found in metamorphic rocks behaves as planes of weakness. Slip may be common in presence of these structures when they are inclined towards the free slope.



c) The jointing structures: joints of any type are always to be studied with great caution in rocks making slopes for two reasons – **1**. Very few rocks are free from joints. The rocks are subjected to tension, compression or shear since their formation and joints are developed in them. **2**. They occur in group or sets affecting the rocks and reducing the shearing strength of rock mass considerably. While studying slope the *inclination* of jointing should be considered carefully. A set joints developed and being inclined toward the free side of the slope reduces the stability of the slope. Fault and shear zones are very sensitive to slip especially when lubricated with water.

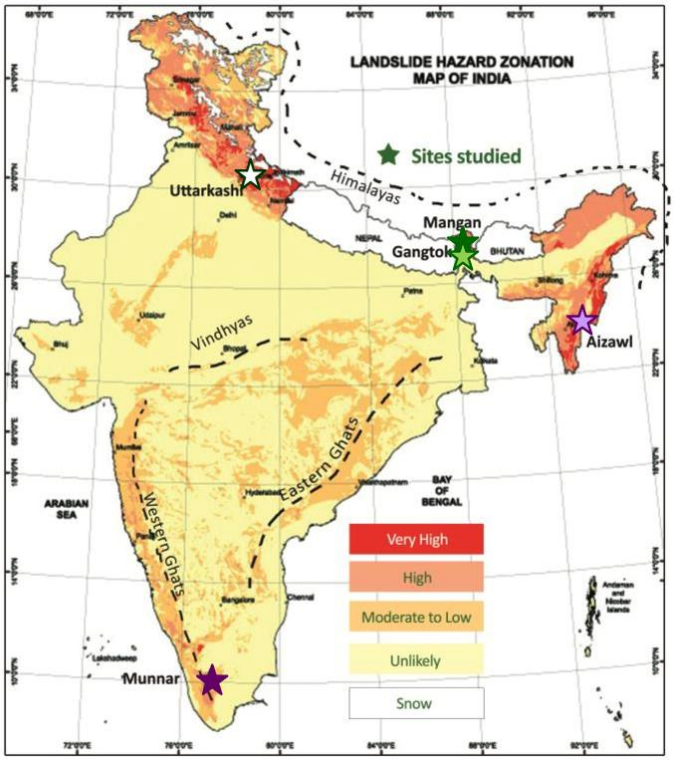


5. HAZARD ZONATION MAP OF MASS MOVEMENT

Landslide hazard zonation (LHZ) map is an important method to identify vulnerability of a slope or its parts. It is based on different ground characters and causative factors influencing stability of slopes. It is a tool which helps in tackling the menace of land sliding in following ways:

A. It helps the planners and engineers to identify hazard prone areas and to choose proper site or place for the infrastructure development.
B. It helps in taking precautionary measures to avoid syn-construction problems in hilly terrains and to undertake proper mitigation techniques to arrest or minimize further deterioration.
C. In case of road and rail networks in the hilly terrains landslides are major problems. Slope failure vulnerability can identify different locations where precautions can be taken.
D. It helps in identifying the most vulnerable areas so that Proper LHZ maps around the dam and reservoir site will help in controlling slope failures in reservoir area to control siltation and over spilling of water.
E. Transportation and water pressure tunnels can be realigned to avoid known and vulnerable landslide areas, especially at their mouth or portals.

The LHZ maps are made by incorporating different factors by mapping them, involved in the process of mass wasting and movement. These maps can be synthesized by using GIS technique to identify most and least vulnerable areas. These maps can be made on the scales of 1: 50,000 for regional scale, 1: 25,000 to 1: 50,000 for macro scale and 1: 2,000 to 1: 10,000 for micro scale zonation. The suitability of map scale will depend upon the size of the project. The Important factors to be mapped include: (i) Lithology, (ii) Topography and Slope Morphometric Analysis, (iii) Structural Geology, (iv) Surface Hydrology, (v) Forest Cover and Vegetation, (vi) Anthropogenic Land Use, (vii) Groundwater Condition.



6. MITIGATION AND PREVENTIVE MEASURES

Monitoring and control of mass movement: Our attempt should be to determine the causes of leading to instability of an area of some concern to man, monitor movements taking place in mountainous areas or in periglacial regions and as seasonal phenomenon may be understood.

A) Monitoring: monitoring of slope movement means we should understand the prone slope areas well before actual failure takes place. Some symptoms are indicative of possible slope failure. Monitoring can be achieved by surveying techniques by recording minor displacement by using electronic equipments, laser equipments, and settlement gauge. Pore water pressure is important factor and should be continuously monitored.

B) Control: Many slides are quick; therefore, the area of *weakness* should be established through its past history. The strength of mass may be improved by using following techniques. Before proceeding to control, one should compile the history of a slide area, study its areal extent as well as the depth up to which the mass is unstable and frequency of its failure. This is then followed by following geotechnical examinations –

1. Composition of the failing mass: Whether it is entirely soil or rock or a mix of the two;
2. Structural disposition of the mass: Especially dip and strike in stratified rocks and presence of planes of weakness;
3. Position of groundwater table within and around the critical area.
4. Relation of mass prone to failure with surface water body and
5. The slope of the ground.

- *Prevention and Mitigation*

  All slopes are susceptible to mass-wasting hazards if a triggering event occurs. Thus, all slopes should be assessed for potential mass-wasting hazards. Mass-wasting events can sometimes be avoided by employing engineering techniques to make the slope more stable. Among them are:

  - Steep slopes can be covered or sprayed with concrete to prevent rock falls.
  - Retaining walls could be built to stabilize a slope.

  - Drainage pipes could be inserted into the slope to more easily allow water to get out and avoid increases in fluid pressure, the possibility of liquefaction, or increased weight due to the addition of water. For diverting the surface flow, a series of drainage ditches at the top of slope may be necessary.
  - Oversteepened slopes could be graded to reduce the slope to the natural angle of repose.

  - In mountain valleys subject to mudflows, plans could be made to rapidly lower levels of water in human-made reservoirs to catch and trap the mudflows.

Some slopes, however, cannot be stabilized. In these cases, humans should avoid these areas or use them for purposes that will not increase susceptibility of lives or property to mass-wasting hazards.

7. SUMMARY

The earth is one of the most dynamic planet supporting different kinds of life including human beings who are in constant interaction with their surroundings, the environment. The processes which act on the earth constantly change its face. Sometimes sudden and swift action of nature cause harm to economic and social institutions of human beings. These surprising actions are called as natural disasters. There are many natural hazards which can inflict losses to human beings and their socio-economic gains. The important natural hazards are *drought*, *flood*, *cyclone*, *landslides*, *volcanism*, *earthquakes, tsunami* and *bolides impact*. These events are part and parcel of earth's dynamics and cannot be prevented from occurring. But, their impact can be minimized by reducing its severity, frequency and possibly its area of recurrence. This entails awareness, preparedness and mitigation, based on detailed analysis of its genesis, its past occurrences, probability of future events in terms of recurrence and magnitude.

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Nearly all exposed rocks and soils are subjected to weathering and erosion by natural processes termed as mass wasting. The constant but slow, down slope movement under the influence of gravity of disintegrated, degraded rocks, rock debris and resultant soil on slopes is termed as mass movement. When after a long period of lull and dead slow movement, there is a sudden transport of large amount of material then it is termed as landslide. As such it is a part of natural system and process, perhaps the first step in making of soil, which is the base of all kind of vegetation, especially agriculture. At the same time, it is a dreaded natural hazard, may cause loss of natural resources, infrastructure, property and life if there is improper development in landslide hazard prone areas

Landslide occurs when ever downward pull of gravity or shearing stresses overcome the static and resisting forces of the natural earth materials. Gravity is the main driving force for creating landslide movements followed by ingress of water. In general, the causes can be classed into natural and anthropogenic. The important natural causes responsible for land sliding are:

i. Degradation of slope due to weathering and erosion.
ii. Downslope movement of material on slopes with angle greater than the angle of repose.
iii. The presence of weak planes in form of bedding, joints and shear zones inclined towards the slope create potential slip surface causing landslide.
iv. The presence of salts, clay and altered mafic rocks either dissolved, leached or washed by the ingress of water can create weak planes for slope failures.

v. Pore water pressure in soil and weathered rocks as well as joint water pressure in rocks due to presence of ground water or water seeped due to incessant rain resulting into reduction in resistance to shear leading to landslide.

vi. Toe erosion or under cutting caused by river, glacier, sea wave and even wind may make a slope unstable leading to its failure.

vii. Wetting and drying as well as freezing and thawing may result into weakening of slope mass leading to sliding.

viii. Earthquakes and volcanism can also trigger an event of landslide alone as well as in combination.

B. At many instances it is the anthropogenic activities in hilly areas have resulted into slope failures such as:

a. Improper construction of houses and buildings.

b. Excavation and cutting of slope for making roads, rail tracks and other infrastructures.

c. Indiscriminate mining, associated blasting and vibrations caused by heavy machinery.

d. Deforestation and agricultural activity.

Learning resources:

1. **Books:**

1. Geomorphology – Savindra Singh
2. Environmental Geology - K.S. Valdiya
3. Subinoy Gangopadhyay (2013), Engineering Geology, Oxford University Press, New Delhi.
4. Krynine, Dmitri P and Judd, William R (2005), Principles of Engineering Geology and Geotechnics, CBS Publishers, New Delhi.
5. Tony Waltham (2002), Foundation of Engineering Geology, 3rd Edition, CRC Press, London.
6. Bhawani Singh and R. K. Goel (1999), Rock Mass Classification: A Practical Approach in Civil Engineering, Elsevier, Oxford.
7. Bell, F G (1983), Fundamentals of Engineering Geology, Butterworths, London.
8. Engineering Geology Field Manual (2001), 2nd Edition, Vol. 1, US Dept. of the Interior Bureau of Reclamation.
9. Sathya Narayana Swami (2000), Engineering Geology, Dhanpat Rai & Company, Dew Delhi.
10. Alam Masroor M. (2013), Fundamentals of Engineering Geology and Geo-Engineering, Axioe Books, India.

1.

2. **Syllabus of B. Sc. III Geology**
   https://drive.google.com/file/d/120EHc9HiM6KicNhnx6IYn_PEHqL47zf8/view?usp=sharing
3. **Material OER/URL/Instructor-made/**
   A. **Lecture notes**
   https://drive.google.com/file/d/1IryhIeYJOudYzFYrL4fqpZqbKD2fO3Kc/view?usp=sharing

   B. **Online book:**
   https://drive.google.com/file/d/1YAlyzHb7Ehc0pasB3d-FAd7HSnld3Jxw/view?usp=sharing

4. **Instructor-made -**
   A. **Power Point Presentation:**
   https://docs.google.com/presentation/d/1fuBg4cxDjfAwdYgN2oL2EafbaIK34HvY/edit?usp=sharing&ouid=108299766632040200276&rtpof=true&sd=true
   https://docs.google.com/presentation/d/1tY3ZBor-M6llZUFE4LiGNWivYtrEeoA7/edit?usp=sharing&ouid=108299766632040200276&rtpof=true&sd=true

   B. **Video -**
   https://www.youtube.com/watch?v=MpsRJ9LRabg

C. Question Bank:

https://drive.google.com/file/d/13WfUkQlNiTG1DVMh-jhyOXMDdGuZ23JL/view?usp=sharing
https://drive.google.com/file/d/1GlEBukYX8ZHzAtxR3CHIgT3OVrDUleW0/view?usp=sharing

D. Quizzes / Practice tests:

https://forms.gle/HYaHXCKHqPnCKEo97

Detailed Plan of Out-of-class and In-class activities

Sub Unit 1 - **Concept and applications of remote sensing**

Objectives – Student will know

- Know various causes of mass movements.
- Learn mode of rock mass failure and types of mass movement.
- Process, analyze, and interpret data to identify and classify mass wasting sites and connect their development to environmental factors.
- Synthesize susceptibility models with environmental, social, and political considerations to develop a comprehensive landslide risk assessment.

Units	**Out-of-class activity** **Details of Activity**	**In-class activity** **Details of Activity**	**Assessment**
1.1	Students should read out the topic from a book Students study the ppt.	Discussion on the topic Check the level of understanding through Question – answer session	Question – answer session
1.2	Students should read out the topic from a book Students should watch video on given links	Discussion on the topic Help students to understand the concept and components of remote sensing Help students to know various applications of remote sensing	Question to write in detail On-line quiz