

LANDSLIDES

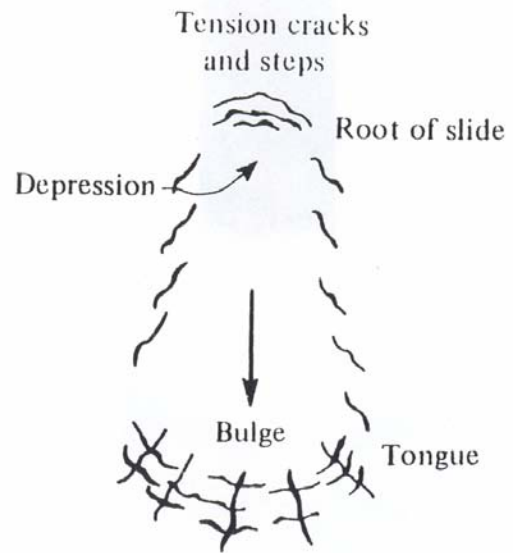


- In many parts of the world, especially in mountainous countries, landslides are very common and have serious consequences for almost all construction activities in these countries.
- Even relatively small changes of the stability may trigger landslides, especially in areas where slides previously have taken place.

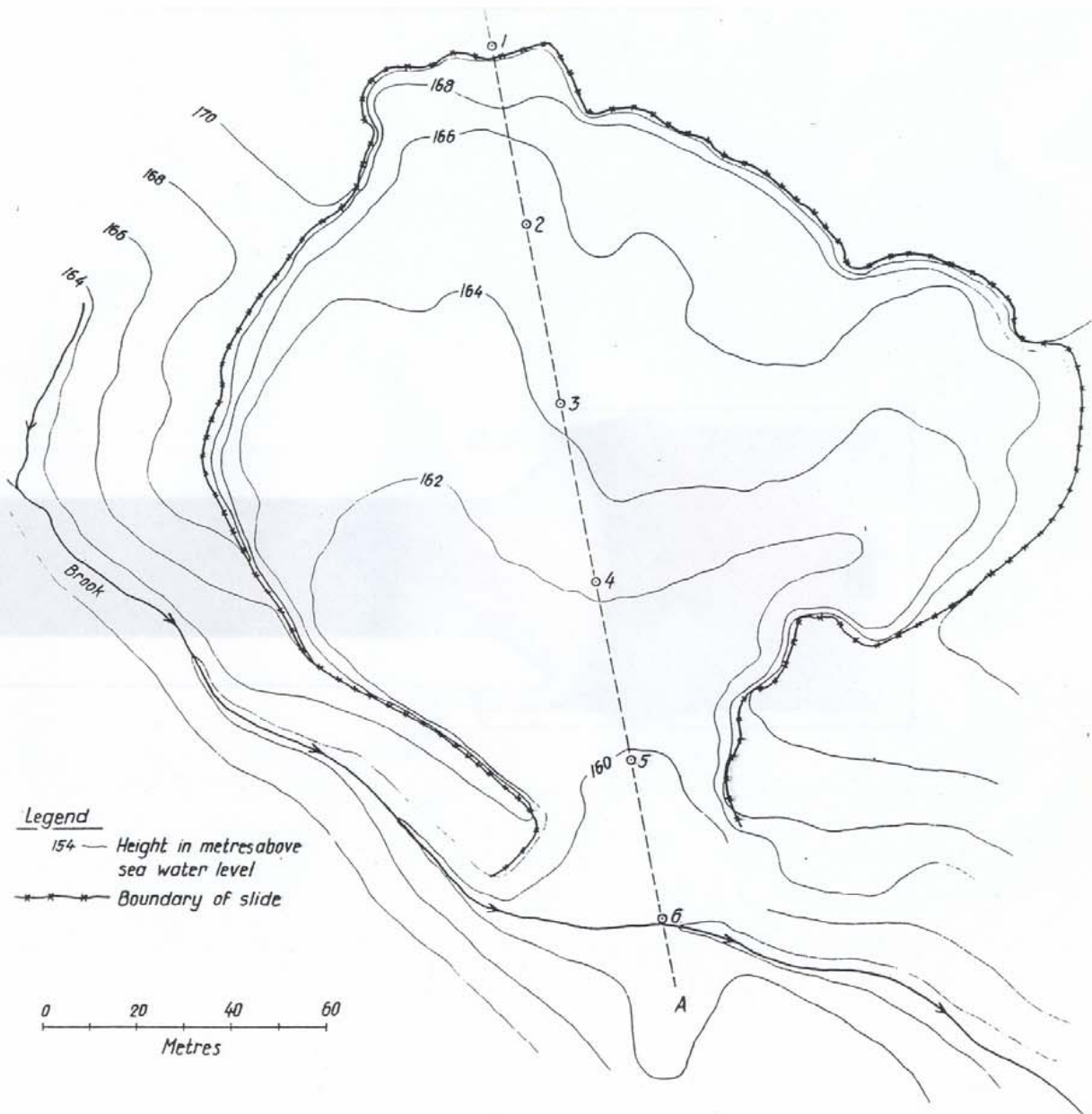
- The first sign of an imminent landslide is the appearance of surface cracks in the upper part of the slope, perpendicular to the direction of the movement. These cracks may gradually fill with water, which weakens the soil and increases the horizontal force which initiates the slide. Frequently, inclined shear cracks can also be observed on both sides of the slide, as well as a slight bulge at the toe of the slope.

- Landslides are primarily caused by gravitational forces but occasionally seismic forces can be a contributing factor. A landslide is primarily the result of a shear failure along the boundary of the moving mass of soil or rock. Failure is generally assumed to occur when the average shear stress along the sliding or slip surface is equal to the shear strength of the soil or rock as evaluated by field or laboratory tests.

- The geologists regard landslides as one of the many natural processes which act on the surface of the earth as part of the general geological cycle.
- The engineer, on the other hand, tries to determine the maximum angle at which a slope is stable and studies the stability of a slope in terms of a factor of safety.



Plan of typical slide in cohesive material. (After Terzaghi and Peck, 1967.)



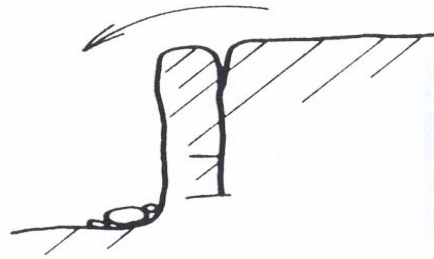
Slide at Ullensaker, December, 1953. (After Bjerrum, 1954.)

Causes of Landslides

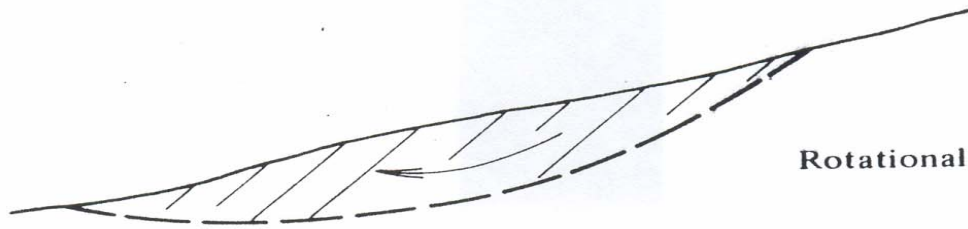
- Construction Operation of Erosion
- Tectonic Movements
- Earthquakes (Vibrations)
- Rains or Melting Snow
- Frost Action
- Dry Spells
- Rapid Draw Down
- Seepage from Artificial Sources of Water
- Seepage from Artificial Sources of Water

Classification of Landslides

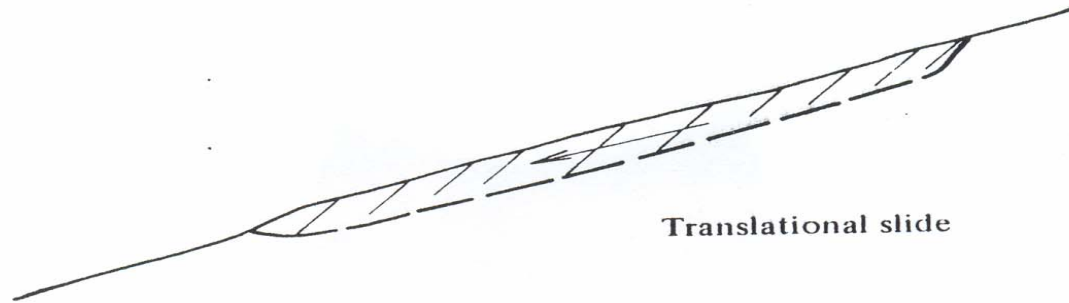
- Falls
- Rotational Slides
- Translational Slides
- Flow



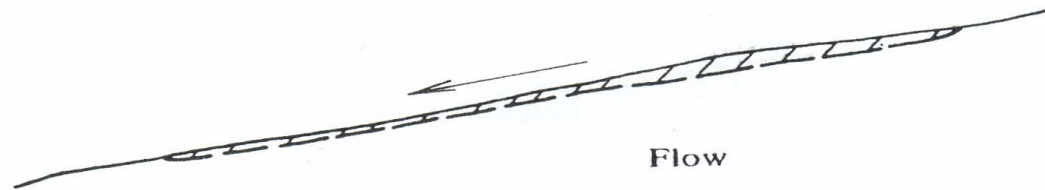
Fall



Rotational slide

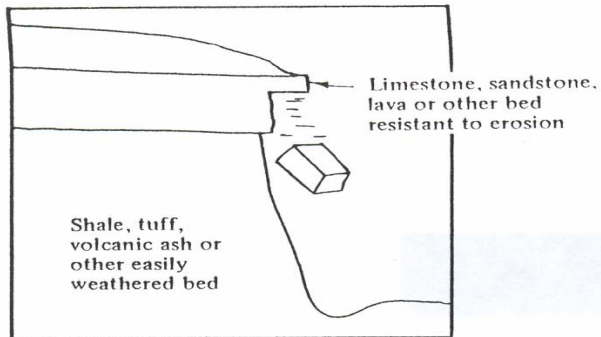


Translational slide

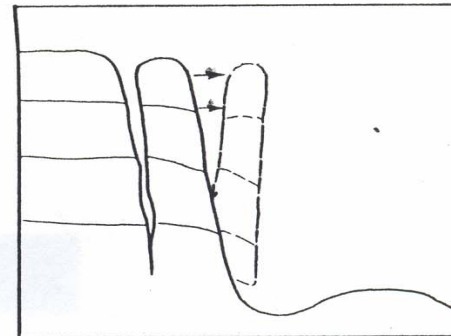


Flow

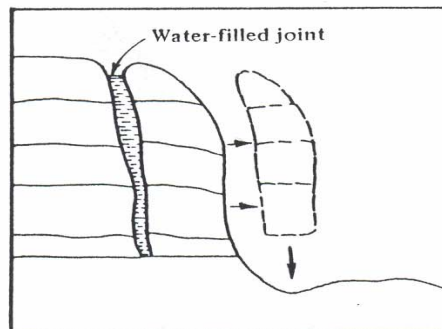
Main slide types.



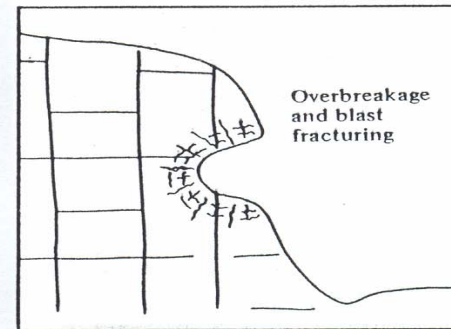
(a) Differential Weathering.



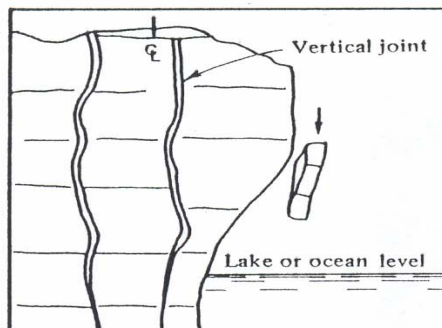
(b) Frost wedging in jointed homogeneous rock.



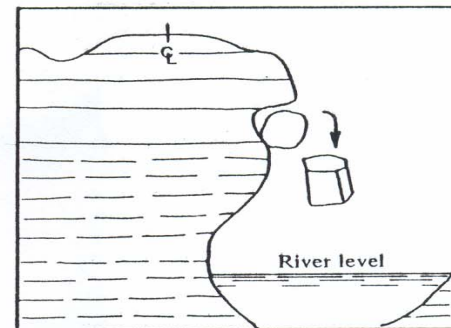
(c) Jointed homogeneous rock. Hydrostatic pressure acting on loosened blocks.



(d) Homogeneous jointed rock. Blocks left unsupported or loosened by overbreakage and blast fracture.

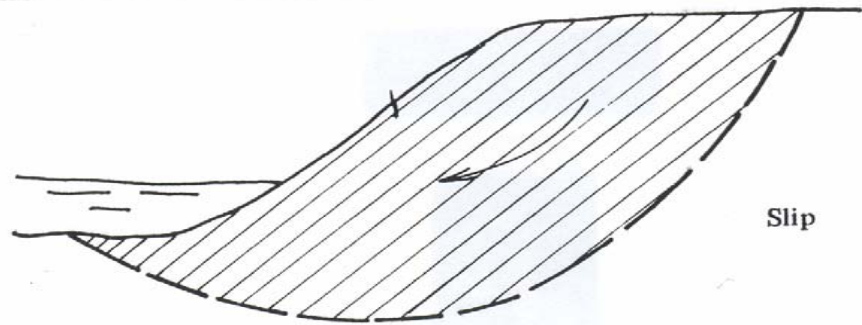


(e) Either homogeneous jointed rock or resistant bed underlain by easily eroded rock. Wave cut cliff.

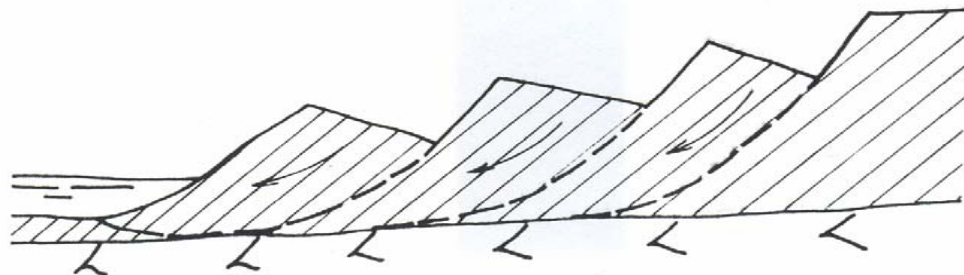


(f) Either homogeneous jointed rock or resistant bed underlain by easily eroded rock. Stream cut cliff.

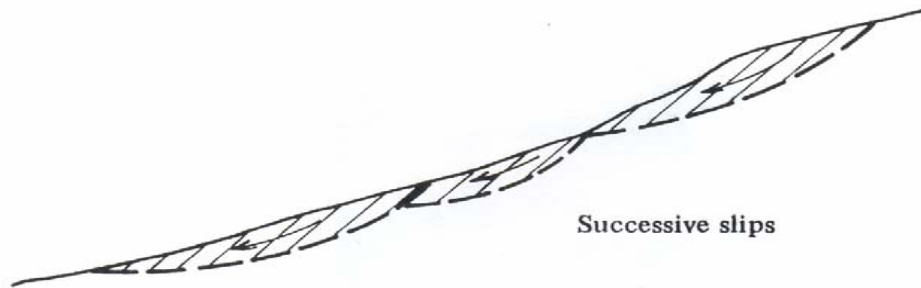
Examples of rockfalls. (After Varnes, 1957.)



Slip



Multiple rotation slide

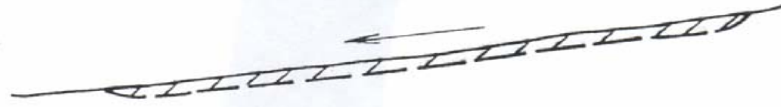


Successive slips

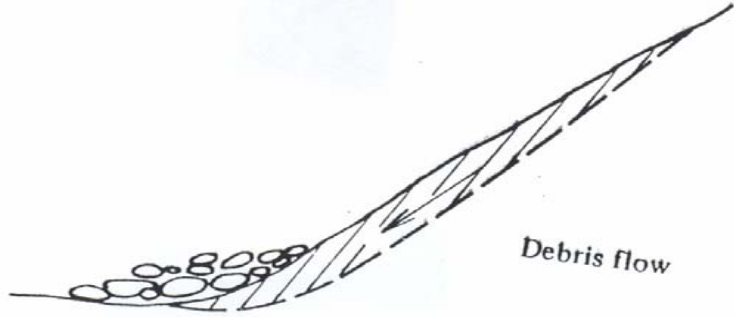
Rotational slides.



Earth flow



Mud flow



Debris flow



Flow slide

Flows.

Movements Associated With Landslides

- Creep
- Creep Rate
- Thickness of Failure Zone
- Total Displacement Before Failure
- Slide Velocity

Investigation for Landslides

- Field Studies
- Laboratories Studies
- Stability Calculations
- It is important that the field and laboratory investigations be supplemented by field measurements so that the behavior of a slope can be checked and corrective measures be taken in times.
- First Step:
- Collection of available information geological, hydrological, topographical, and soil maps.

Instrumentation

- **Surface Movements**
- **Telemeters**
- **Inclinometers**
- **Boreholes Extensometer**
- **Piezometer**
- **Slide Warning Systems**

Analysis of Landslides

- **Determination of shear strength parameters**
 - Angle of internal friction
 - Cohesion
 - Undrained Cohesion
- **Determination of the slip surface**
 - Depends on the geology
 - Bedding planes
 - Faults
 - Old sliding surfaces

Surface of Landslides

May be determined using

- Trenches
- Boreholes
- Trial Pits
- Theoretical Calculations

Methods of Correcting Landslides

- Geometrical Methods
 - Flattening of slope
 - Excavation at top of slope
 - Fill at toe of slope

- **Hydrological Methods**
 - **Surface drains**
 - **Drain holes**
 - **Sand drains**
 - **Inverted filters**
 - **Other methods**
- **Aim:**

drainage of surface water and lowering of ground water level.

- **Mechanical Methods**
 - **Compaction**
 - **Freezing**
 - **Grouting**
 - **Rock Bolts**
 - **Piles**
 - **Retaining Walls, Sheet Pile Walls, and Toe Walls.**

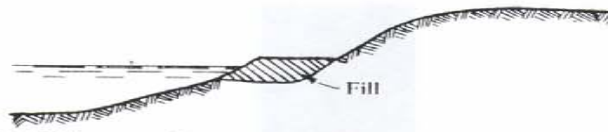
- **Protective Measures**



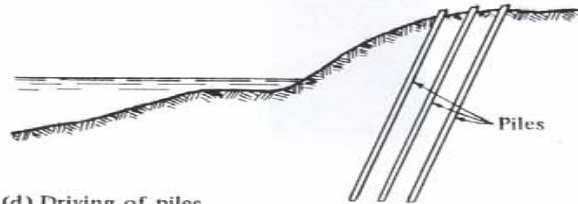
(a) Excavation at top of slope



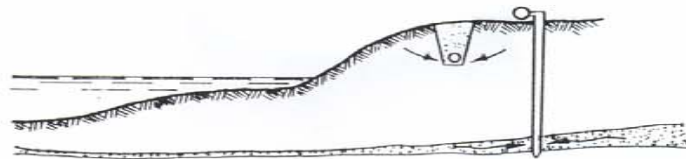
(b) Flattening of slope



(c) Fill at toe of slope



(d) Driving of piles



(e) Lowering of groundwater level



(f) Erosion protection

Stabilization of slopes along the Göta River in Sweden.