Mass movement processes and landforms

DEFINITION.

"Mass wasting is the downslope movement of rock debris in response to gravity..."
Easterbrook (1999).

“...without the direct aid of other media such as water, air or ice.”
Selby (1985).

Classification of mass wasting processes by...

- Velocity
- continuity
- slope material
- shape of moving mass
- water content
- process

Selby (1985), followed Varnes (1975) and suggested combining material and process.

Why does mass wasting occur?

- “Downslope movement occurs when gravitational driving force exceeds frictional resistance of the material resting on the slope.”
  Easterbrook (1999)

Controls on the driving force.

- Material characteristics
- slope angle
Controls on resistance.

• friction between the moveable material and its base
• friction between material grains
• physical properties of the slope material (does it behave like an elastic solid, a plastic solid or a fluid?)

Driving Forces.

The ultimate driving force is gravity. At any point on the earth’s surface, gravity \( F_g \) acts vertically downwards towards the Earth’s centre, but can be resolved into two components on a sloping surface, one parallel to the slope surface \( F_p \) and one perpendicular (“normal”) to it \( F_n \).

\[
F_p = F_g \sin \theta \quad \text{and} \quad F_n = F_g \cos \theta
\]

This is at a maximum on a horizontal surface and at a minimum on a vertical wall.

Stresses acting on slope materials

TENSILE - stresses which act to pull a rock or soil mass apart, changing its SHAPE
EXPANSIVE - opening of fractures or enlargement of pores causes a change of VOLUME
SHEAR - stresses which act to deform a body by sliding one part over another, changing SHAPE
COMPRESSIVE - reductions in void space reduce VOLUME
ANY change of shape or volume by the application of stress is termed STRAIN.

Factors which influence the type of behaviour exhibited by slope materials in response to stress.

Strength of material

• friction
• the normal load (weight of material forcing crystals or mineral grains against each other)
• cementation or cohesion, binding grains or crystals together
All can be changed by addition/loss of water.
What is friction?

“...the mechanical resistance to the relative motion of adjacent masses of material.” Easterbrook (1999)

- Sliding friction - between contiguous masses, separated by a well-defined plane. Varies with roughness of surfaces, area of contact points, moisture at the contact and upward pressure of water or gas. (NB the effect of slope angle)

- Internal friction - friction between grains in a mass of material. A mass of dry, unconsolidated grains will slide until it reaches a stable angle - the ANGLE OF REPOSE.

Effects of water

- Small amounts of water added to a mass of dry grains will lead to an increase in cohesion due to surface tension of films of water on grain surfaces (the sandcastle effect)

- Water can seep along joint or bedding planes in solid materials, weathering the contact and providing an upwards “push,” thereby reducing friction.

- Water adds weight to unconsolidated masses, which can trigger failure in some marginal cases.

- Pore water pressure. If the pores in a mass are full of water, part of the weight of overlying material is carried by the water (like inflating a vehicle tyre), instead of being met at the grain/grain contacts, thereby reducing the friction between grains and so the strength of the material.

SLOPE STABILITY

- We saw previously that slope movements may occur by creep, sliding, flowing or failure. In all cases, movement will occur when the factor of safety (F) is less than 1.

\[ F = \frac{\text{frictional forces}}{\text{gravity force}} \]

On any slope, the value of F may change in response to either INTERNAL (change the resistance) or EXTERNAL (change the stress) TRIGGERS

**INTERNAL TRIGGERS**
- increase in PWP by saturation or rapid drawdown of an adjacent water body
- dissolution of cement

**EXTERNAL TRIGGERS**
- loading of the slope by saturation or construction of buildings, roads
- earthquakes
- removal of lateral support due to weathering, erosion or excavation
- solutional or erosive removal of support from beneath

Mass movement

- Subsidence
- Fall
- Flow
- Slide
- Heave
- Creep
Sliding, flowing and creeping

The process of creep.

Flows

- Earthflows, debris flows, mudflows. Differentiation is difficult and terminology is slippery (!); earthflows are slower than mudflows (but faster than solifluction) and may have a cover of non-fluid material. Debris flows are more viscous than mudflows, which consist primarily of wet, slippery mud while the other two types consist of a coarser matrix.
- In all cases, initiation of movement requires
  - a supply of unconsolidated sediment
  - infrequent, high intensity run-off
  - lack of constraining vegetation
  - favourable topography - steep slopes!

Rapid, discontinuous movements

- Rockslides - rocks break along joints/bedding planes and slide down a planar surface.
- Debris slides - masses of unconsolidated material break loose and slide on the underlying surface (very common where thin regolith overlies bedrock).
- Rockfall - rock breaks loose from steep slopes and falls through the air (or bounces/rolls)
- Slump - downward and outward sliding of a mass of material along a concave-up, curved shearing plane, with some backward rotation of the land surface at the top of the failure.

Mass wasting occurs in all environments.

But very large landslides are most common in tectonically active upland areas, where they are favoured by the lethal combination of
- steep slopes
- rapidly incising rivers
- glaciers on valley floors
- severe physical weathering producing jointed and fractured rock
- fluctuating groundwater pressure
- episodes of intense rainfall.

- On lower slopes and lowland areas, most landslides occur as a result of water pressure increases during heavy rain or snowmelt.