LECTURE #12: Landslide Types & Ground Collapse

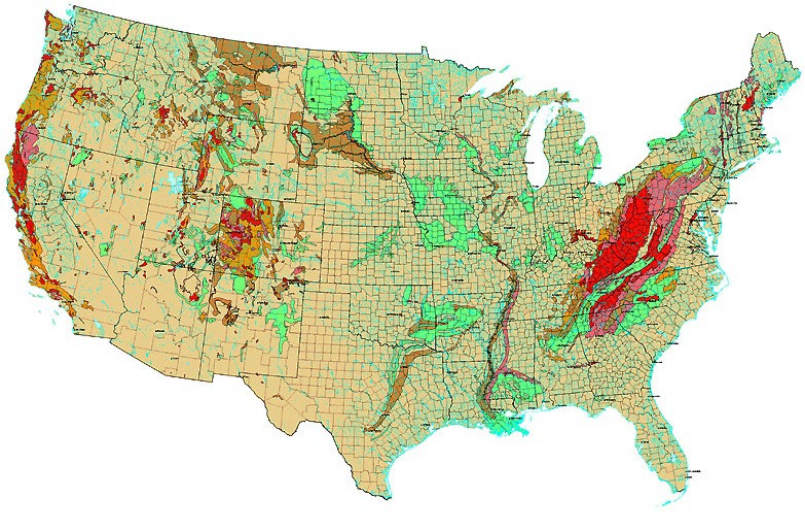
Date: 24 February 2025

I. Landslides

- wide-spread hazard: global reach
  - affects coastal and inland locations
  - urban and rural populations

  - can be initiated by other hazards
    - volcanic eruptions (lahars, volcanic landslides)
    - severe storms (erosion of cliffs)
    - tsunamis
    - earthquakes

  - can be initiated by human activity
    - road cuts
    - skiing (snow avalanches)



landslide hazard map for the US

- Deadly in Pittsburgh's history …
  - In 1942, a rock fall buried a bus near Aliquippa, killing 22 people on board
  - In 1951, excavators for a new office building made an eight-foot deep cut at the base of a hill along Island Avenue in Stowe, triggering a 500-foot wide landslide that destroyed six houses, covered the road and dislocated a streetcar line and various utility lines

  - In 1983, a rockslide killed two people who were sitting in their cars at a traffic light on Saw Mill Run Boulevard

  - In 2006, Kilbuck Township – massive landslide closed Rt. 65 for a month

II. General Information

- landslide: down-slope displacement of material (known as a *mass movement*)
  - can occur both on land and under water
  - can occur in rock, soil, ice/snow

- significant problem in U.S. annually
  - in every state
  - $2 - $4 billion in damage
  - 25 - 50 deaths on average

- many different types that are classified by:
  - rapidity of movement
  - type of materials transported

- slope stability
  - driving forces vs. resisting forces
  - driving force
    - gravity
    - excess loading

  - other factors:
    - amount of water
    - strength/cohesiveness of materials

- unconsolidated materials:
  - angle of repose: maximum angle at which granular material can be piled
    - for dry sand = ~33 - 35°

    - can be somewhat higher or much lower depending on the material

    - also affected by:
      - particle size
      - particle shape
      - sorting
      - packing
      - moisture content

1995 La Conchita, CA landslide

- role of water:
  - increases loading
  - reduces cohesion
    - dissolves cements between particles
    - expansion of clays reduces friction between grains
    - frost wedging weathers rocks

III. Initiation of Mass Movements:

- saturation by water (adds lubrication)
  - heavy rains
  - rain following a prolonged drought

- over steepening of slopes
  - erosion by streams, waves, glaciers
  - human activity (road construction, mining activities)

- freeze/thaw cycles
- earthquakes
- volcanic eruptions
- steep slopes
  - creation of unconsolidated debris
  - removal of vegetation *(either human caused or after a wildfire)*

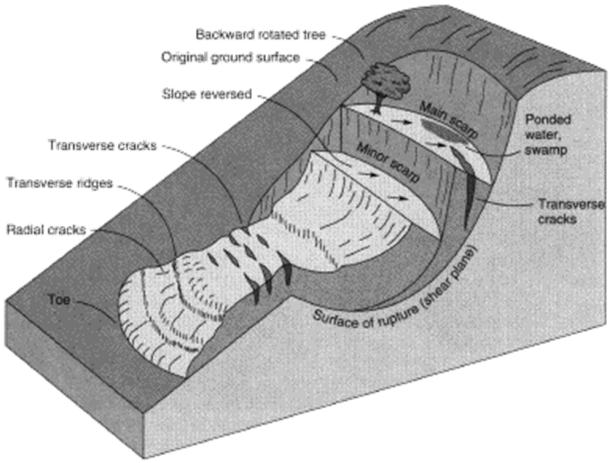
- vibrations
  - machinery
  - traffic
  - thunder

- overloading
  - snow
  - stockpiling (rock, ore)

IV. General Types of Mass Movements:

1. **fall:** material moves through air, lands at base of slope
   - very rapid process
   - initiated by natural or human activity
   - example: rock-fall

2. **slide:** material moves but stays in contact with underlying surface
    - cohesive blocks of material
    - no internal shearing
    - forms a head-scarp
    - slide types:
        - <u>rockslide</u>
            - ➢ most common on steep slopes (road cuts, valleys)
            - ➢ velocities of 100+ miles per hour



- <u>landslide</u>
    - ➢ moves rapidly as a unit or series of units along the underlying surface
    - ➢ material moves until frictional resistance exceeds driving force

Landslide progression
Polhemus Road, San Mateo County, CA (1996-1997 rainy season)

- <u>slump</u>
    - ➢ sliding of material along curved surface
    - ➢ common in unconsolidated sediments, weaker rock units

3. **flow:** materials break up and moves as a viscous fluid (differential shearing)
   - no distinct basal plane/surface
   - greatest velocity at upper surface
   - *can be the wettest, driest, fastest and slowest types of mass movements*
   - falls & slides can undergo transitions to flows

   - flow types:
     - <u>creep</u>
       - very slow movement of soil down slope
       - tell-tale indicators
       - most important in terms of total volume

       - initiated:
         - freeze-thaw cycles
         - wetting-drying cycles
         - biological displacement

bent tree trunks: evidence of soil creep

     - <u>solifluction</u>
       - very slow movement of soil down slope
       - water/ice saturated sediments
       - most important in colder/alpine environments

     - <u>mud and debris flows</u>
       - rapid movement of soil and water

       - water = ~ 30% total volume (mudflows)

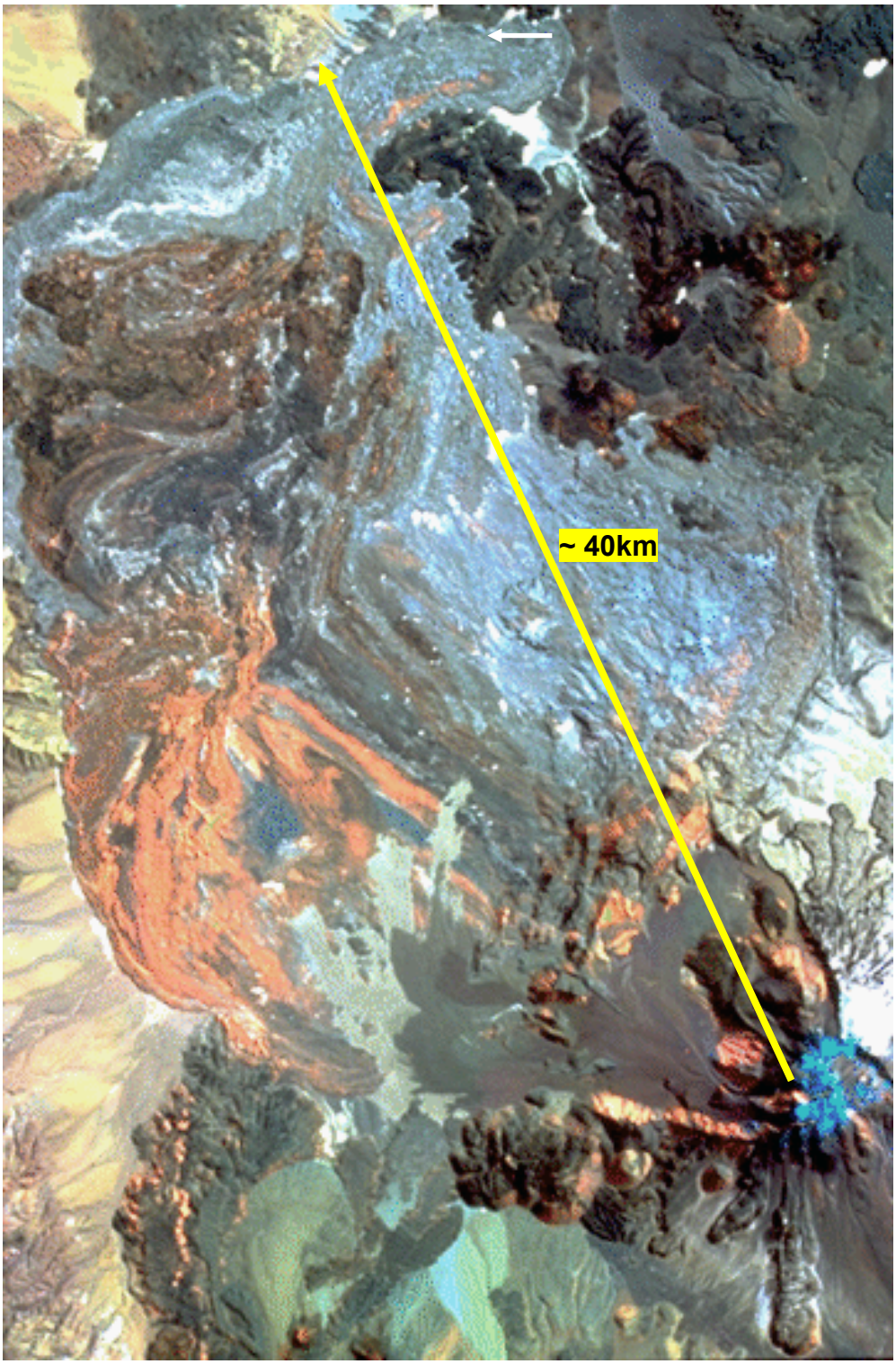
       - e.g., lahars, flash floods

Lahar at Mt. St. Helens volcano

     - <u>debris avalanche</u>
       - unconsolidated debris moves rapidly down slope
       - highest velocities
       - semi-circular scarp at the head, chute, and debris fan

       - *example:* Peru, 1970:
         - earthquake triggered avalanche
         - deposit moved 7 miles in < 3 minutes
         - 80m (~260 ft.) high wave of debris coming down the valley
         - 30,000 people killed

- *example #2:* Socompa Volcano, Chile (7,000 years ago)
  - major collapse produced a massive debris avalanche
  - 500 km^2 coverage
  - due to large uplift thrust fault
  - 3 km blocks slid in-place
  - smaller fragments flowed rather than sliding



Satellite image of Socompa Volcano, Chile showing the large debris avalanche. The flow stopped over 50km away (white arrow).