Mass Wasting

Introduction

- Landslide and other ground failures posting substantial damage and loss of life
- In U.S., average 25–50 deaths; damage more than $3.5 billion
- For convenience, definition of *landslide* includes all forms of mass-wasting movements
- Landslide and subsidence: naturally occurred and affected by human activities

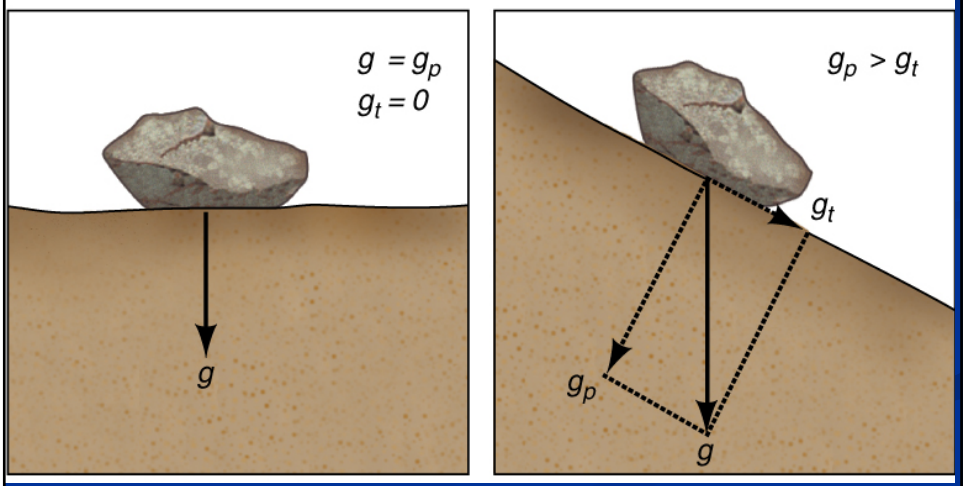
Mass wasting

- Downslope movement of rock and soil debris under the influence of gravity
  - Transportation of large masses of rock
  - Very important kind of erosion

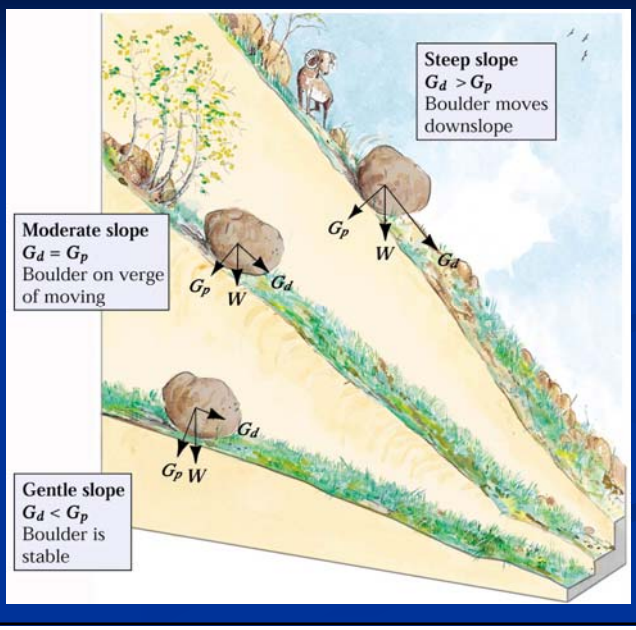
Mass wasting

Gravity is the driving force of all mass wasting

Effects of gravity on a rock lying on a hillslope



Boulder on a hillside



Mass Movement

- Mass movements occur when the force of gravity exceeds the strength of the slope material
- Such an occurrence can be precipitated by slope-weakening events
  - Earthquakes
  - Floods
  - Volcanic Activity
  - Storms/Torrential rain
  - Overloading the strength of the rock

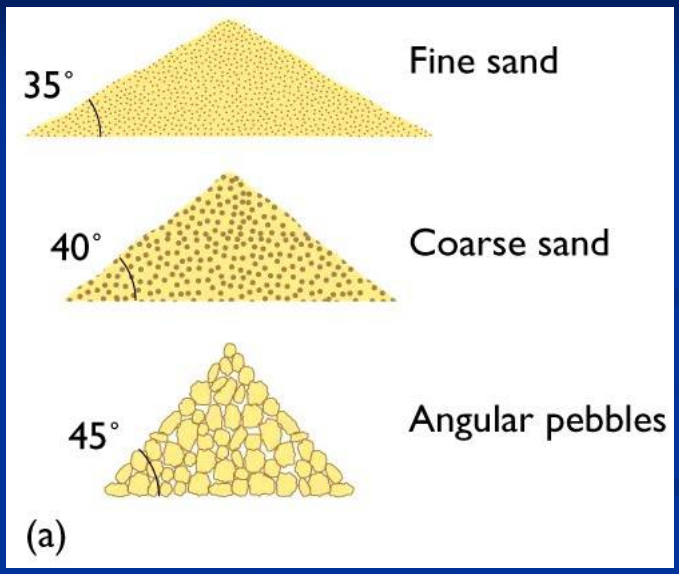
Mass Movement

- Can be either slow (creep) or fast (landslides, debris flows, etc.)
  - As terrain becomes more mountainous, the hazard increases
- In developed nations impacts of mass-wasting or landslides can result in millions of dollars of damage with some deaths
- In less developed nations damage is more extensive because of population density, lack of stringent zoning laws, scarcity of information and inadequate preparedness
- **We can't always predict or prevent the occurrence of mass-wasting events, a knowledge of the processes and their relationship to local geology can lead to intelligent planning that will help reduce losses of life and property

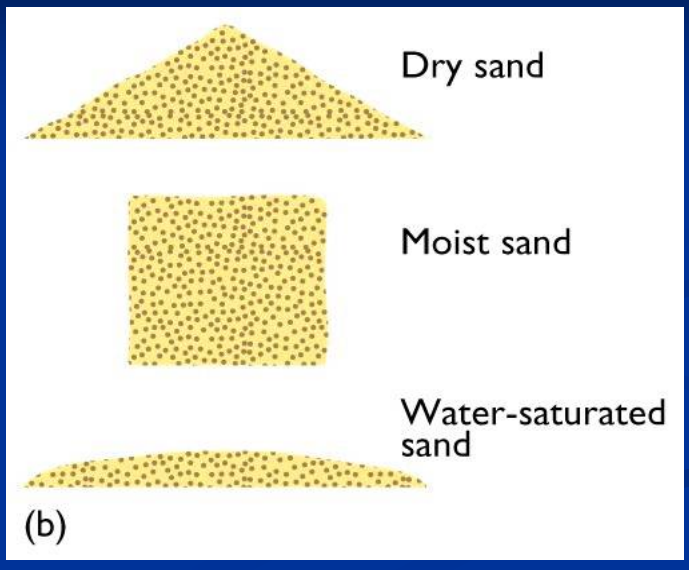
Controls and Triggers of Mass Wasting

- Important factors include:
  - The role of water
    - Diminishes particle cohesion (friction)
    - Water adds weight
  - Oversteepening of slopes—slope angle
    - Stable slope angle (**angle of repose**) is different for various materials
    - Oversteepened slopes are unstable

Angle of Repose- Effect of Grain Size

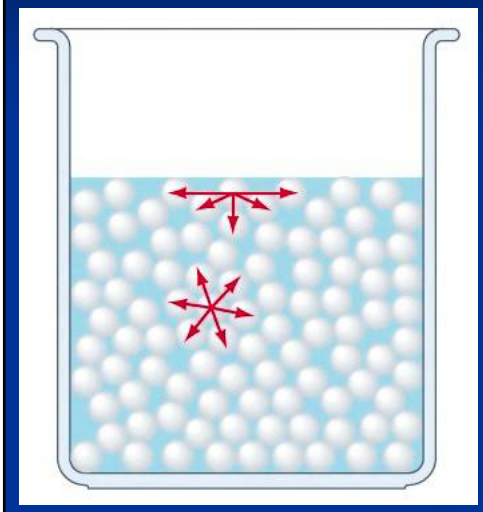


Angle of Repose- Effect of Moisture Content



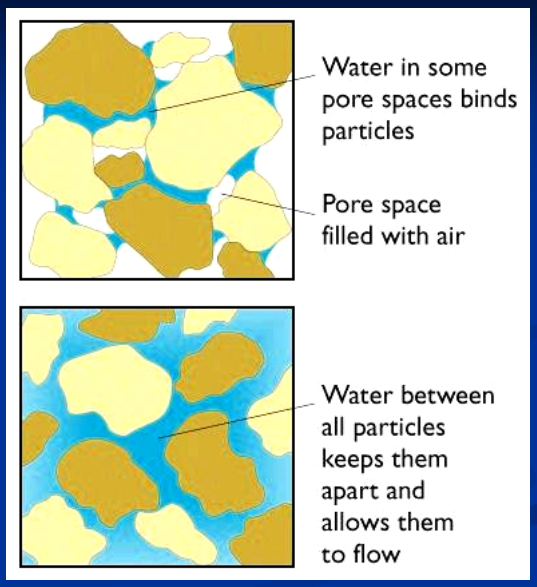
How do they do that?

Surface Tension

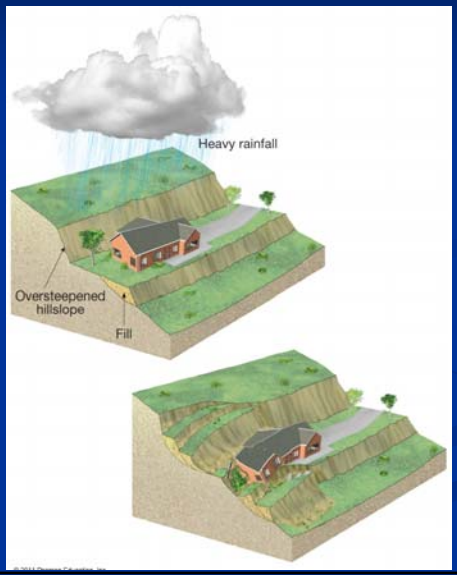


Unsaturated Soil

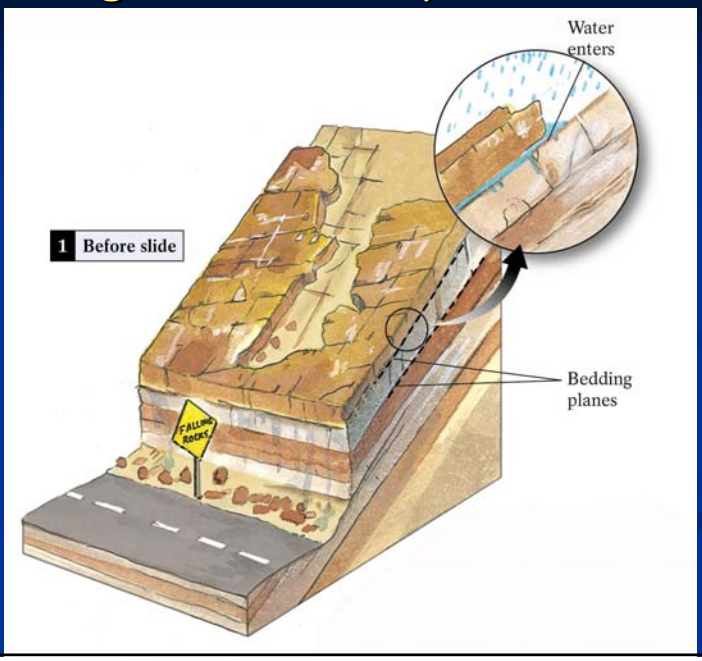
Saturated Soil



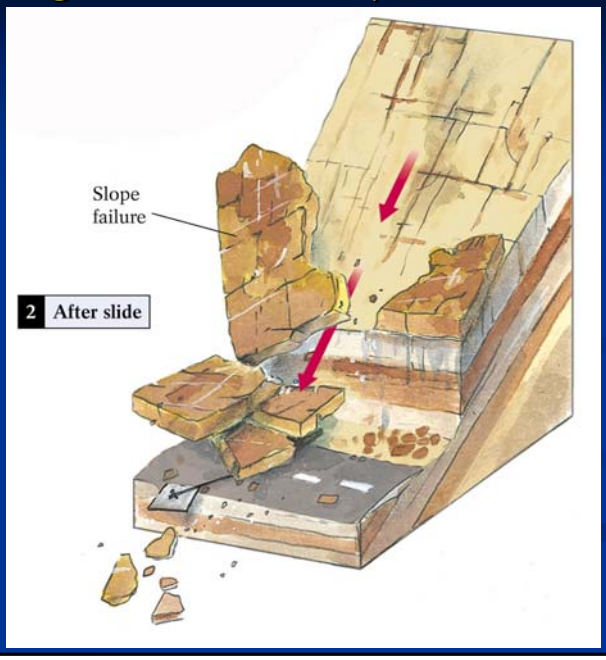
Slope Instability Caused by Oversteepening



Water causing failure in slopes of solid bedrock



Water causing failure in slopes of solid bedrock



Controls and Triggers of Mass Wasting

- Important factors
  - Removal of anchoring vegetation
    - Root system binds soil and promotes stability
  - Earthquakes as triggers
    - May cause expensive property damage
    - Can cause **liquefaction**—Water-saturated surface materials behave as fluid-like masses that flow

Fire increases the susceptibility for erosion and mass movement

Controls and Triggers of Mass Wasting

- Landslides without triggers
  - Slope materials weaken over time.
  - Random events that are unpredictable

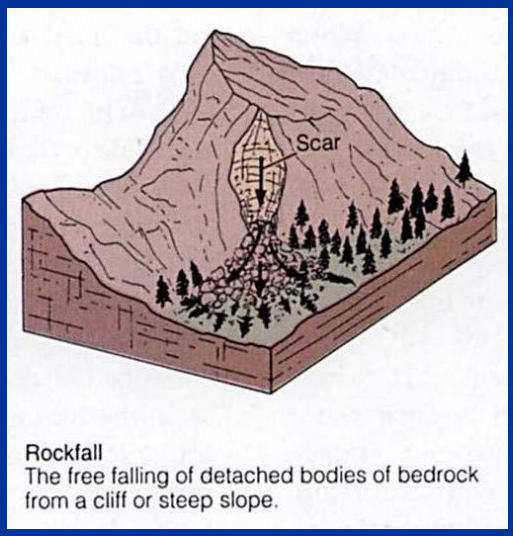
Weathered Shale

Fig. 11.6

Classification of Mass Wasting Processes

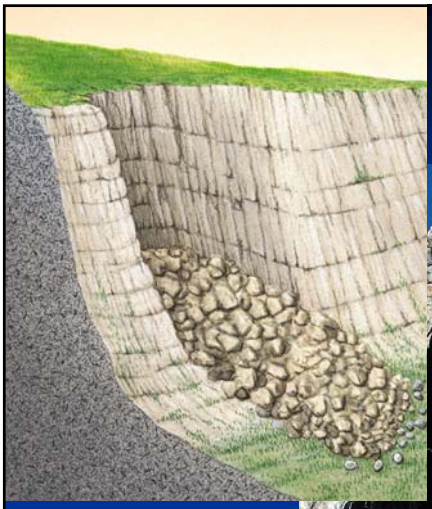
- Generally, each event is classified by:
  - Type of material involved
    - Mud, Earth, Rock
  - Type of motion
    - **Fall** (free-falling pieces)
    - **Slide** (material moves along a surface as a coherent mass)
    - **Flow** (material moves as a chaotic mixture)
  - The velocity of the movement
    - Fast or Slow

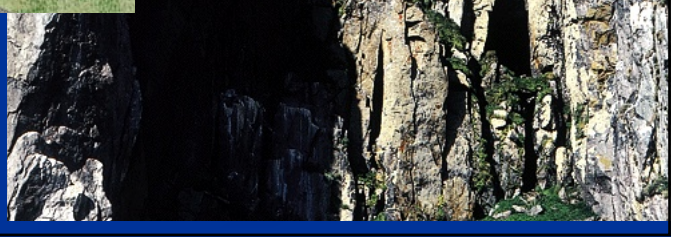
Mass Wasting Processes

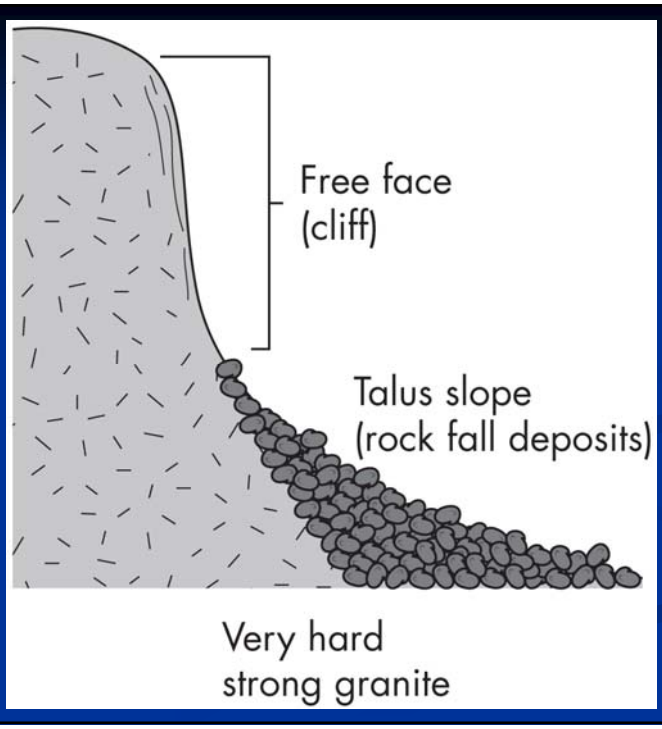


Rockfall
The free falling of detached bodies of bedrock from a cliff or steep slope.

Rockfalls







Sunday May 9, 1999
50 people injured
8 people dead

Rockfall was small
-25-30 cubic yards
-Weathered basalt
-500 feet above

Six dead after Sacred Falls landslide

A roar like thunder, then screams of agony

In the aftermath: Rocks continue to fall, making the area too hazardous to enter

Dead and injured: Six are dead and dozens are hurt, but 'everybody's accounted for'

List of victims

By Lori Tighe
and Rod Ohira
Star-Bulletin

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With rocks and debris still tumbling from steep ledges today, Fire Department officials called off the search for more victims of a deadly landslide at Sacred Falls.

Six people were killed and dozens injured in the Mother's Day tragedy at the popular hiking spot in Hauula, but firefighters said today that nobody was reported missing.

"I'm pretty comfortable that everybody's accounted for," said Fire Chief Attilio Leonardi. "But we're leaving our options open, in case there are any reports of people missing."

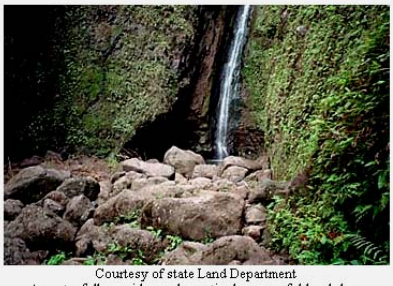
"It's unsafe for rescue people or anyone else to go up there," he said. The governor has ordered the state park closed until further notice.

Hotlines

Hotlines have been set up for relatives of those who may have been caught in the Sacred Falls landslide. **Mainland U.S.** and **neighbor island** callers should use **1-800-898-2353.** Callers on **Oahu** should use **523-4122.**

A pool is nestled at the bottom of the 87-foot falls. It is large enough for swimming and visitors often jump or dive off the low ledge. Large rocks surround the base of the pool where visitors sunbathe.

Falls draws thousands yearly



Courtesy of state Land Department
A waterfall provides a deceptively peaceful backdrop to rocks from Sunday's landslide.

Geologists say exact cause unknown

Koolaus and other ranges are susceptible to slides

By Craig Gima
Star-Bulletin

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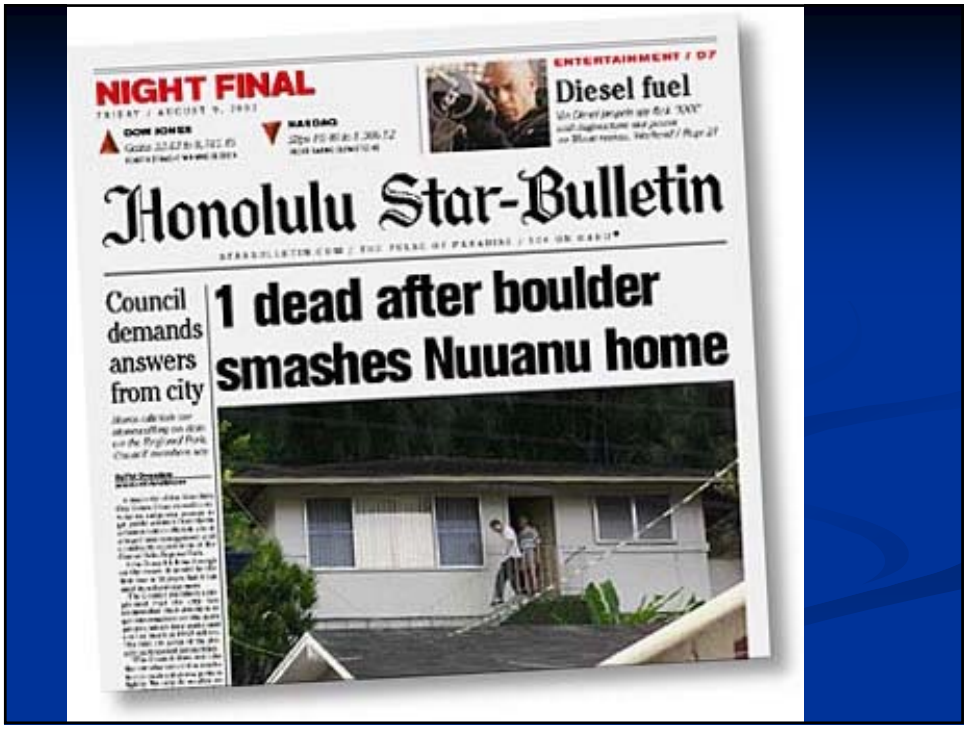
It may have been the weather -- the heat and lack of rain -- that caused a section of an old lava flow to give way. Or it may have been tree roots that cracked the rock and the wind that caused the roots to move back and forth until the rocks broke off and fell.


NIGHT FINAL

FRIDAY / AUGUST 9, 2002

DOW JONES

NASDAQ

ENTERTAINMENT / D7

Diesel fuel

Honolulu Star-Bulletin

Council demands answers from city

1 dead after boulder smashes Nuuanu home

TheHonoluluAdvertiser.com
October 9, 2002

Printable version | E-mail this story

Posted on: Saturday, August 10, 2002

Tumbling rocks an unpredictable reality in Hawai'i

By Mike Gordon
Advertiser Staff Writer

The five-ton boulder that killed Dara Rei Onishi as she slept in her home early yesterday was caused by the same geologic forces that produced a deadly landslide at Sacred Falls in 1999, the Kamehameha Highway road closure at Waimea Bay in 2000 and a landslide in February that dumped tons of rocks onto the base of Manoa Falls.

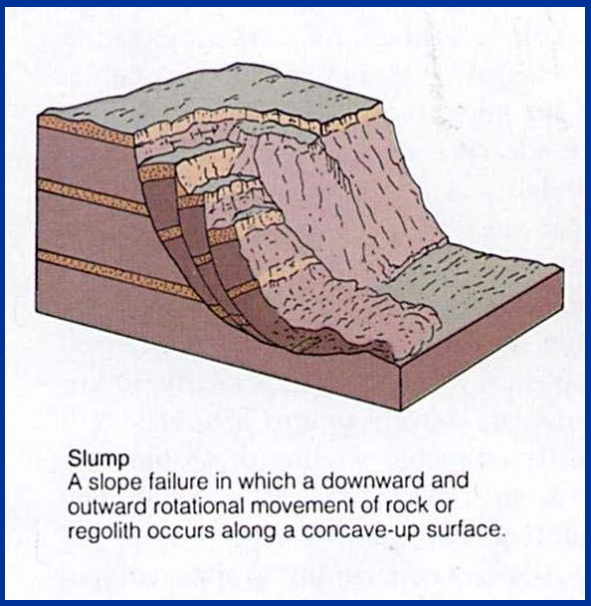
Such incidents illustrate a simple fact: Falling rocks are part of the natural erosion of the Islands, and there is no way to predict when or where they will plummet.

"It's a common occurrence in areas where there aren't any people," said state geologist Glenn Bauer, of the Department of Land and Natural Resources. "It happens. The island is old."

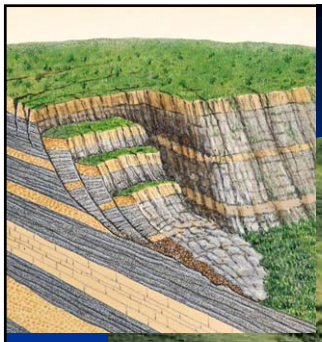
But geologists also say boulders rarely plow through homes.

"Any individual house is probably not at any big risk," said

Bad Car Day



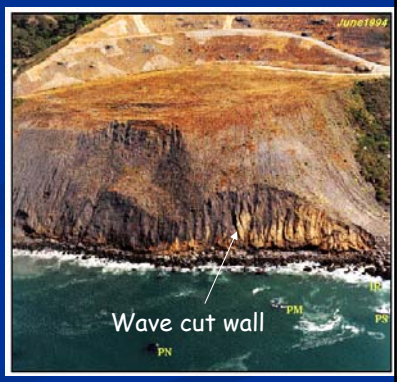
Slump
A slope failure in which a downward and outward rotational movement of rock or regolith occurs along a concave-up surface.



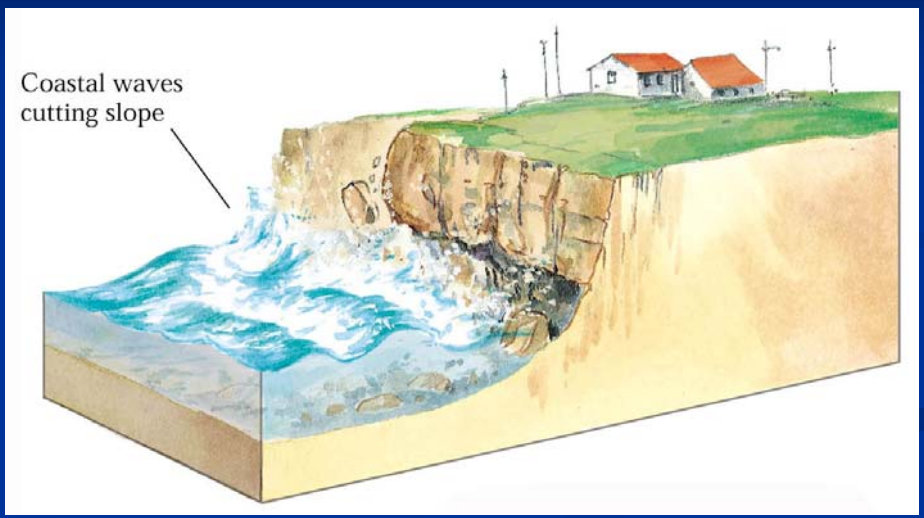
Slump

What causes slumps?

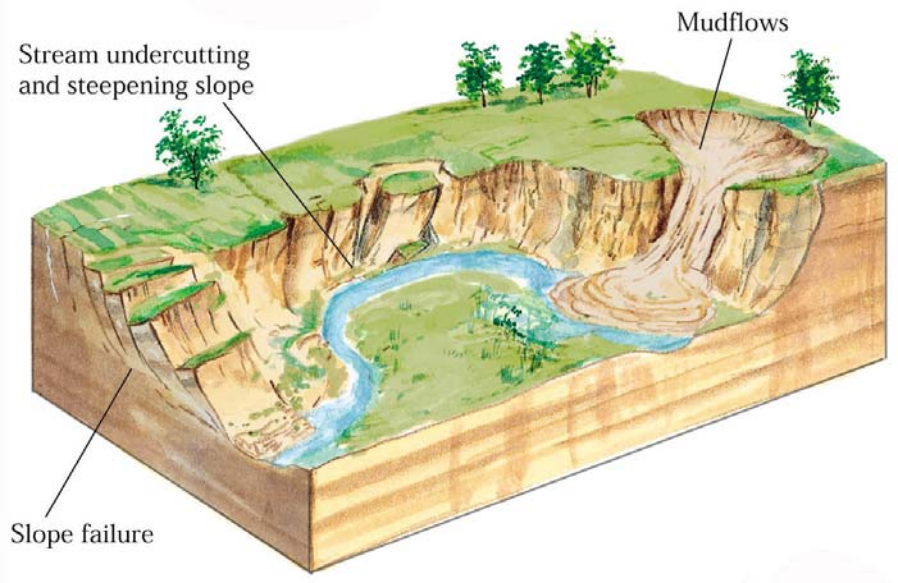
- Most common reason for slumping
  - Erosion at the base of the slope
  - Reduces the support for overlying sediments
- Erosion at the base of a slope has many causes
  - Stream channel, wave action, seepage of water into the ground during the rainy season, etc.



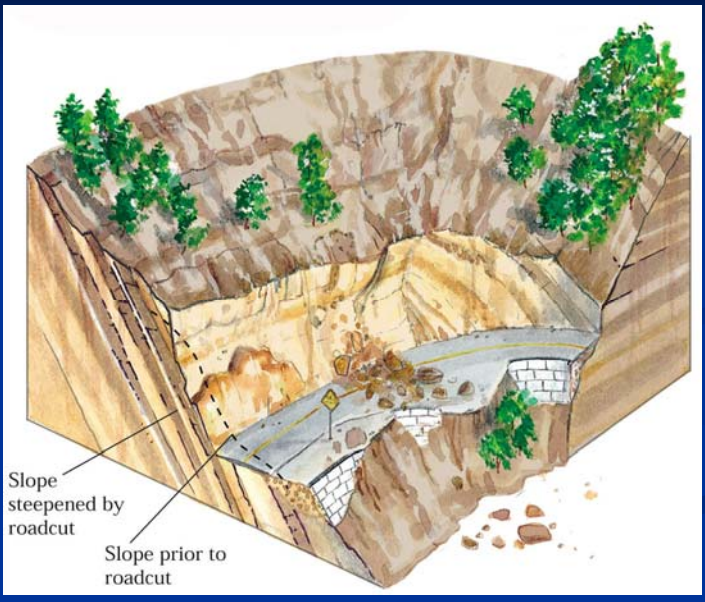
Processes that oversteepen slopes



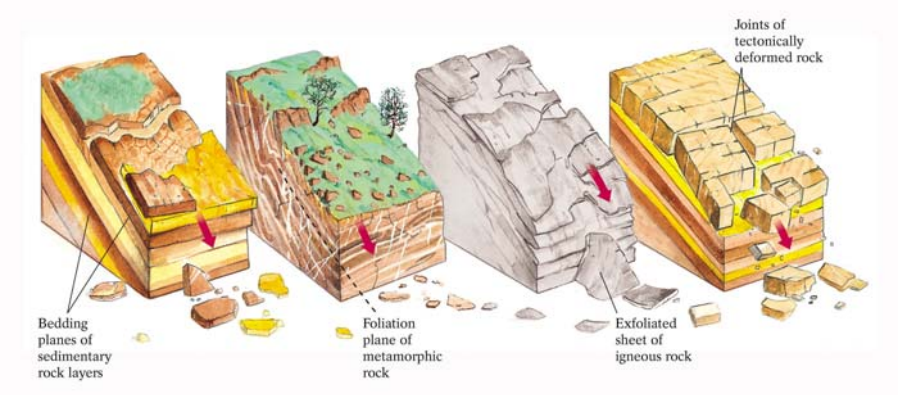
Processes that oversteepen slopes

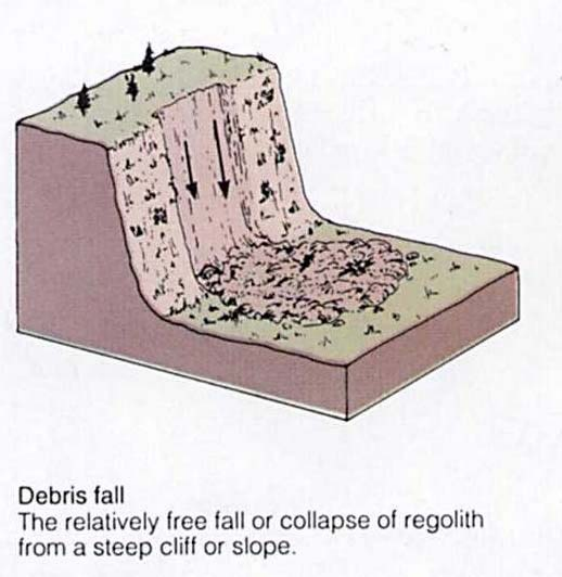


Processes that oversteepen slopes

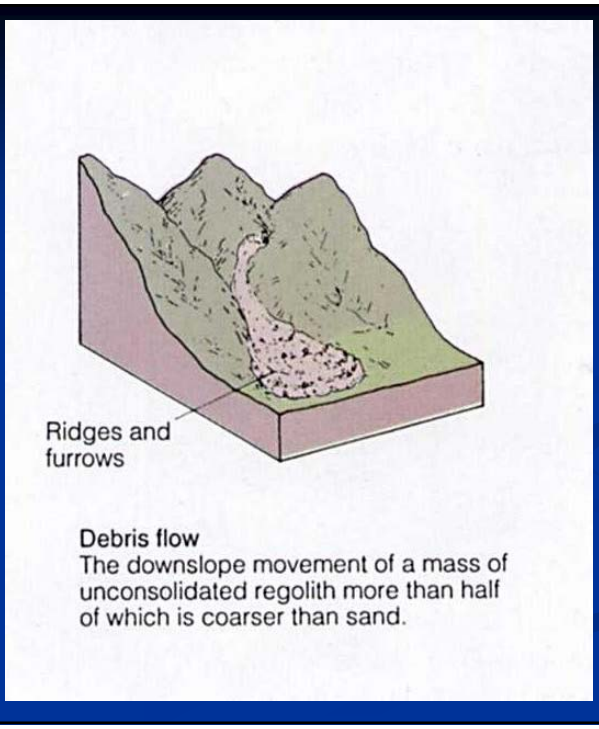


Slopes susceptible to mass movement





Debris fall
The relatively free fall or collapse of regolith from a steep cliff or slope.

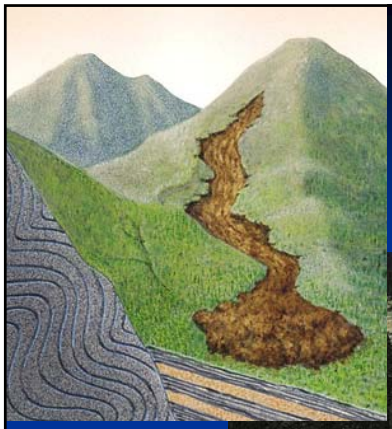


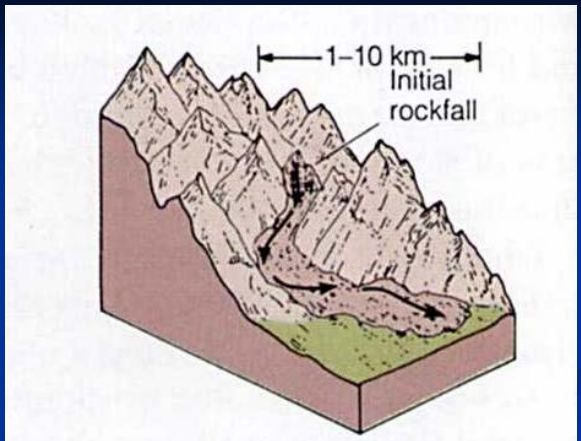
Debris flow
The downslope movement of a mass of unconsolidated regolith more than half of which is coarser than sand.

Debris flows

- Occur when the rock/soil mass loses coherency and lots of water is involved
- Debris becomes mixed up completely and flows as liquid mud
- Often carry large clasts
- Can be very destructive

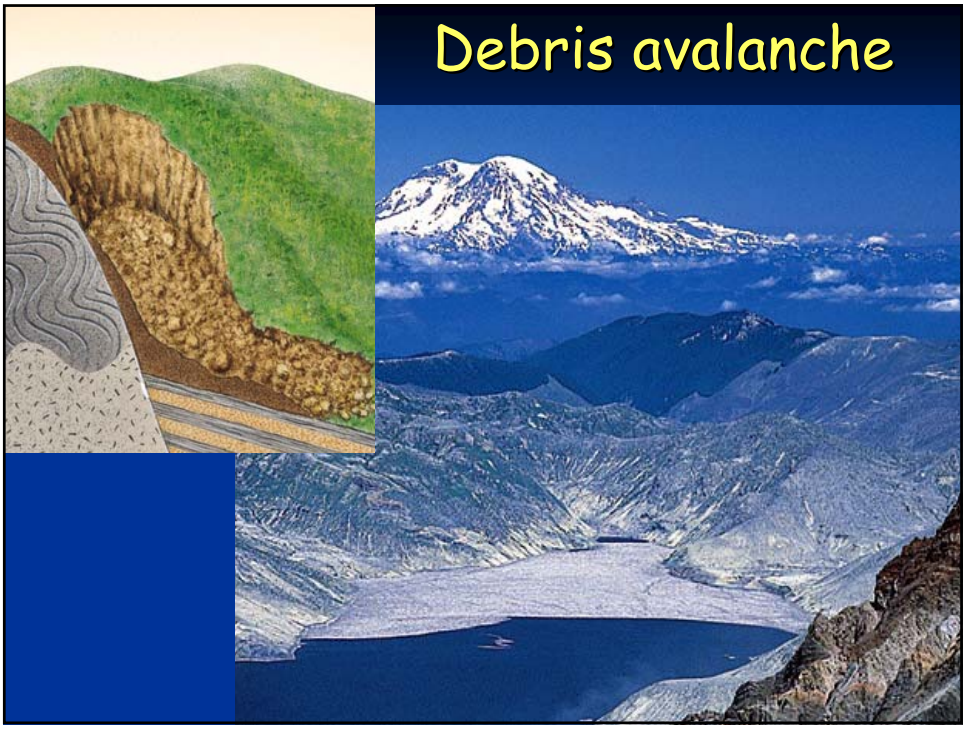
Debris flow

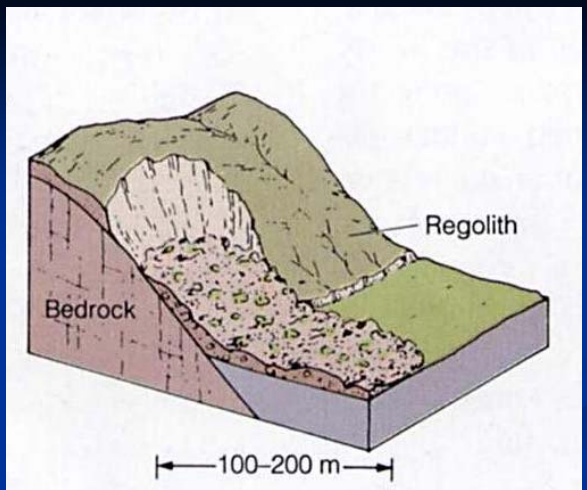




Rock or debris avalanche
Often massive flow of rock or regolith moving at a high velocity (≥10 meters/second).

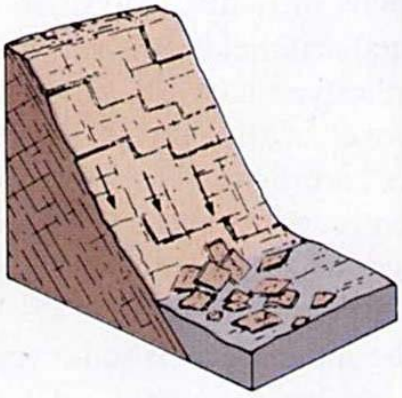
Debris avalanche



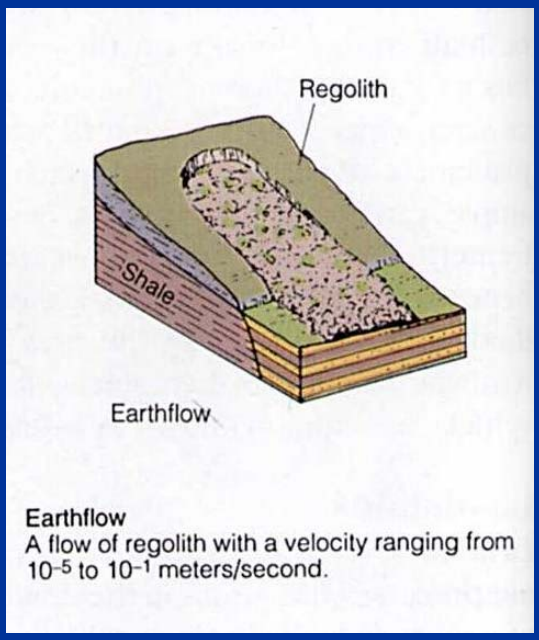


Debris slide
The slow to rapid downslope movement of regolith across an inclined surface.

Debris slide

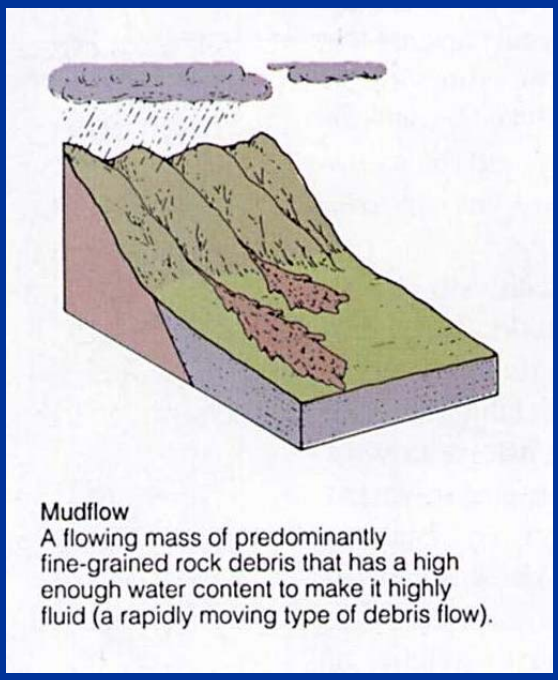


Rockslide
The sudden and rapid downslope movement of detached masses of bedrock across an inclined surface.

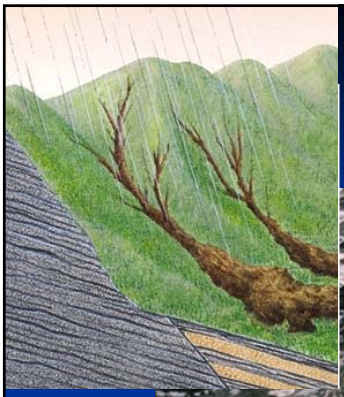


Earthflow
A flow of regolith with a velocity ranging from 10^{-5} to 10^{-1} meters/second.

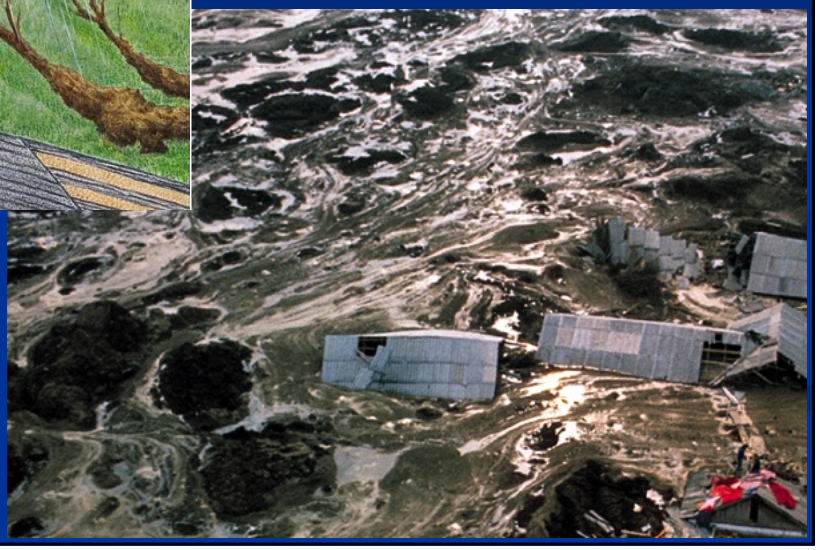
Earthflow



Mudflow
A flowing mass of predominantly fine-grained rock debris that has a high enough water content to make it highly fluid (a rapidly moving type of debris flow).

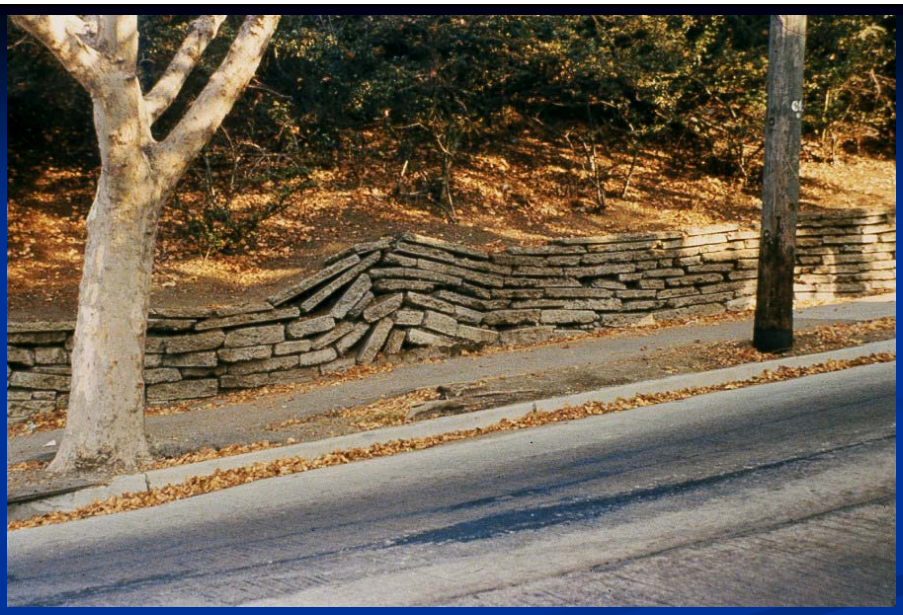


Mudflow

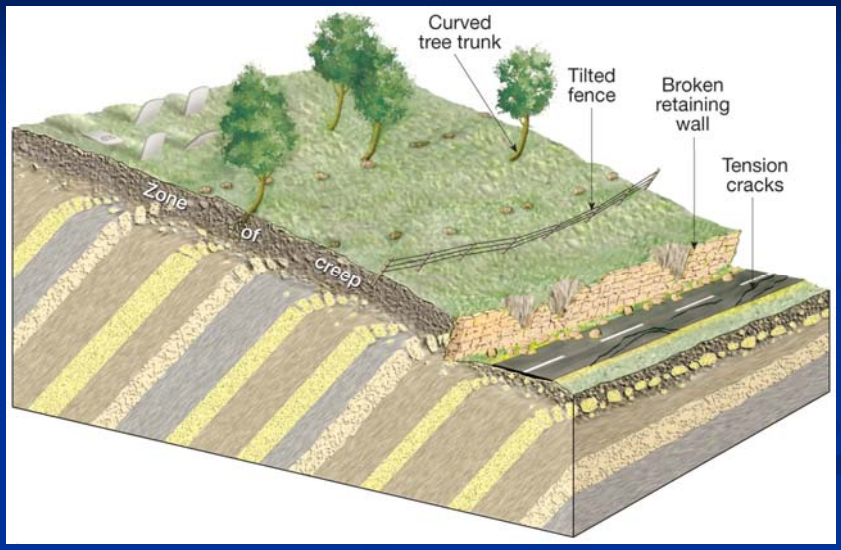


Soil Creep

- Creep
  - Gradual movement of soil and regolith downhill
  - Aided by the alternate expansion and contraction of the surface material
- Mass movement that moves very slowly
- Weak soils on steep slopes move slowly down hill



Some Visible Effects of Creep

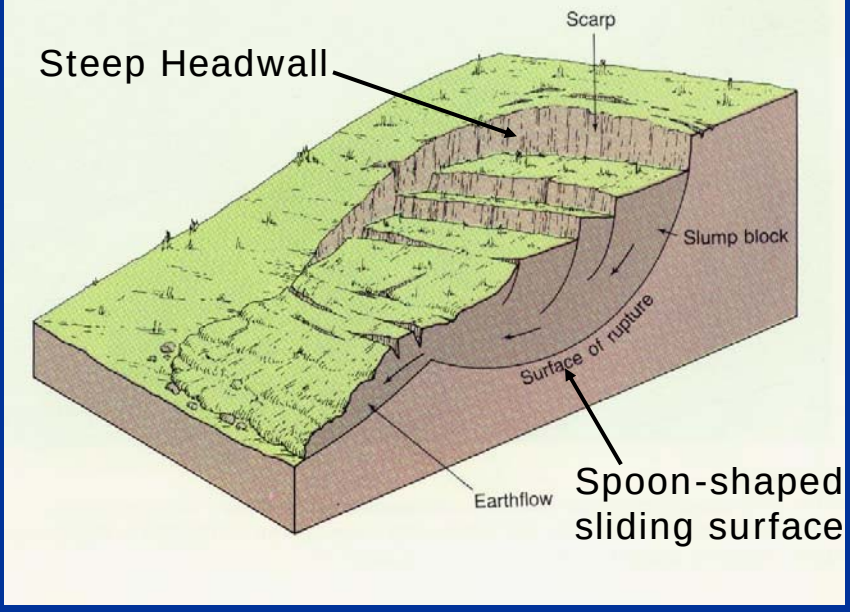


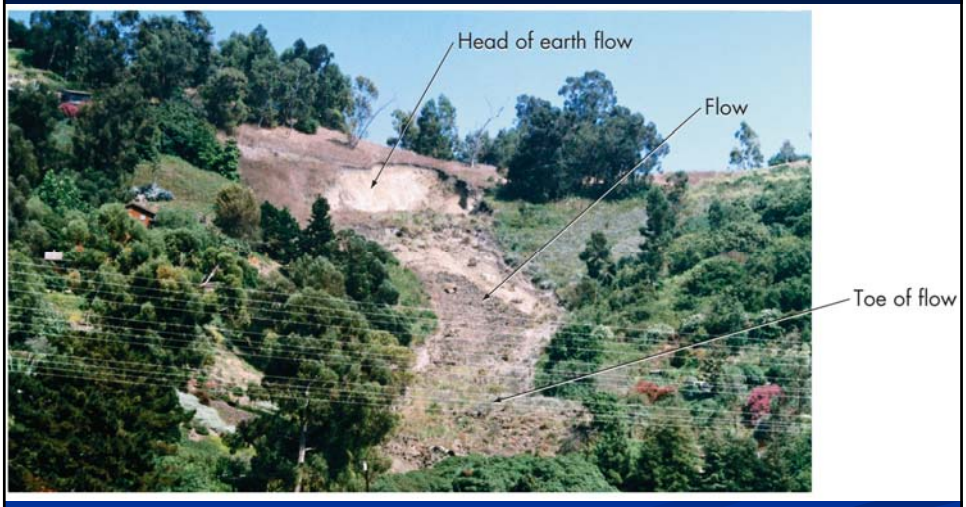
Landslides

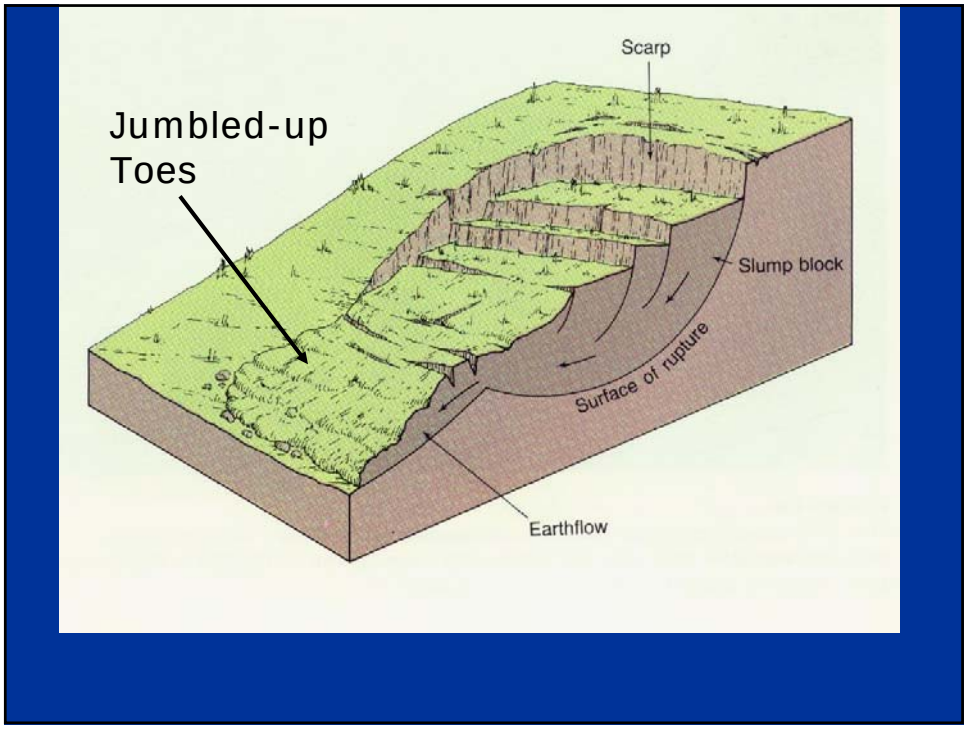
- Occur when a large piece of rock and/or soil breaks off and slides down hill
- Often initiated by earthquakes and by very heavy rainstorms
- Can occur when humans foolishly overload a road bordering a canyon or steep drop off with heavy equipment

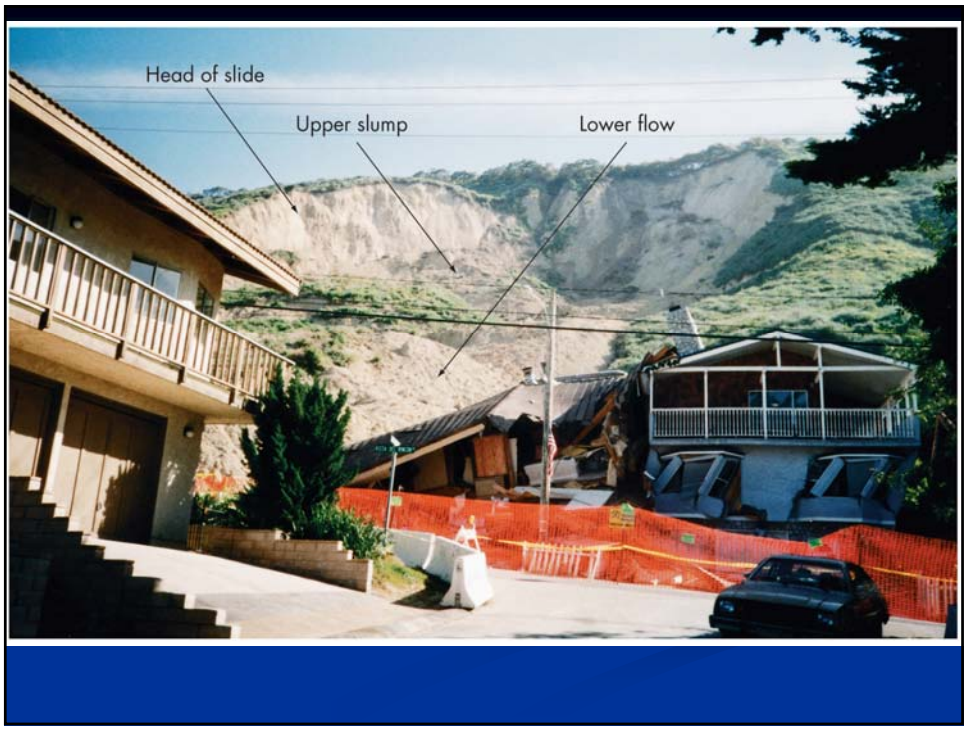
Landslides

- Initiated when rock/soil originally held in place by internal cohesion suddenly loses that cohesion
- Form on slopes that are steep enough for the weight of the surficial material to overcome the cohesive force and fail


Scarp
Steep Headwall
Slump block
Surface of rupture
Earthflow
Spoon-shaped
sliding surface


Head of earth flow
Flow
Toe of flow


Scarp
Jumbled-up Toes
Slump block
Surface of rupture
Earthflow

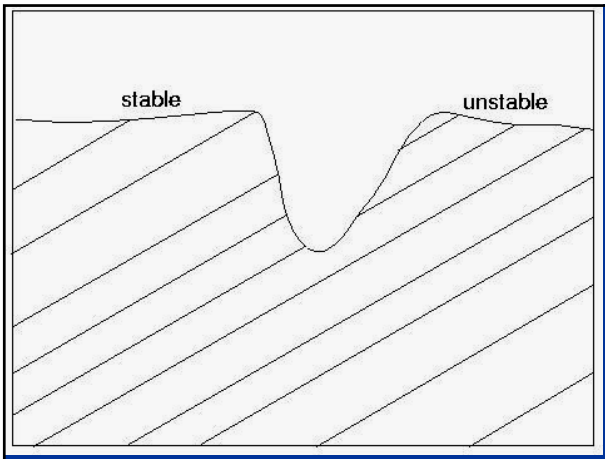

Head of slide
Upper slump
Lower flow

Landslides

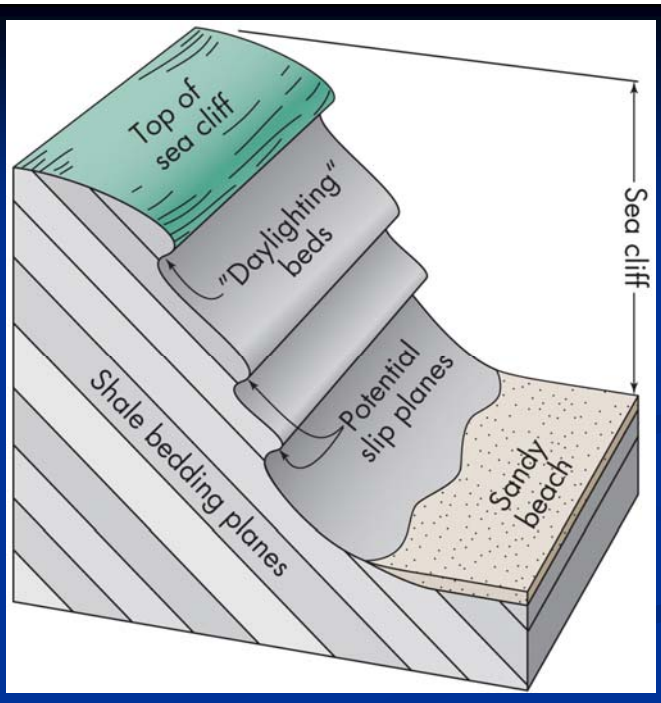
- Tendency to slide increases with increasing surface slope
- Addition of water promotes sliding by adding weight and by reducing cohesion
- Friction along the slide surface controls the speed of the downslope movement

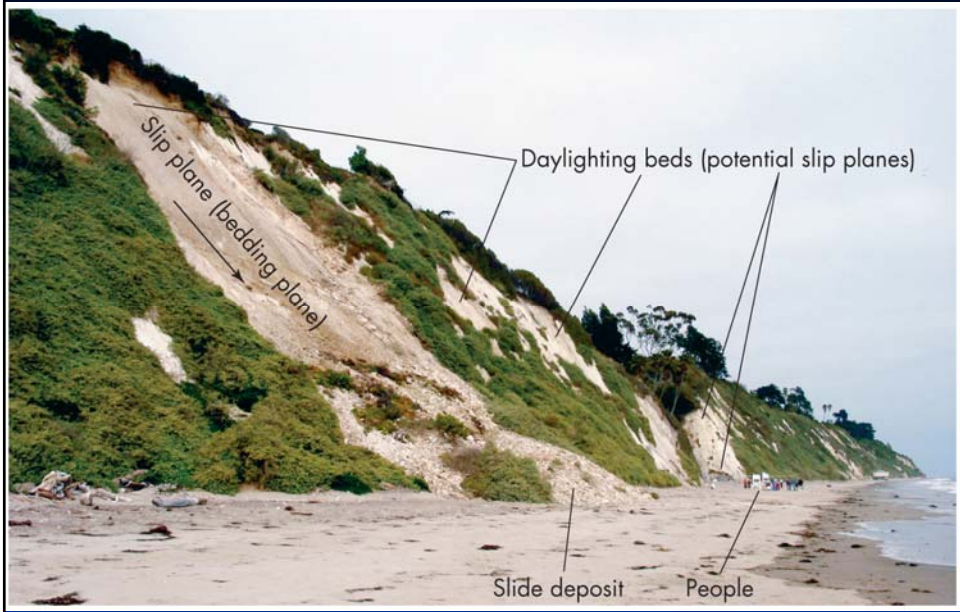
Landslides

- Addition of water reduces friction along the surface and allows the mass to slide faster
- Some slides move as coherent mass
- Others break up and the material inside becomes jumbled and disorganized



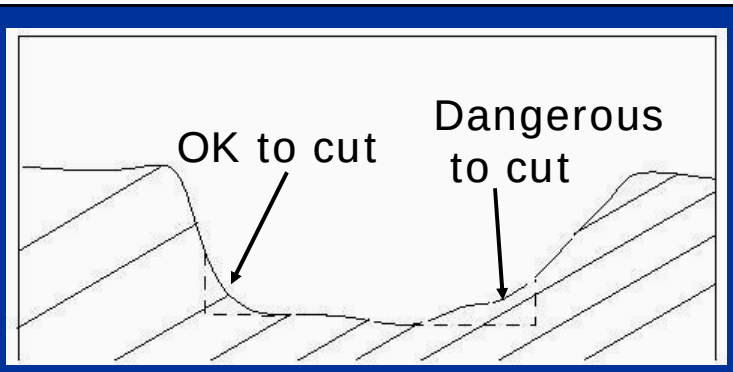
If bedding dips down-slope, a landslide is more likely to develop





Landslides

- Certain areas are more prone than others
- Usually because of local geological factors
  - Reducing vegetation that was stabilizing the soil
  - Over watering (decrease friction)



Cutting a slope during construction can cause a landslide

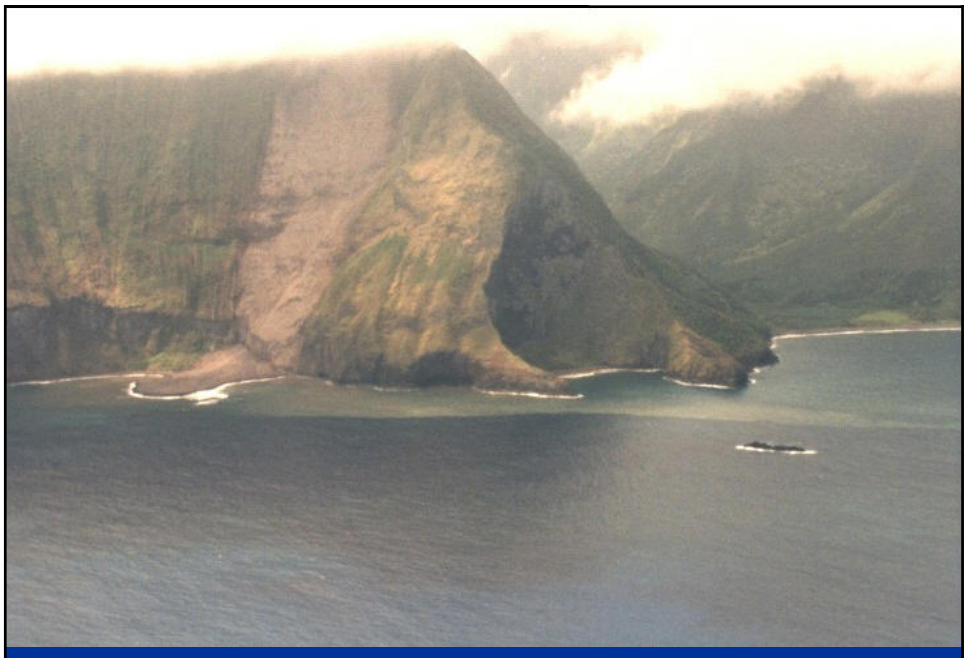
LaConchita (S. California) landslide,
January, 1995

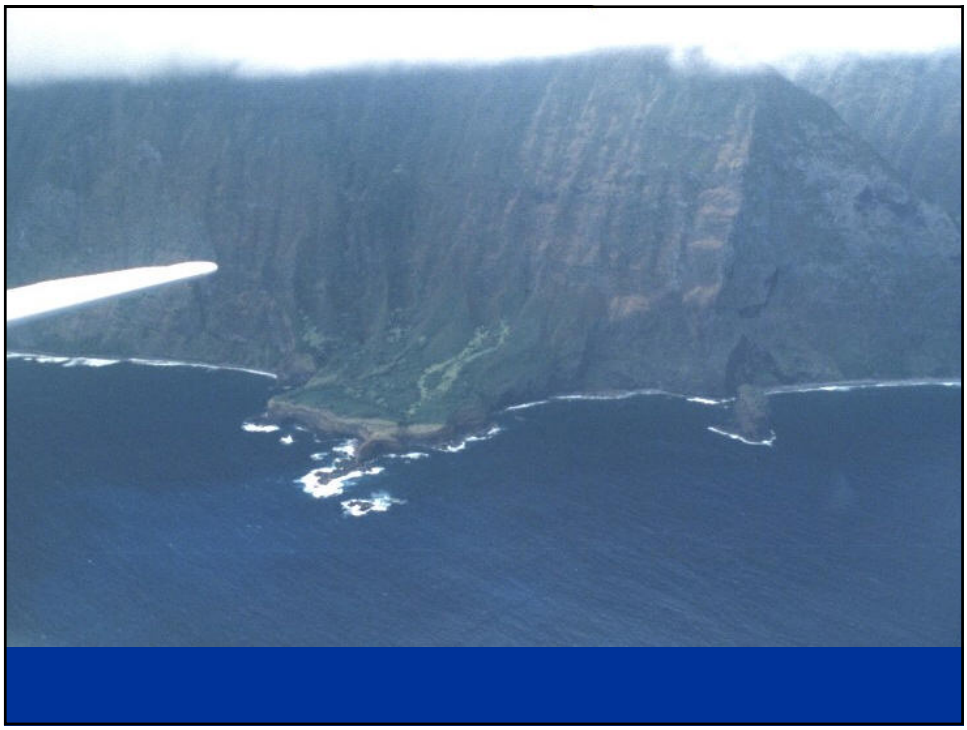
LaConchita (S. California) landslide, January, 2005

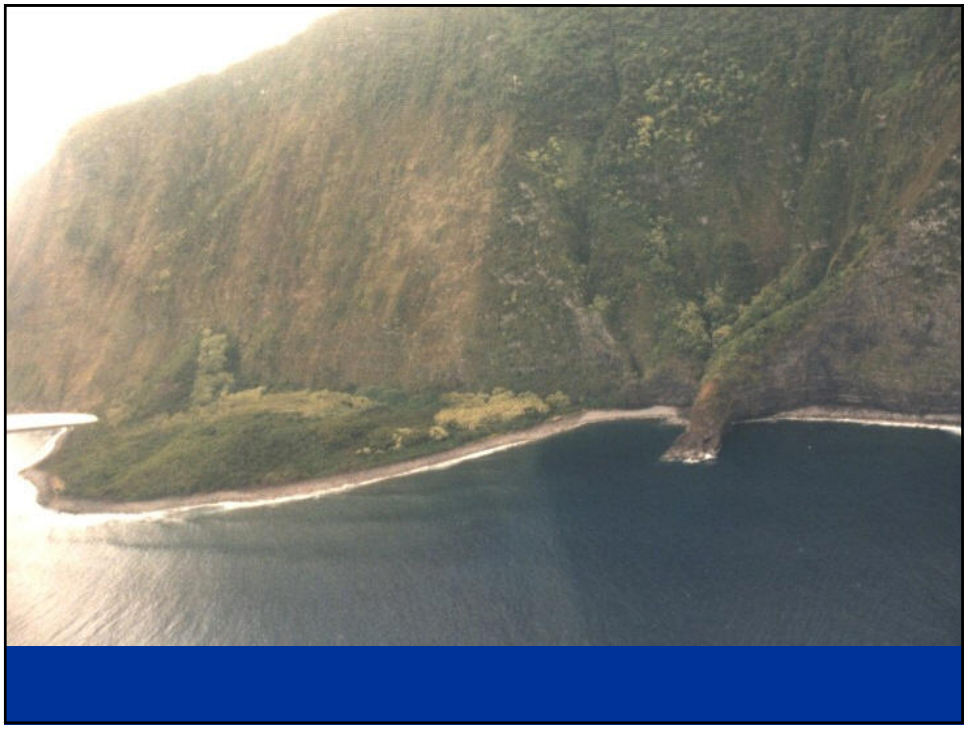
LaConchita (S. California) landslide, January, 2005

Our Islands Are Unstable

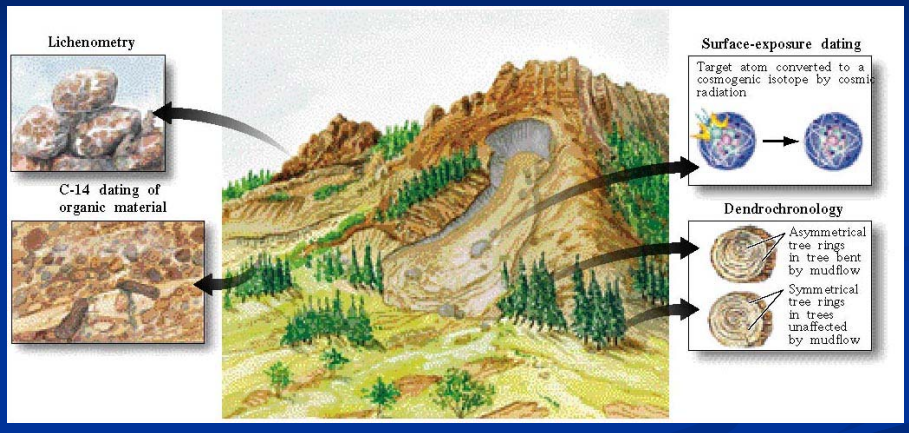
- From Shoreline to Mountains
- Even the youngest parts of the volcanoes are subject to landsliding



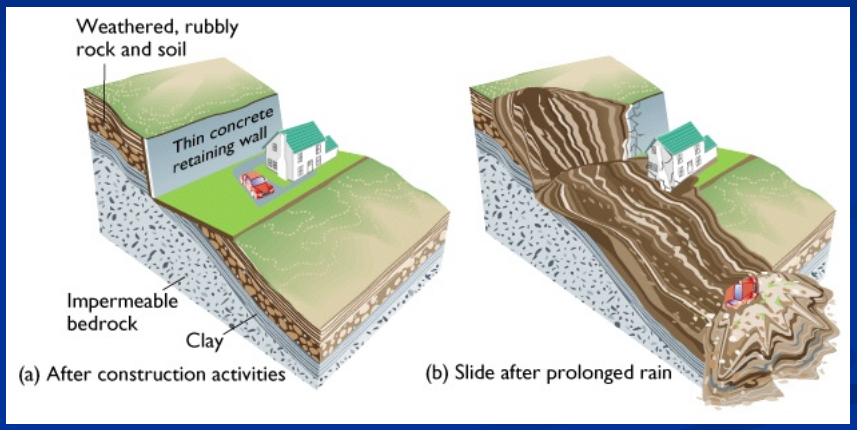


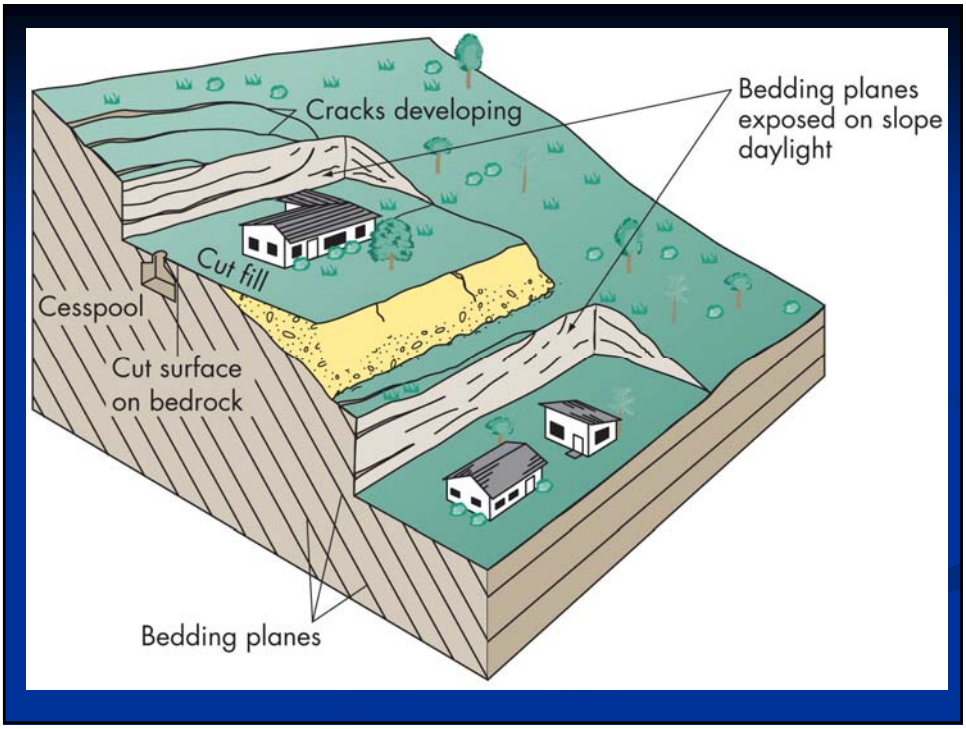


Dating mass-movement events



Landslide Induced by Poor Construction Techniques



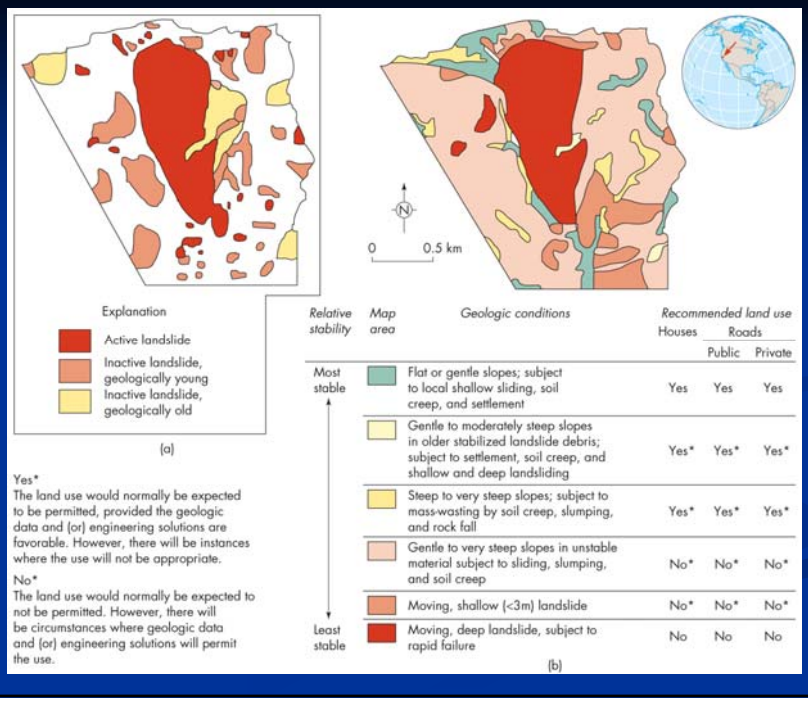


Human Land Use and Landslide

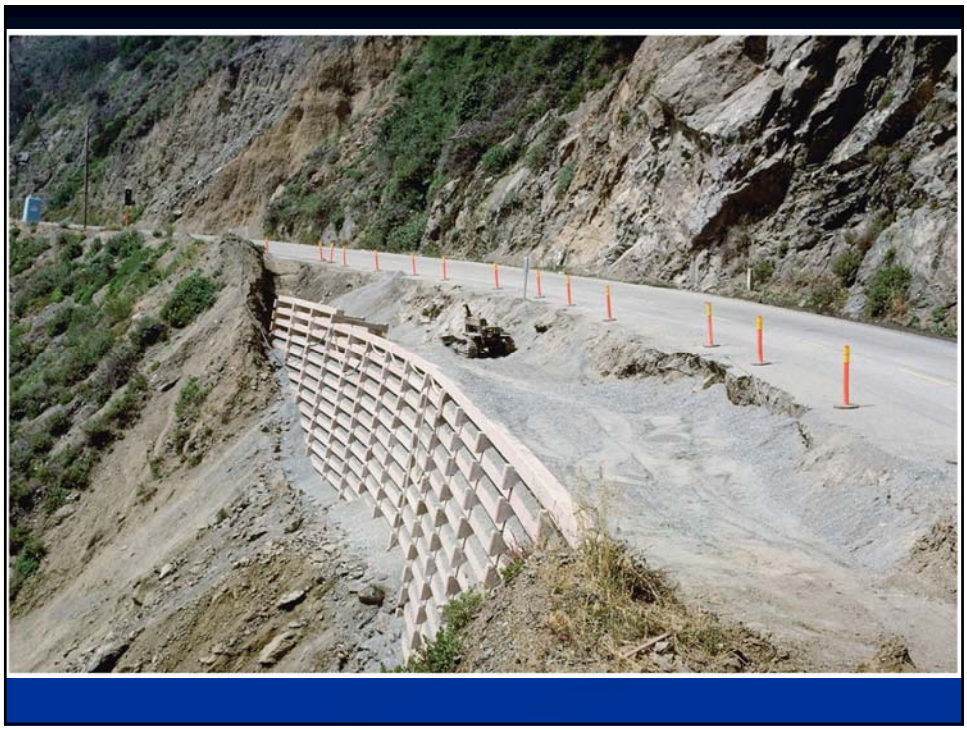
- Urbanization, irrigation
- Timber harvesting in weak, relatively unstable areas
- Artificial fillings of loose materials
- Artificial modification of landscape
- Dam construction

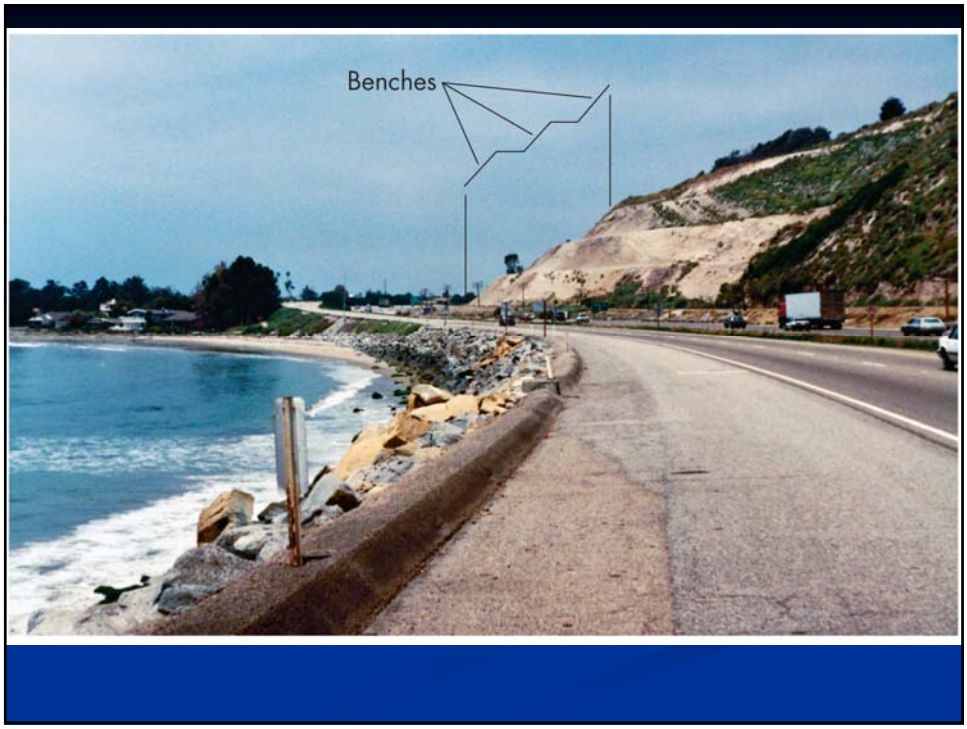
Minimizing the Landslide Hazard

- Identifying potential landslides
  - Photographic analysis
  - Topographic map and detailed field check
  - Historic data
- Landslide hazard inventory map
  - Grading code from the least stable to the most stable
- Application of geologic and engineering knowledge before any hillside development



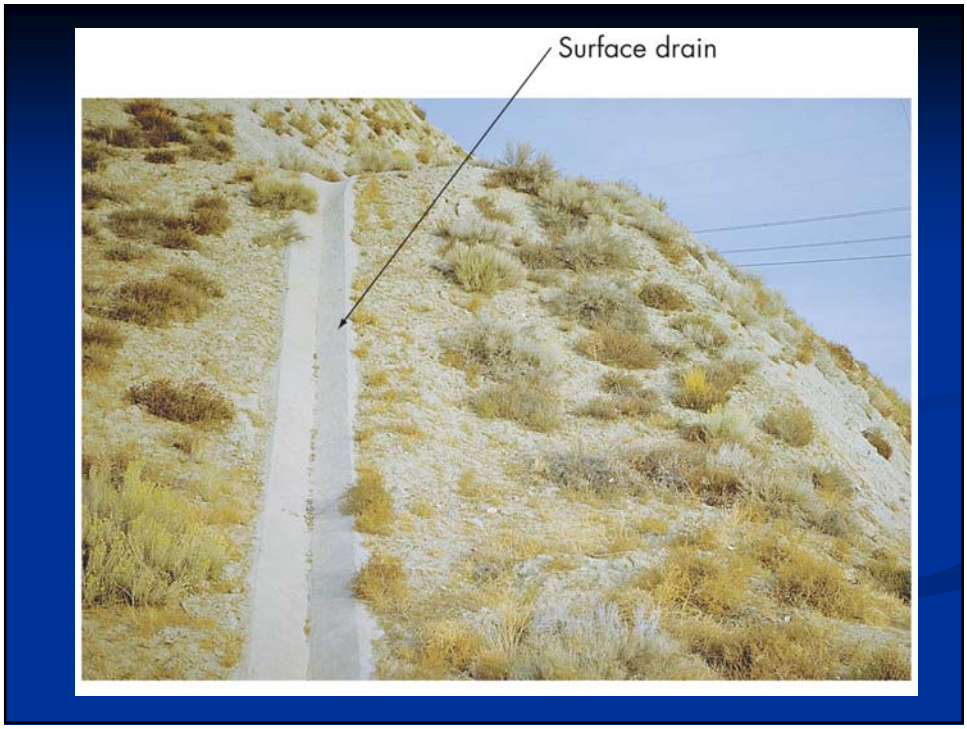

Soil cement being applied

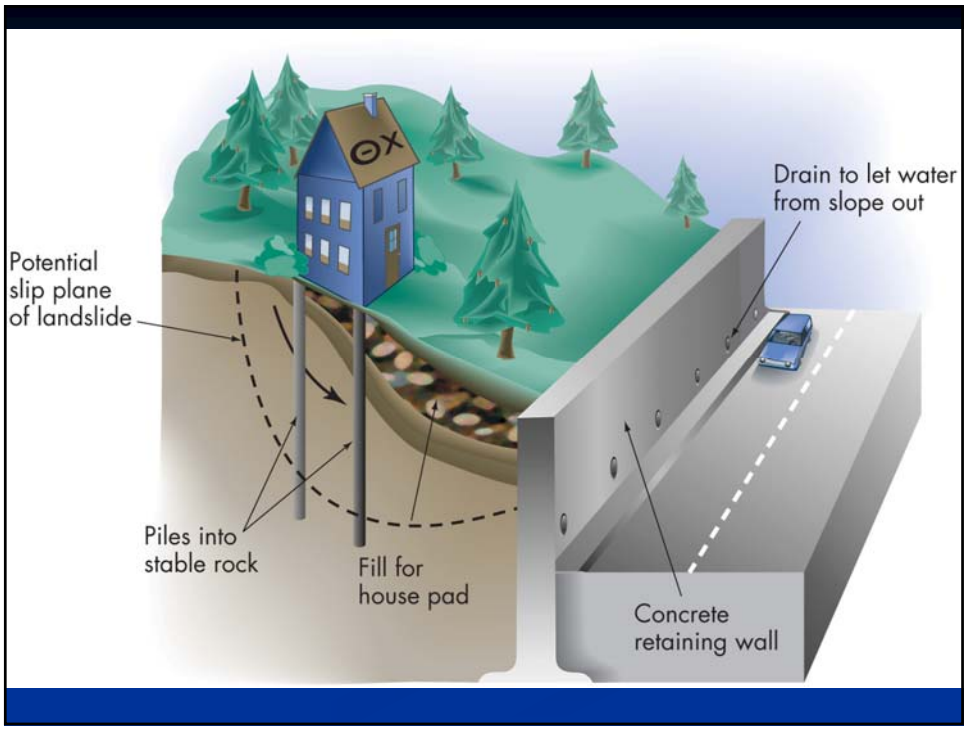


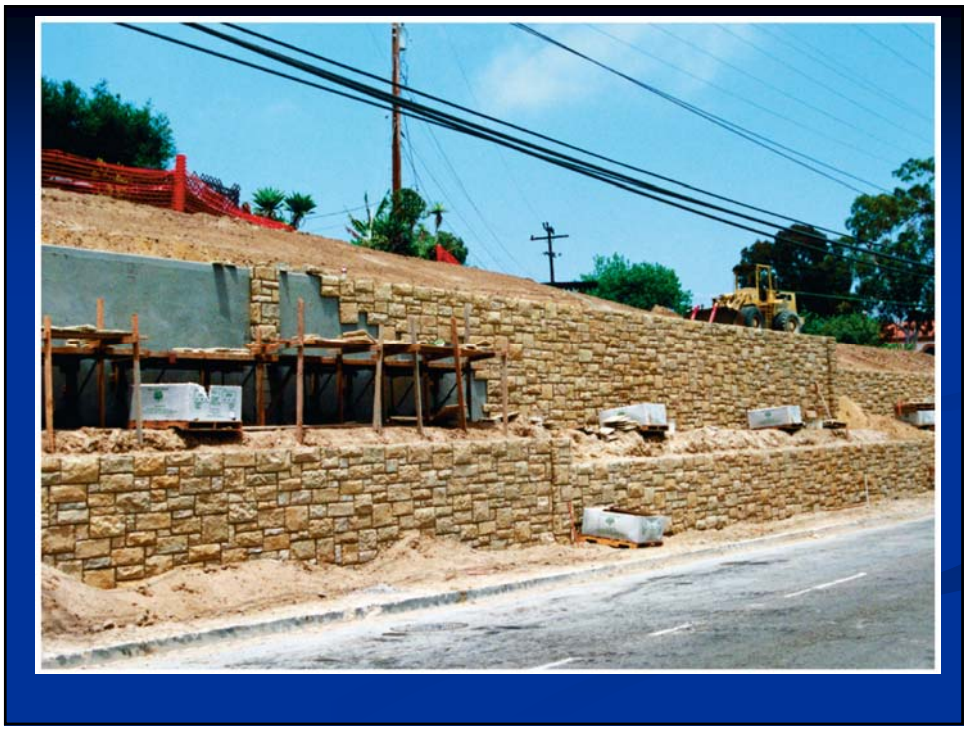


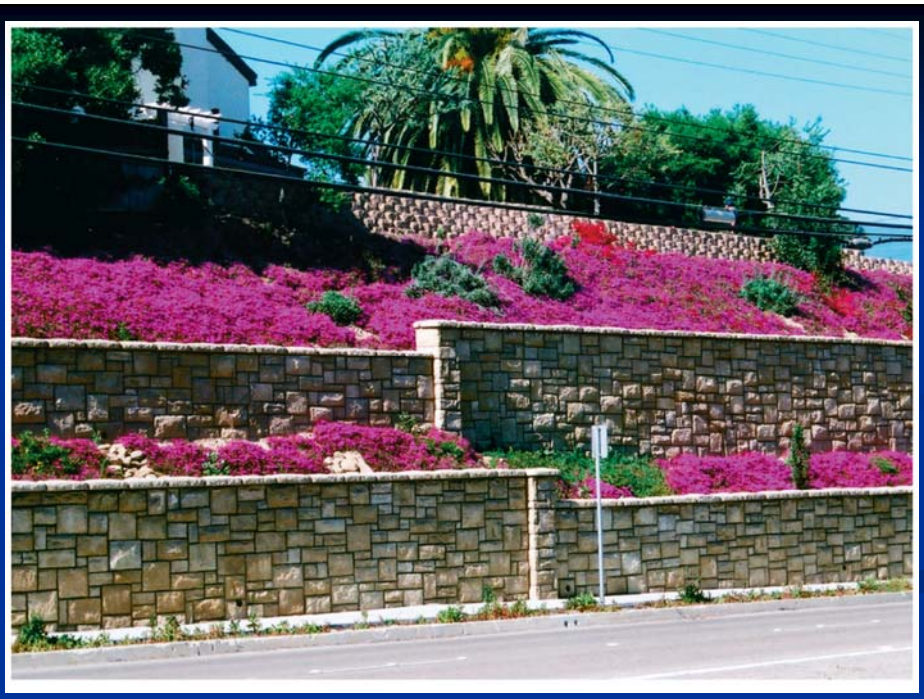
Minimizing the Landslide Hazard

- Preventing landslides
  - Drainage control: Reducing infiltration and surface runoff
  - Slope grading: Reducing the overall slope
  - Slope supports: Retaining walls or deep supporting piles
- Avoid landslide hazards
  - Landslide warning for critical evacuations
  - Correcting landslides


Surface drain


Potential slip plane of landslide
Drain to let water from slope out
Piles into stable rock
Fill for house pad
Concrete retaining wall





Warning of Impending Landslides

- Monitoring changes
  - Human surveillance
  - Instrumental survey: Tilt meter and geophones
- Landslide warning system
  - Info for public awareness and education
  - Enough time for public evacuation
  - Stop or reroute traffic flow
  - Emergency services

What Can You Do?

- Professional geologic evaluation for a property on a slope
- Avoid building at the mouth of a canyon, regardless of its size
- Consult local agencies for historical records
- Watch signs of little slides—often precursor for larger ones

What Can You Do?

- Look for signs of structure cracks or damage prior to purchase
- Be wary of pool leaking, tilt of trees and utility poles
- Look for linear cracks, subsurface water movement
- Engineering solutions (e.g., retaining walls: to stabilize slopes, drainage pipes: to drain water, grade slopes: to reduce oversteepening and diversion walls: to protect structures)
- Put observations into perspective, one aspect may not tell the whole story