CGEO UNAM 2017

Curso de sismologia ambiental

Características, tipologías e impacto de los Procesos Geológicos Superficiales (PGS)

1 – Landslides characterization, classification and impact

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INTRODUCTION

Características, tipologías e impacto de los Procesos Geológicos Superficiales (PGS)

Landslides characterization, classification and impact

LANDSLIDES

•For convenience, definition of *landslide* includes all forms of ***mass-wasting*** movements
•Landslide and subsidence: **naturally occurred and affected by human activities**
•Landslide and other ground failures cause substantial **damage and loss of life**

SLOPES

•The most common landforms consists of cliff face and talus slope or upper convex slope, a straight slope, and a lower concave slope
•Dynamic evolving feature, depending upon topography, rock types, climate, vegetation, water, and time
•Materials constantly moving down the slope at varied rates

Vajont before

Vajont after

Social significance of landslides

Vajont, Italy, 1963	2,000
Huascaran, Perú, 1970	18,000
Nevado del Ruis, Colombia, 1980	22,000
Vargas State, Venezuela, 1999	30,000
Haiyuan, China, 1920	100,000

Landslide damage is highly focused, affects selected groups!

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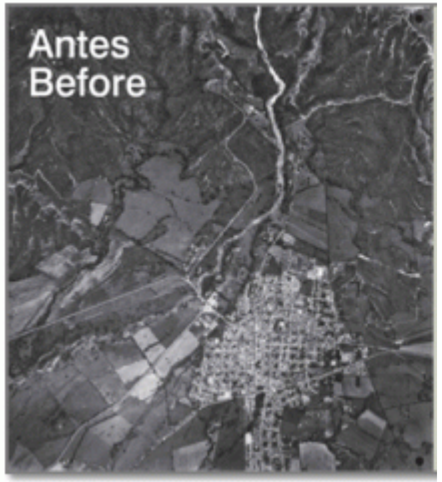

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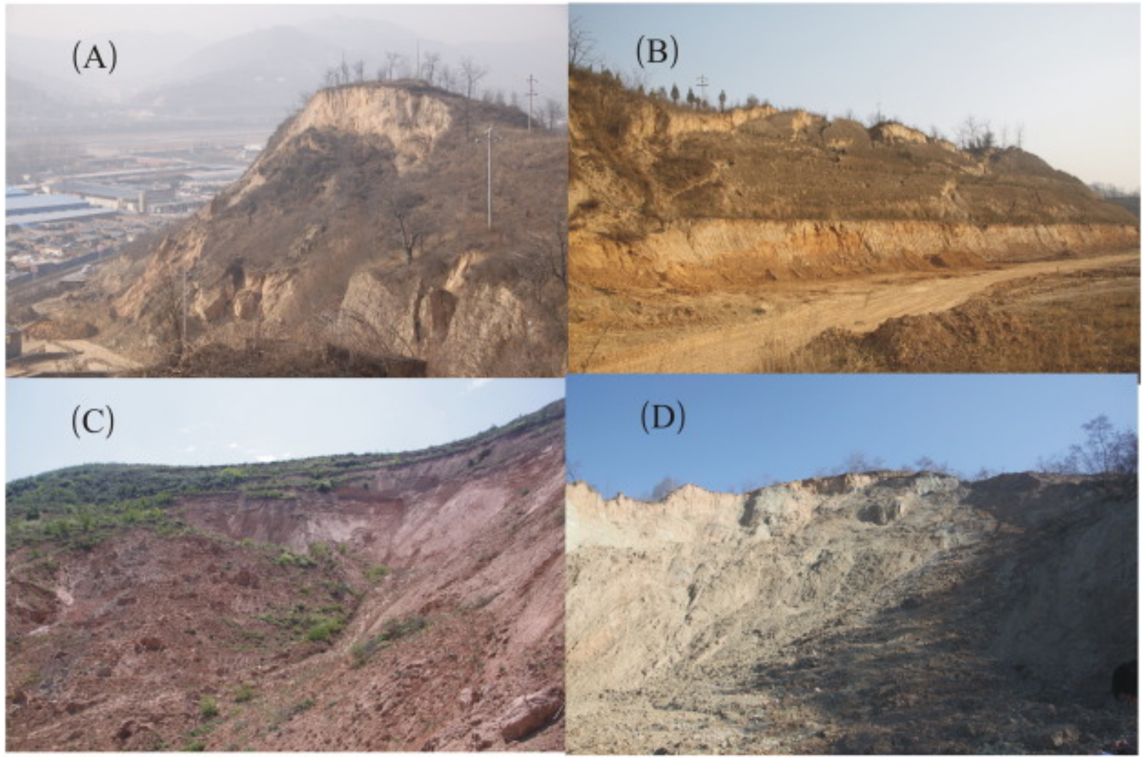

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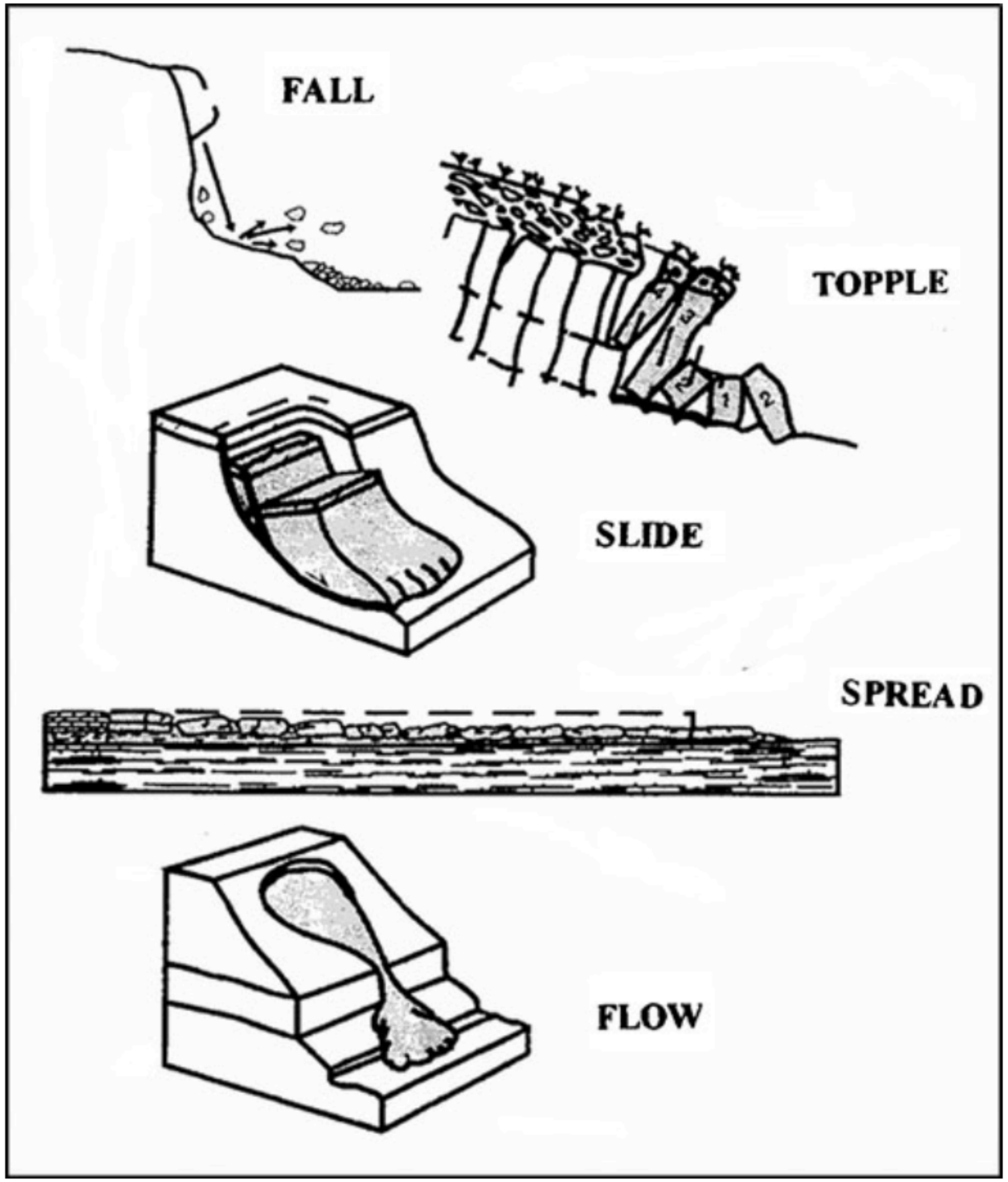
Landslide damage is highly focused, affects selected groups!

HOW TO DEAL WITH THAT?




*“Similar **landslides** in similar **materials** are caused by similar **processes** under similar **conditions**“*

Varnes, D. J. (1984). IAEG Commission on Landslides & other Mass Movements. Landslide hazard zonation: a review of principles and practice, 63.



1) Types of movement

The scale of the diagrams could vary from a few metres to hundreds of metres

Cruden, D. M., & Varnes, D. J. (1996). Landslides: investigation and mitigation. Chapter 3-Landslide types and processes. Transportation research board special report, (247).

2) Velocity classes

Hungr, O., Leroueil, S., & Picarelli, L. (2014). The Varnes classification of landslide types, an update. Landslides, 11(2), 167-194.

Table 2 Landslide velocity scale (WP/WLI 1995 and Cruden and Varnes 1996)

Velocity class	Description	Velocity (mm/s)	Typical velocity	Response[a]
7	Extremely rapid	5×10^{3}	5 m/s	Nil
6	Very rapid	5×10^{1}	3 m/min	Nil
5	Rapid	5×10^{-1}	1.8 m/h	Evacuation
4	Moderate	5×10^{-3}	13 m/month	Evacuation
3	Slow	5×10^{-5}	1.6 m/year	Maintenance
2	Very slow	5×10^{-7}	16 mm/year	Maintenance
1	Extremely Slow			Nil

[a] Based on Hungr (1981)

3) Materials

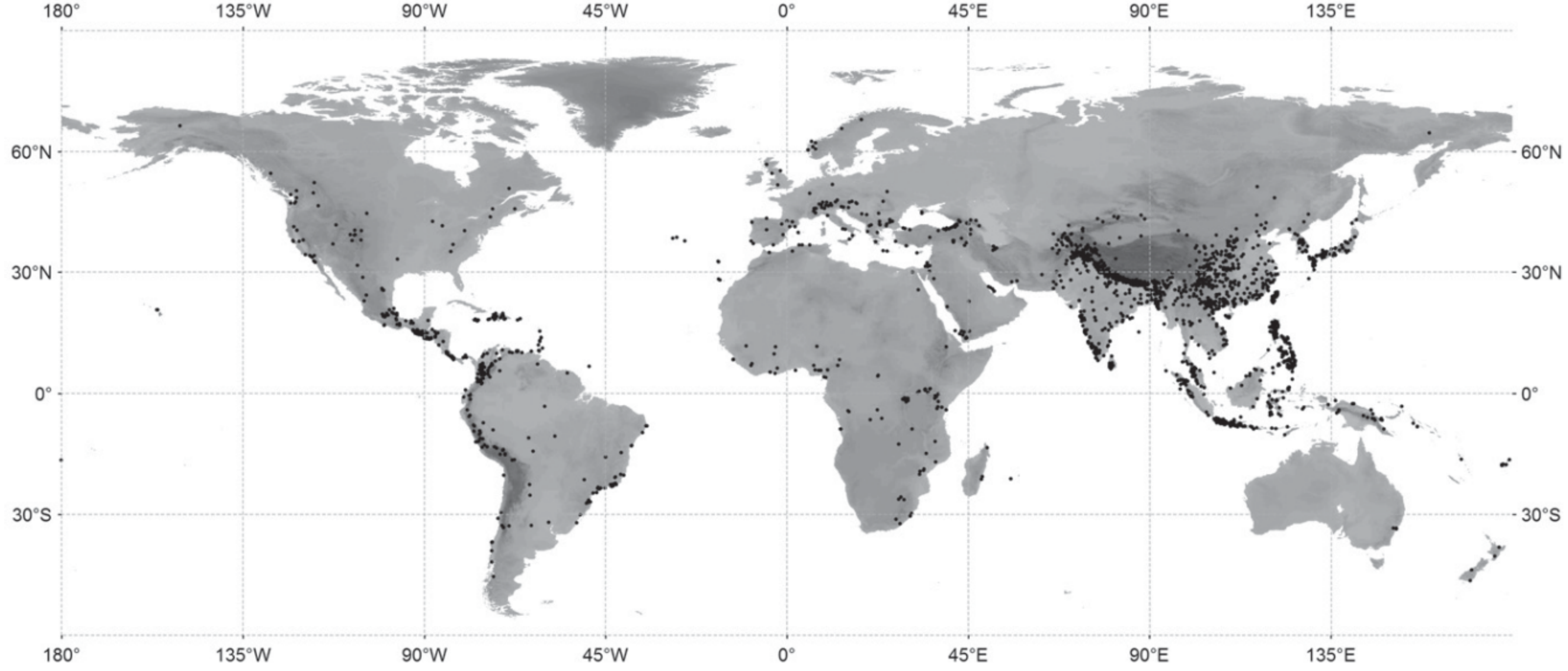
Hungr, O., Leroueil, S., & Picarelli, L. (2014). The Varnes classification of landslide types, an update. Landslides, 11(2), 167-194.

Table 3 Landslide-forming material types

Material name	Character descriptors (if important)	Simplified field description for the purposes of classification	Corresponding unified soil classes	Laboratory indices (if available)
Rock	Strong	Strong—broken with a hammer		UCS>25 MPa
	Weak	Weak—peeled with a knife		2<UCS<25 MPa
Clay	Stiff	Plastic, can be molded into standard thread when moist, has dry strength	GC, SC, CL, MH, CH, OL, and OH	$I_p > 0.05$
	Soft			
	Sensitive			
Mud	Liquid	Plastic, unsorted remolded, and close to Liquid Limit	CL, CH, and CM	$I_p > 0.05$ and $I_l > 0.5$
Silt, sand, gravel, and boulders	Dry	Nonplastic (or very low plasticity), granular, sorted. Silt particles cannot be seen by eye	ML	$I_p < 0.05$
	Saturated		SW, SP, and SM	
	Partly saturated		GW, GP, and GM	
Debris	Dry	Low plasticity, unsorted and mixed	SW-GW	$I_p < 0.05$
	Saturated		SM-GM	
	Partly saturated		CL, CH, and CM	
Peat		Organic		
Ice		Glacier		

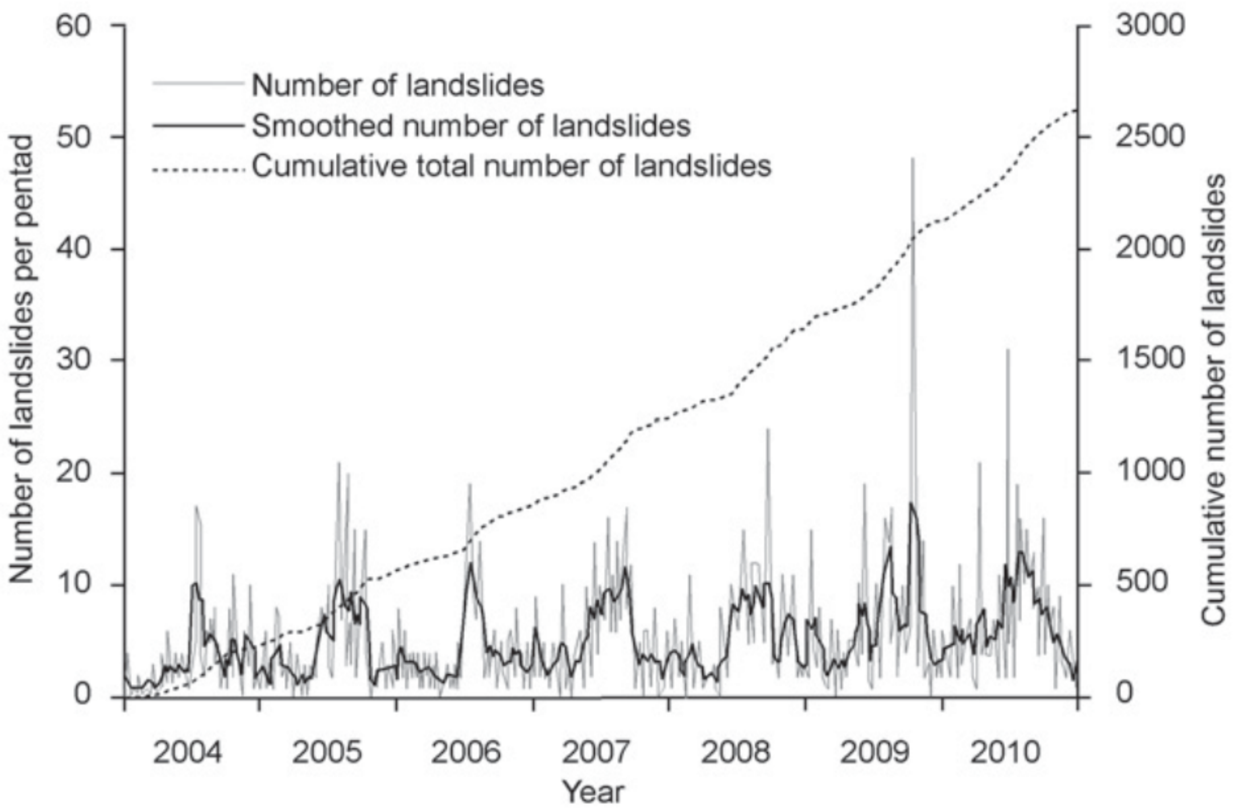
4) Geomorphic controls of landslides occurrence

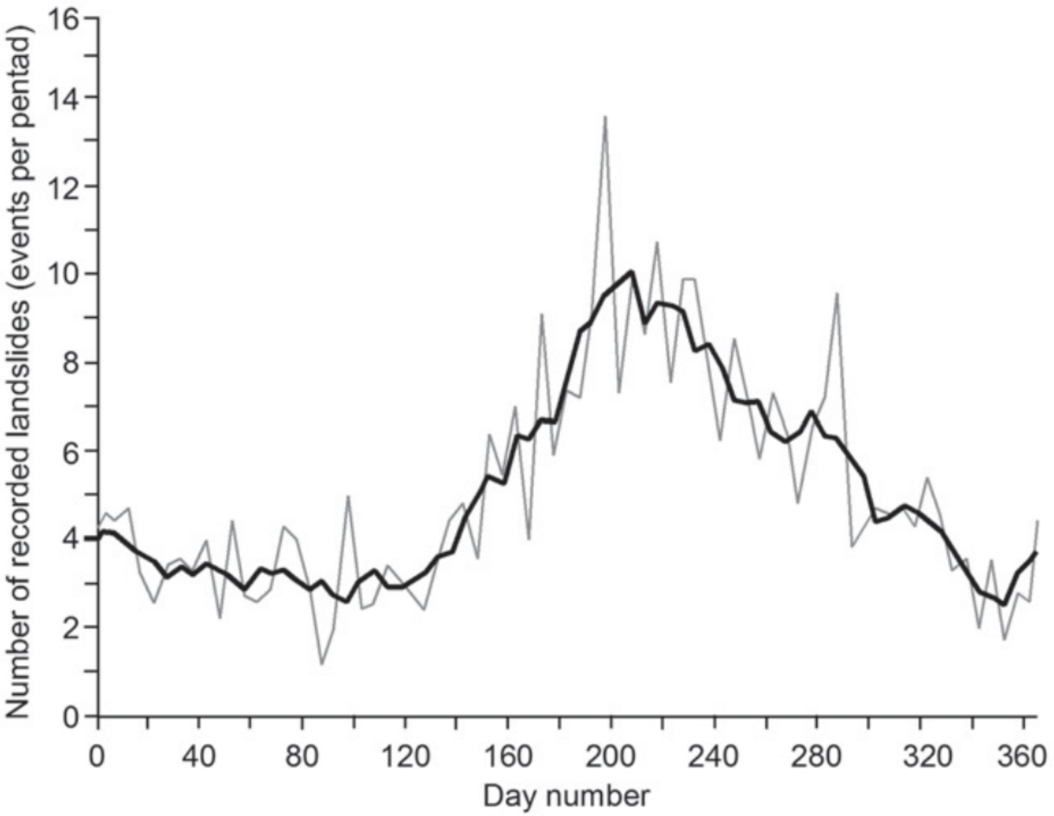
Petley, D. (2012). Global patterns of loss of life from landslides. Geology, 40(10), 927-930.



5) Climatic controls of landslides occurrence

Petley, D. (2012). Global patterns of loss of life from landslides. Geology, 40(10), 927-930.





Landslide classification

ROCK SLIDES	Translational (or Wedge) Rock Slide Rotational Rock Slide(Slump) Compound Rock Slide Rock Collapse
FALLS AND TOPPLES	Rock (Debris) Fall Rock Block Topple Rock Flexural Topple
SOIL SLIDES	Clay Slump (Rotational) Clay Slide (Compound) Sand (Gravel, Talus, Debris) Slide
FLOWS	Dry Sand (Silt, Gravel, Talus, Debris) Flow Sand (Silt, Debris, Peat) Flow Slide Sensitive Clay Flow Slide Debris Avalanche Debris (Mud) Flow Debris Flood Earth Flow Rock Avalanche

Time for a break…

SLOPE STABILITY

Safety Factor = Resisting/Driving Forces
•If SF >1, then safe or stable slope
•If SF <1, then unsafe or unstable slope

Driving and resisting force variables:
•Slip surface – "plane of weakness"
•Type of Earth materials
•Slope angle and topography
•Climate, vegetation, and water
•Shaking

Causes vs. triggers

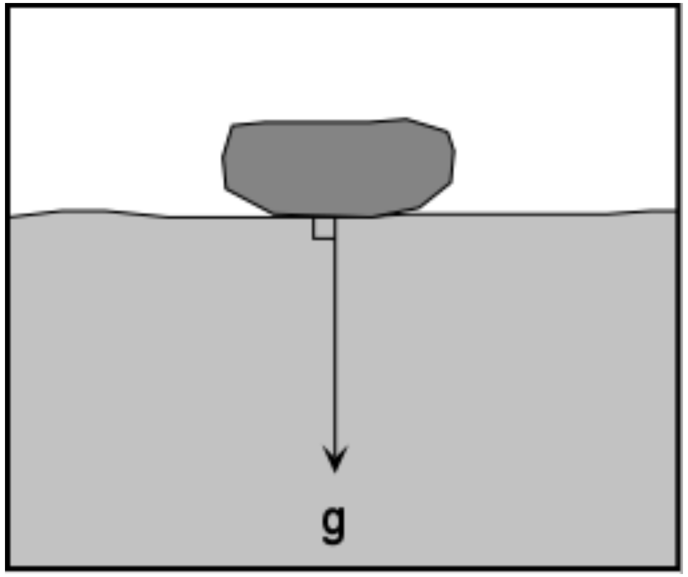
Material

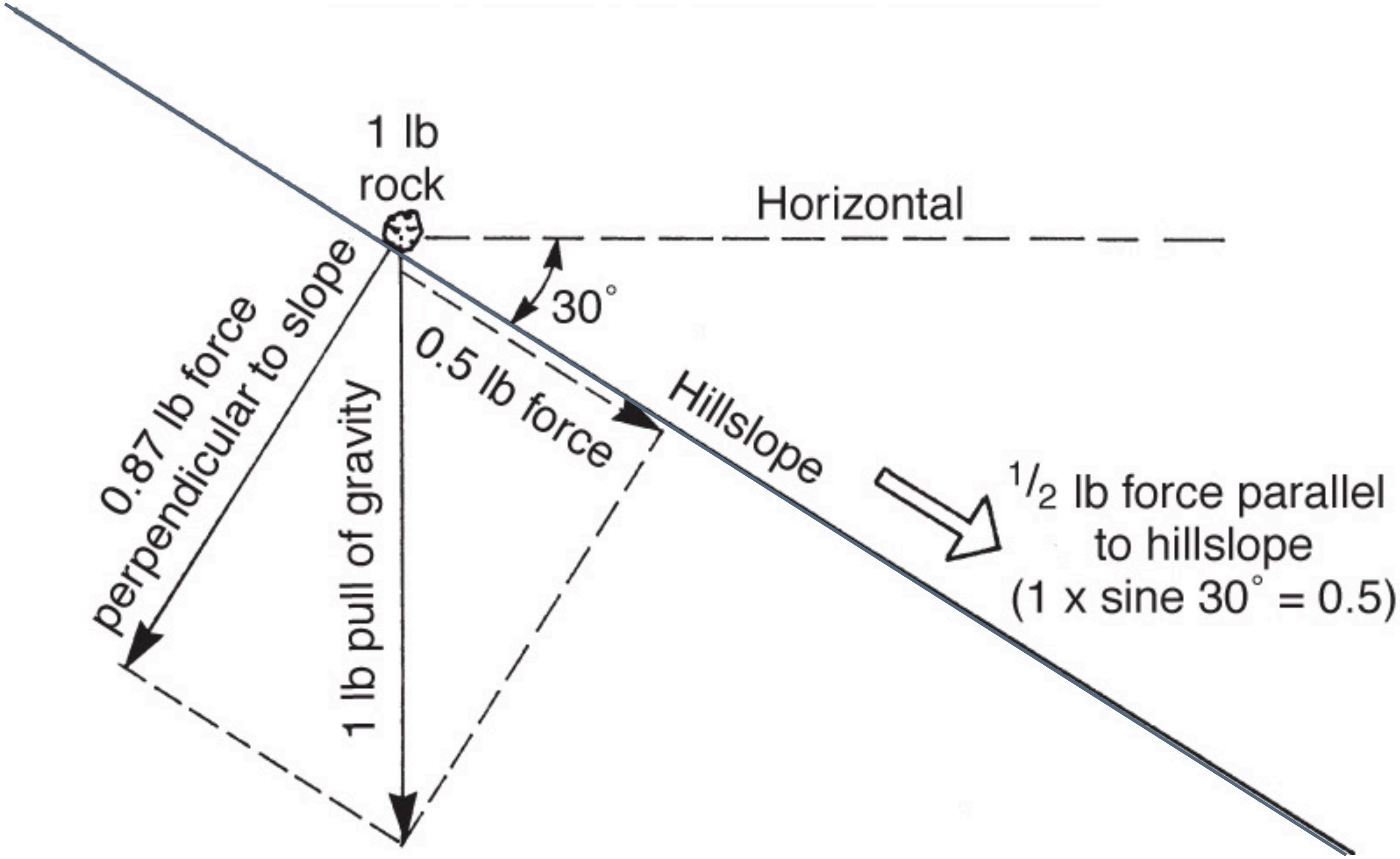
Morphology/slope

Water

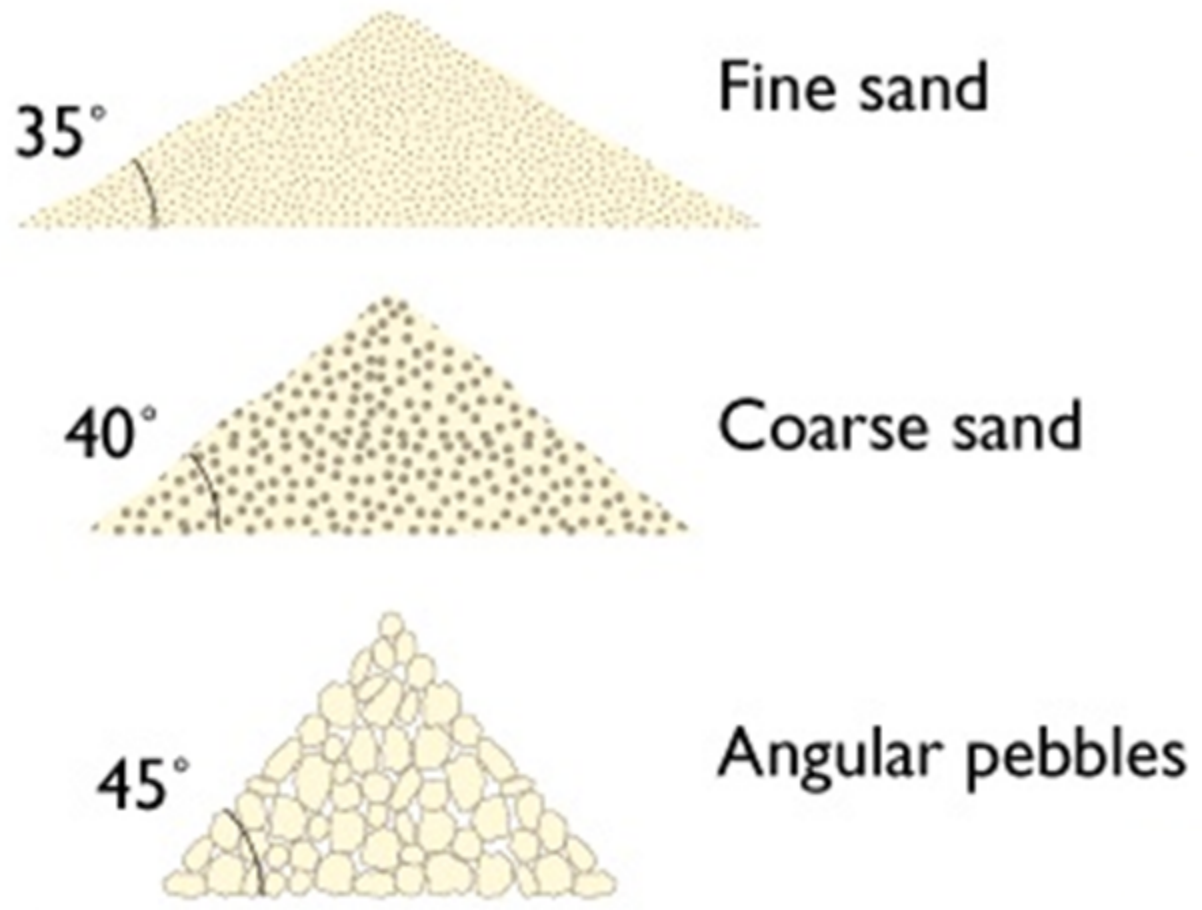
Triggering processes

Morphology: gravity and slope gradient effect

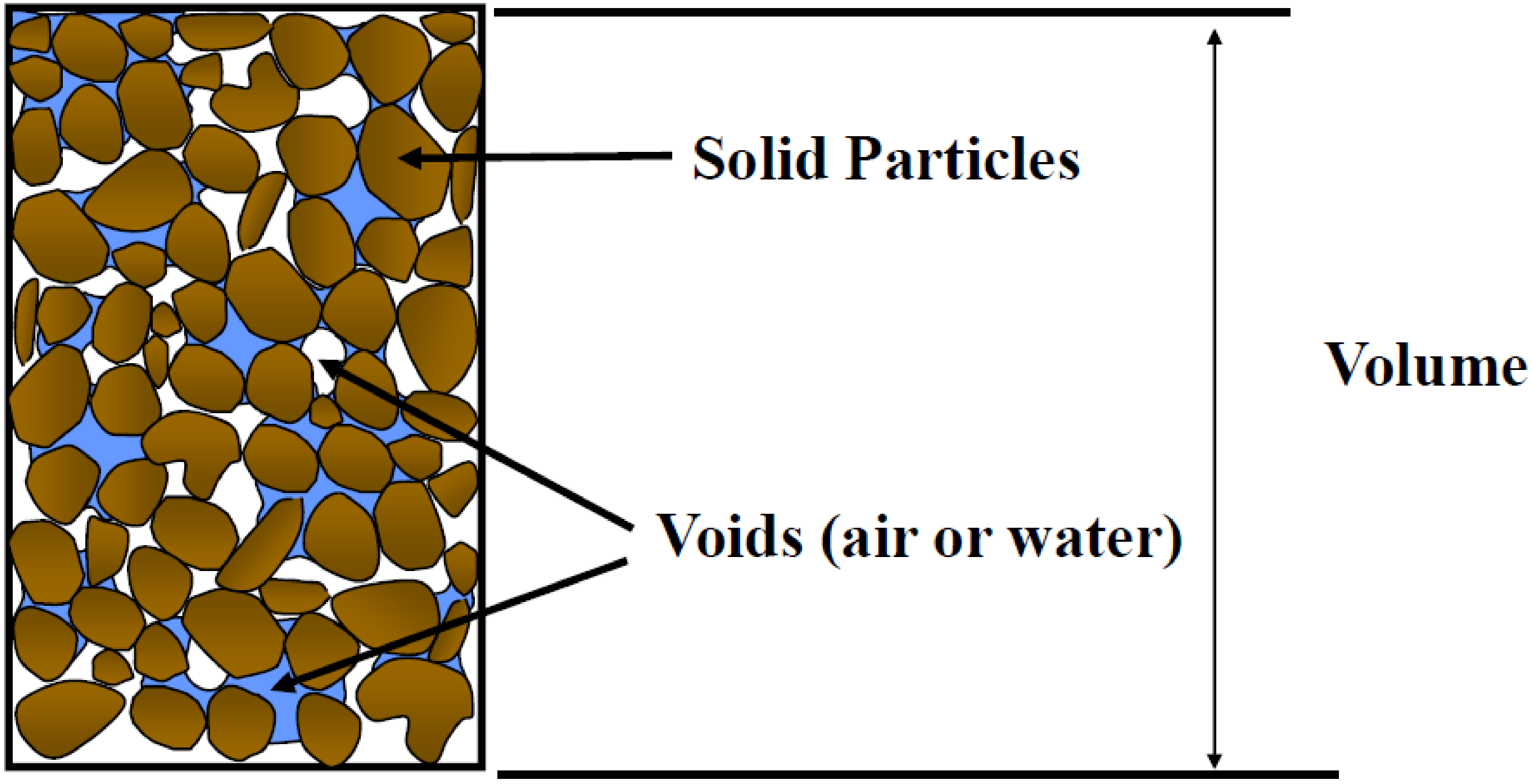




Angle of repose varies for different grain size and shape



The mineral skeleton of soils



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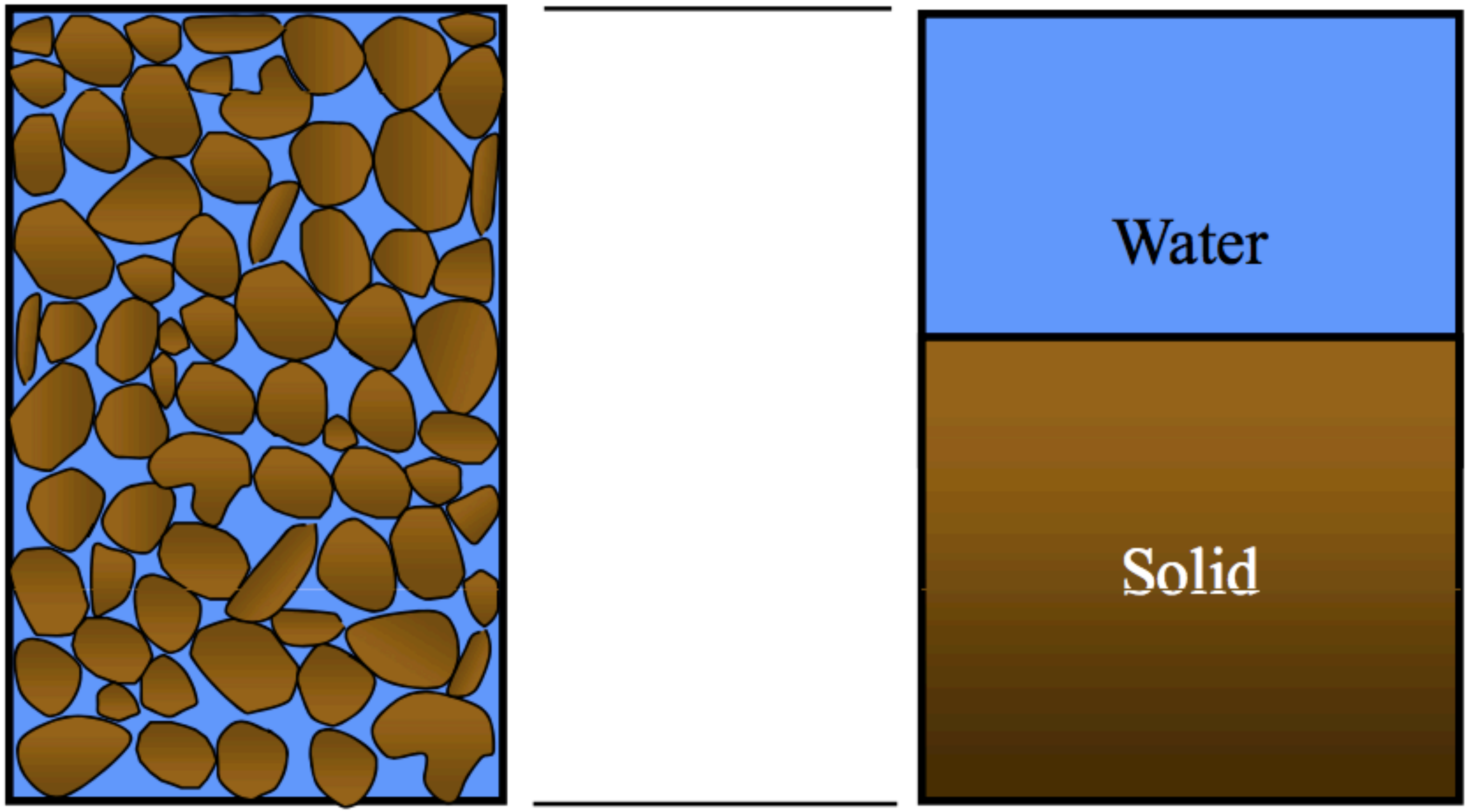

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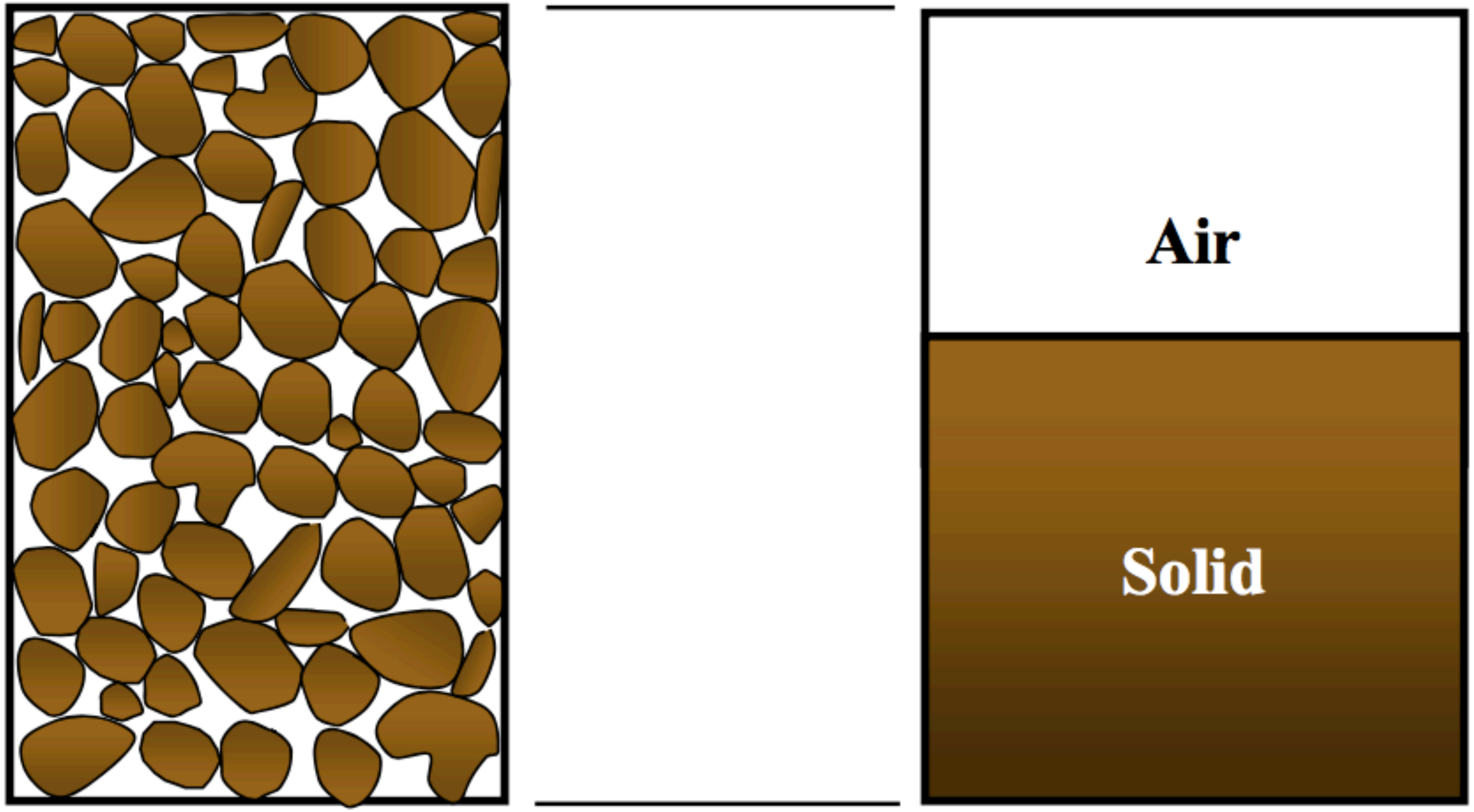
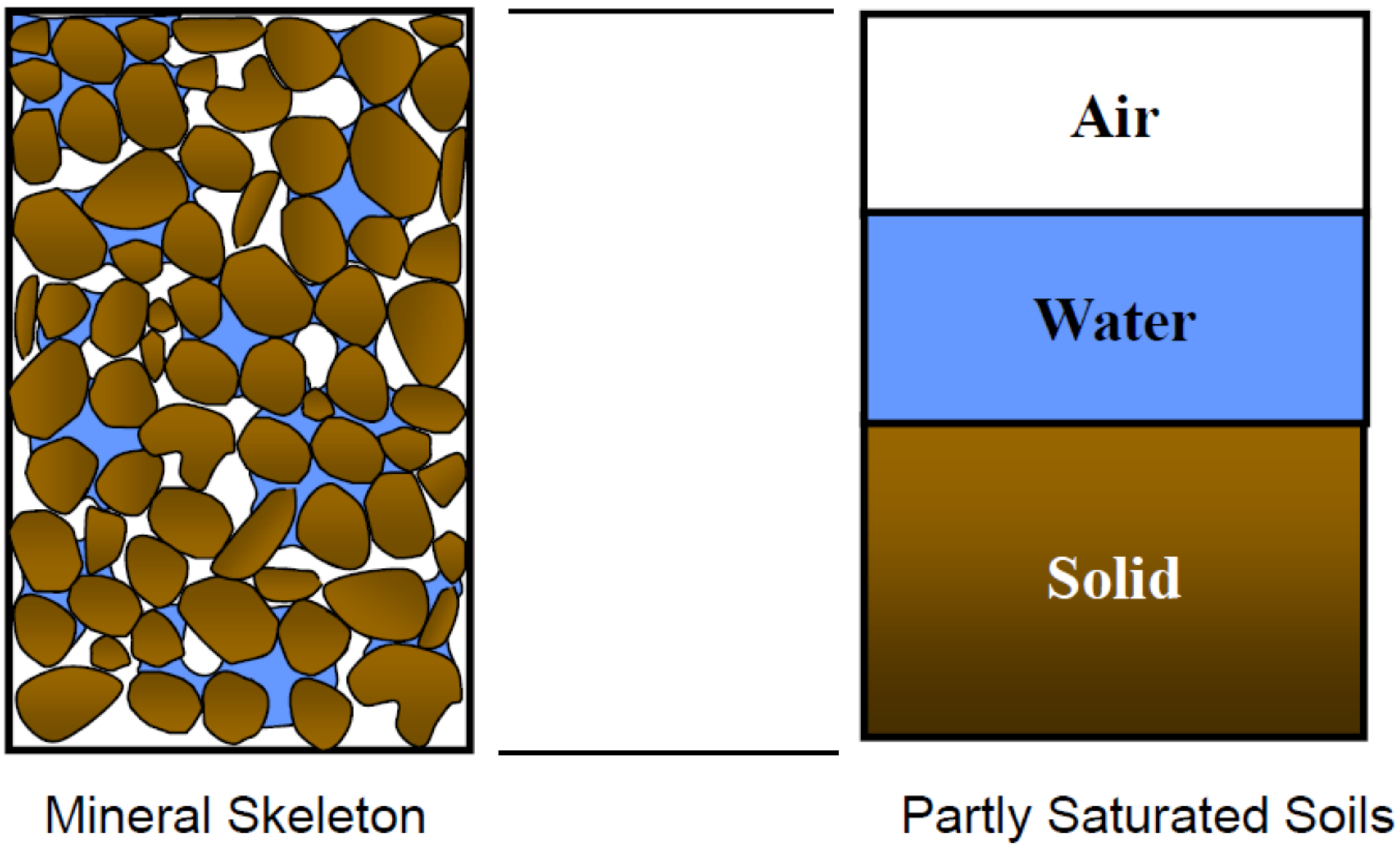
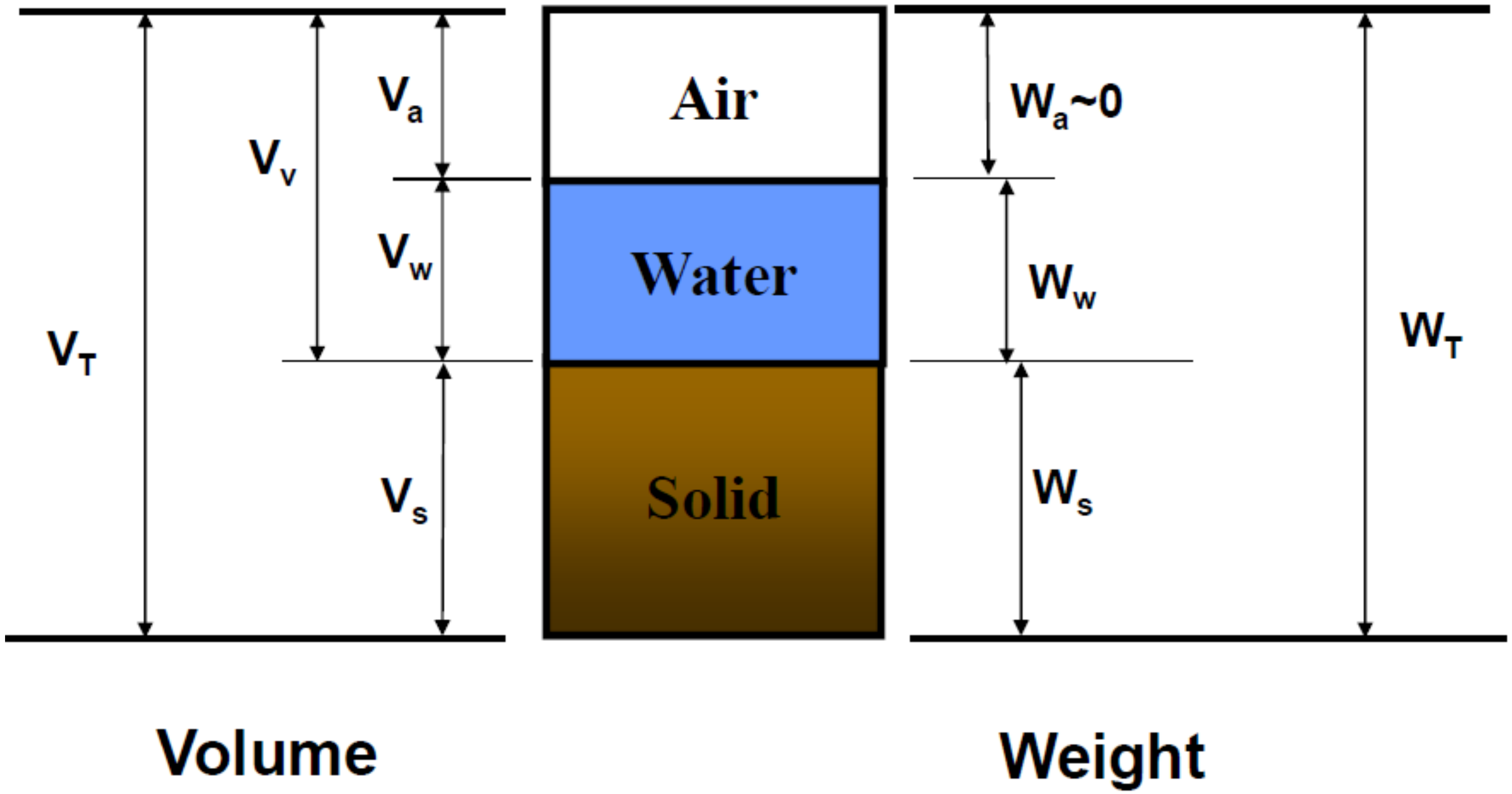


Three phase diagram



Three phase diagram

<u>Notation</u>
M = mass or weight
V = volume
s = soil grains
w = water
a = air
v = voids
t = total



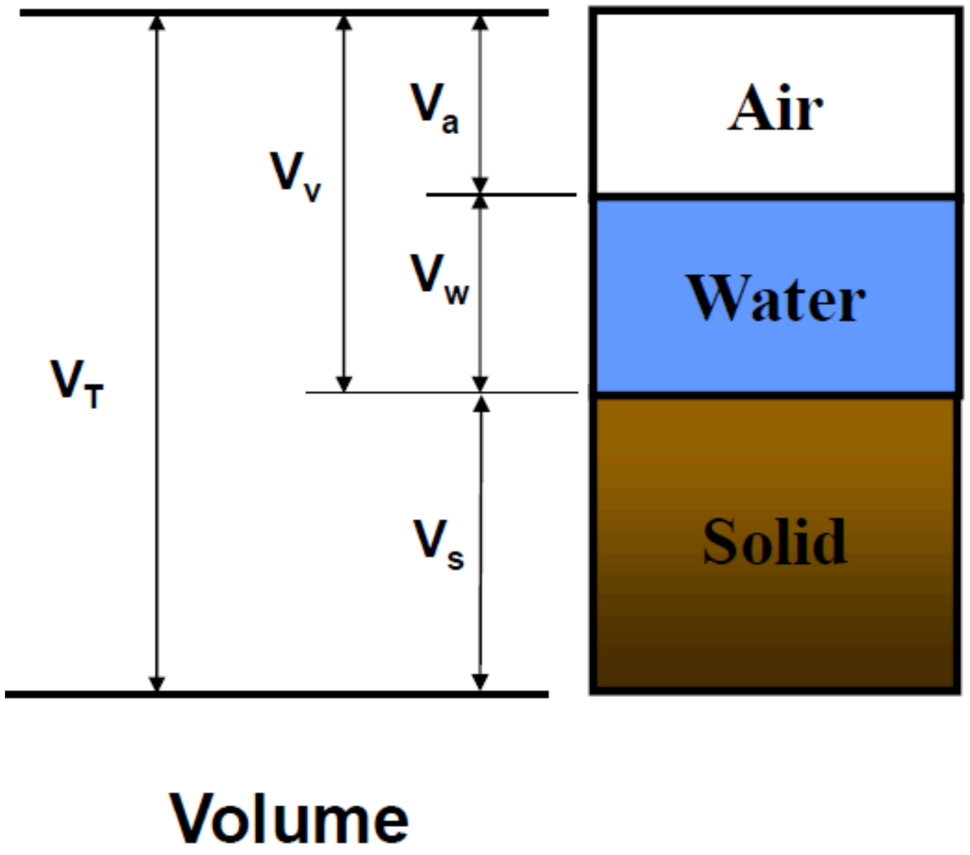
Three phase diagram

Porosity

$$n = \frac{V_V}{V_T}$$

Degree of saturation

$$S = \frac{V_w}{V_V}$$



Three phase diagram

Natural unit weight

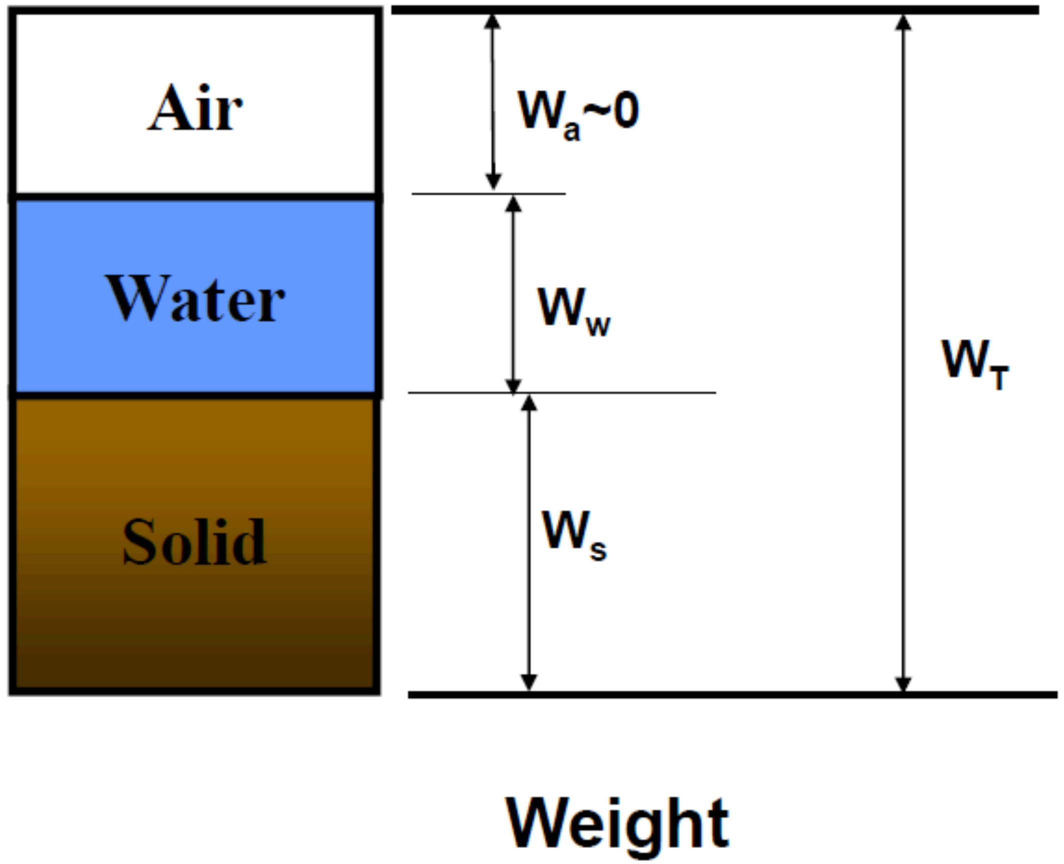
$$\gamma = \frac{W_T}{V_T}$$

Dry unit weight

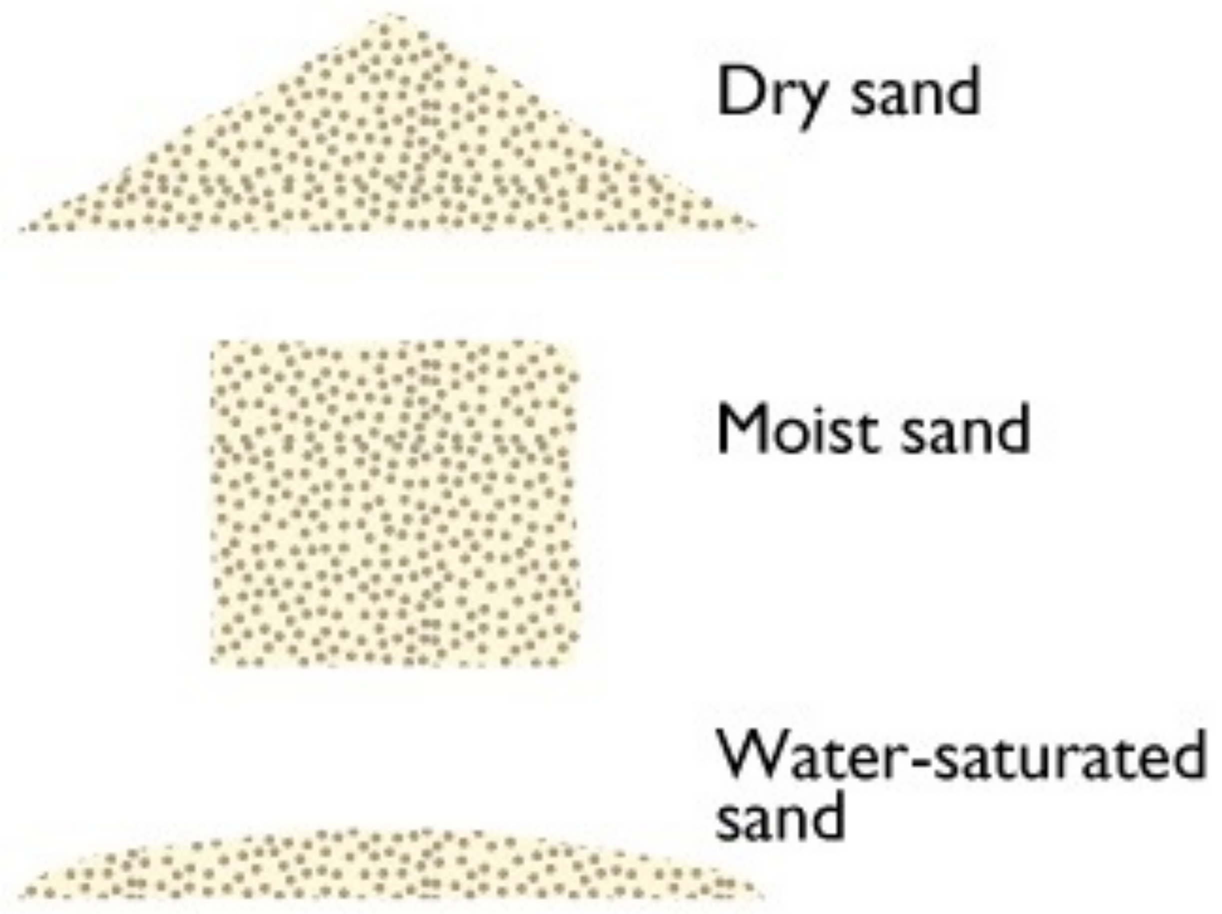
$$\gamma_S = \frac{W_S}{V_T}$$

Saturated unit weight

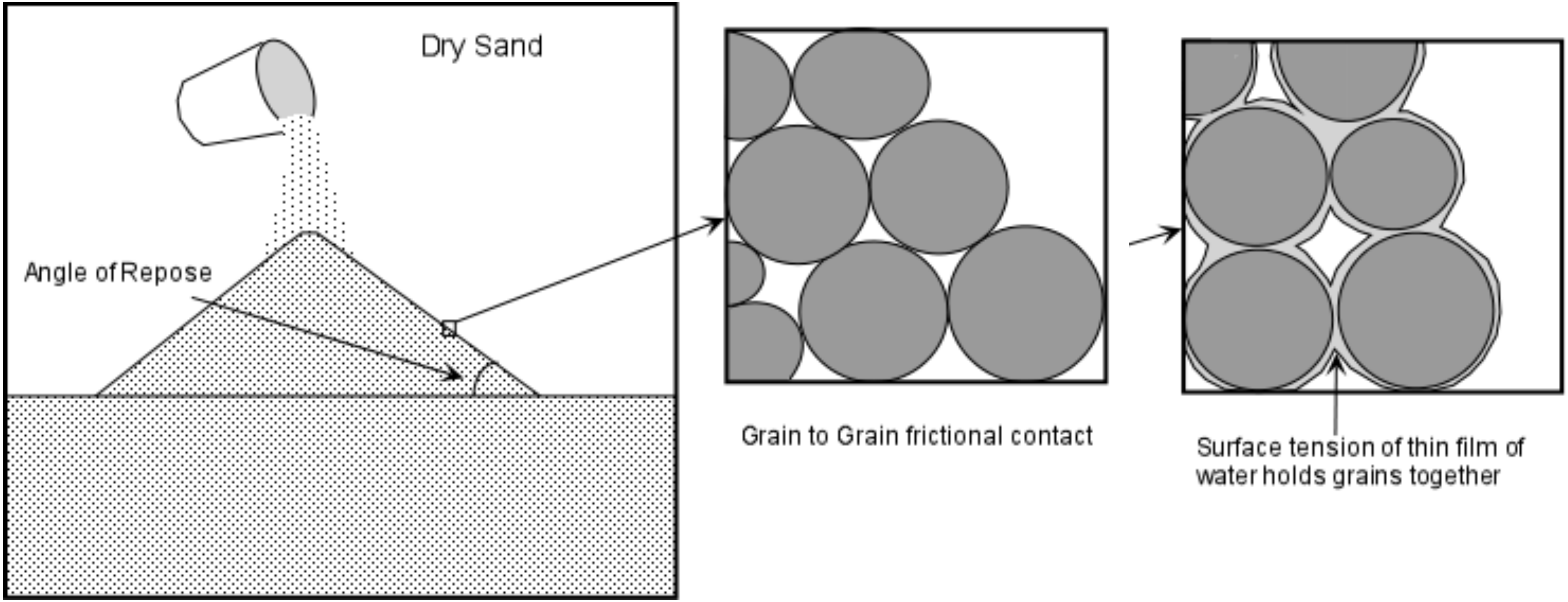
$$\gamma = \frac{W_S + V_V * \gamma_w}{V_T}$$



Angle of repose varies for different saturation conditions

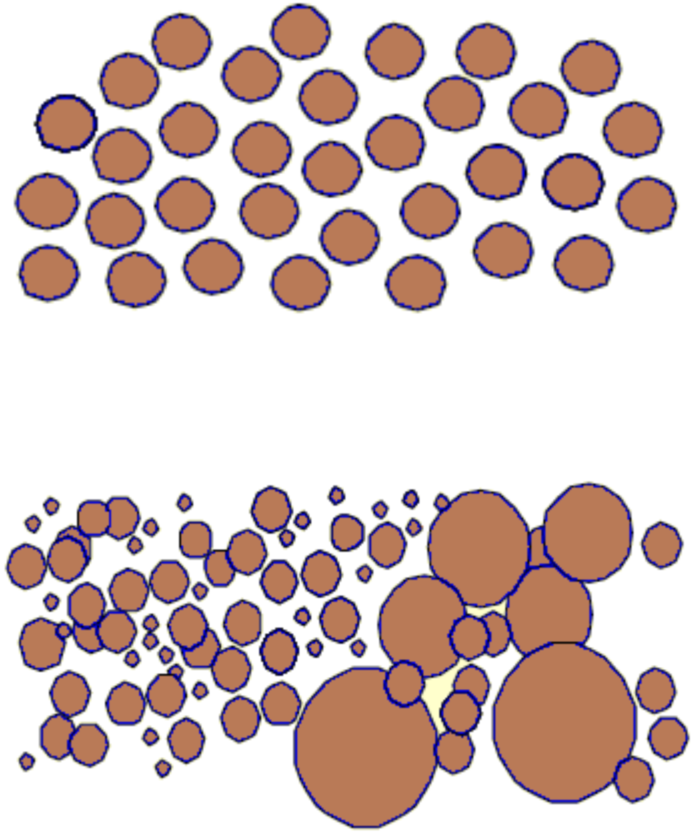


Water decreases soil cohesion and strength

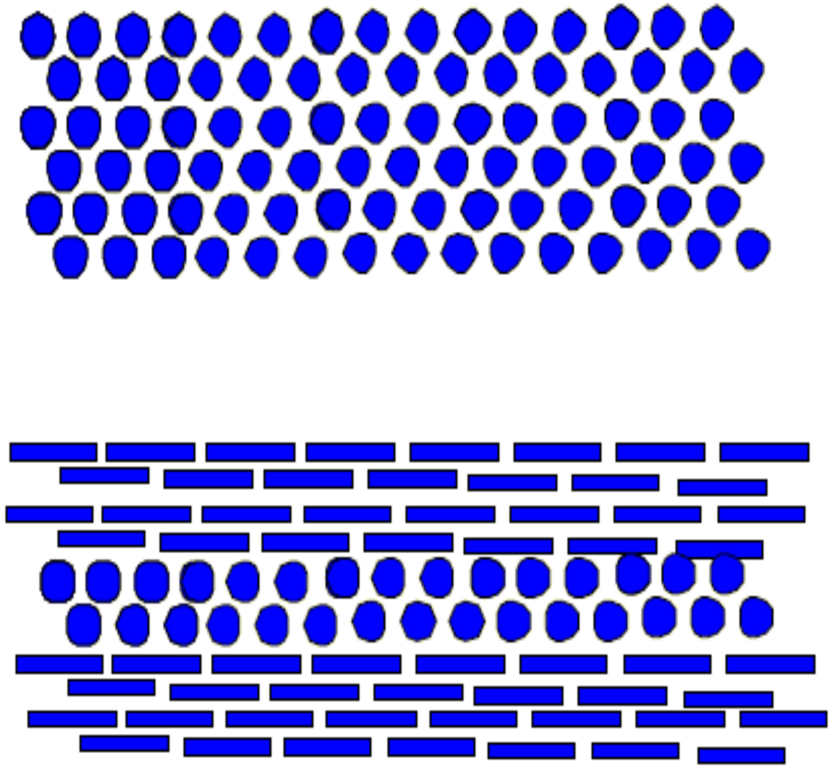


Main characteristics of soils

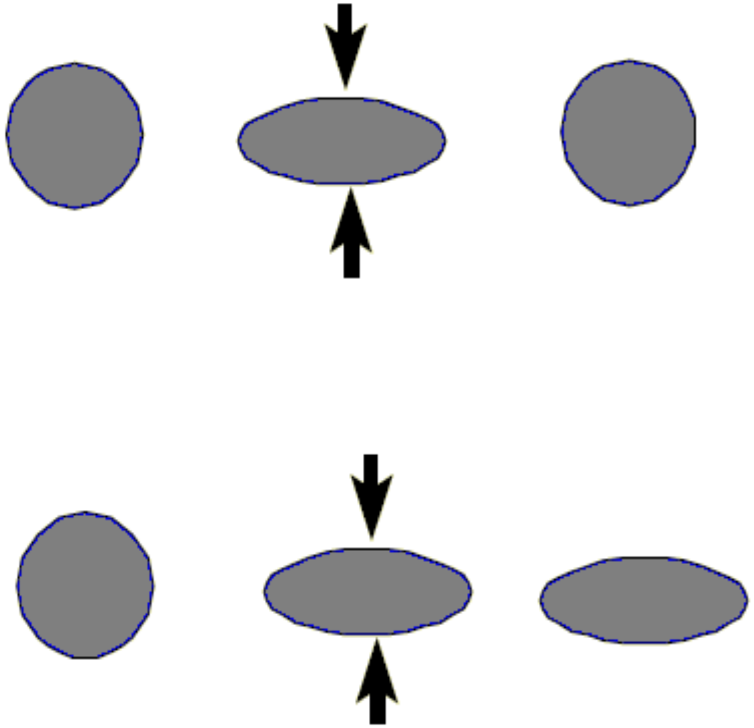
Heterogeneous

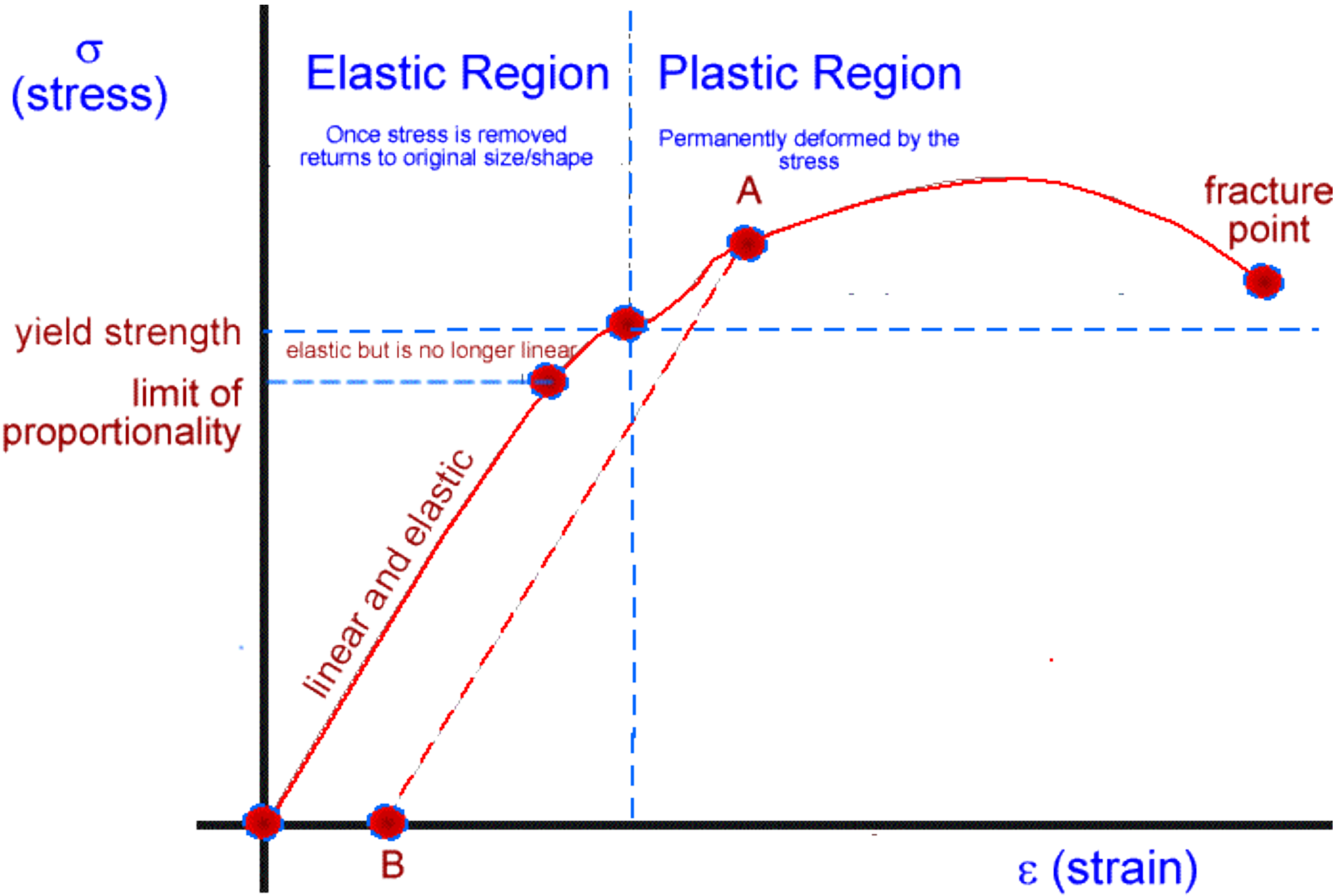


Anisotropic



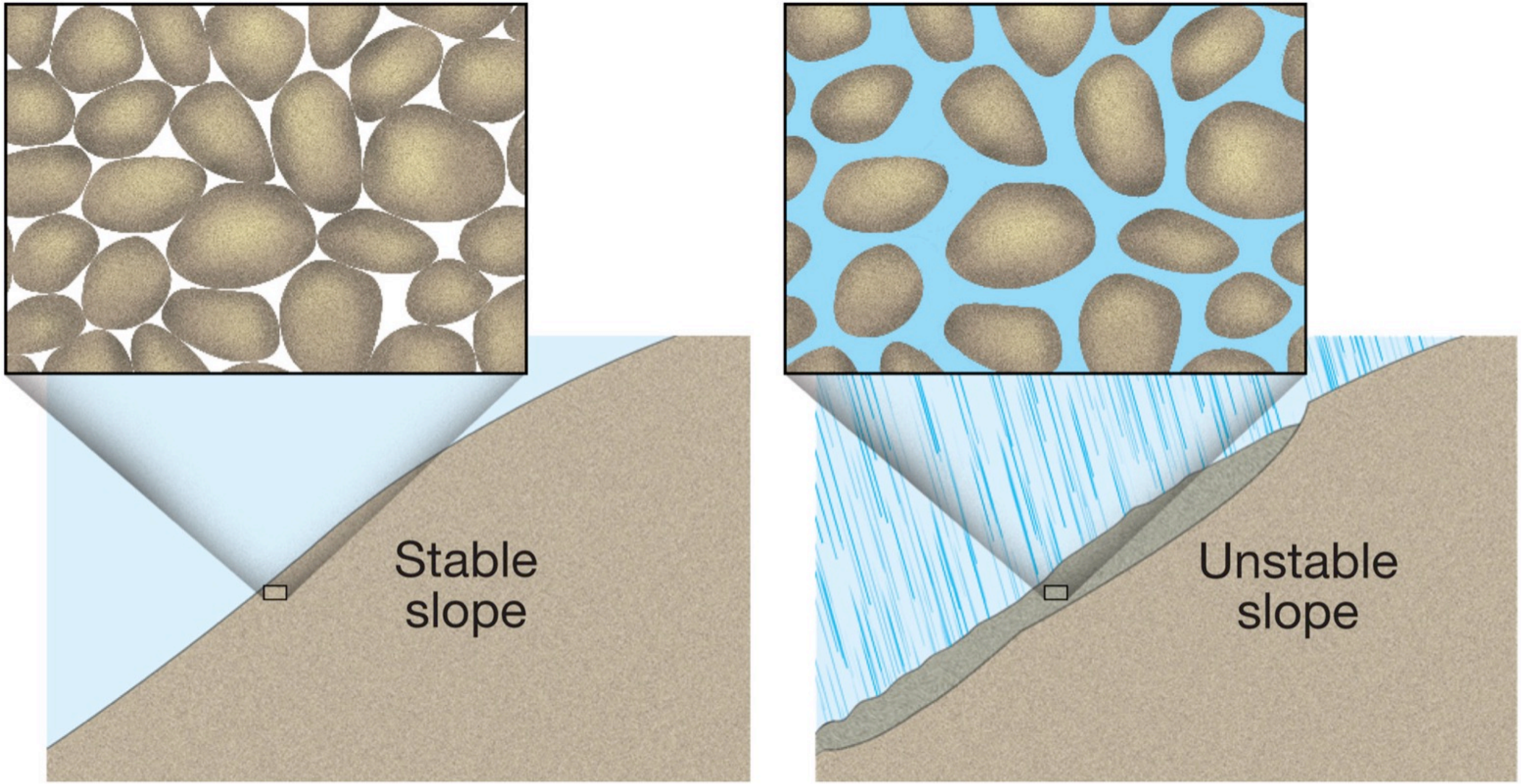
Non-conservative





σ
(stress)
Elastic Region
Plastic Region
Once stress is removed
returns to original size/shape
Permanently deformed by the
stress
A
fracture
point
yield strength
elastic but is no longer linear
limit of
proportionality
linear and elastic
B
ε (strain)

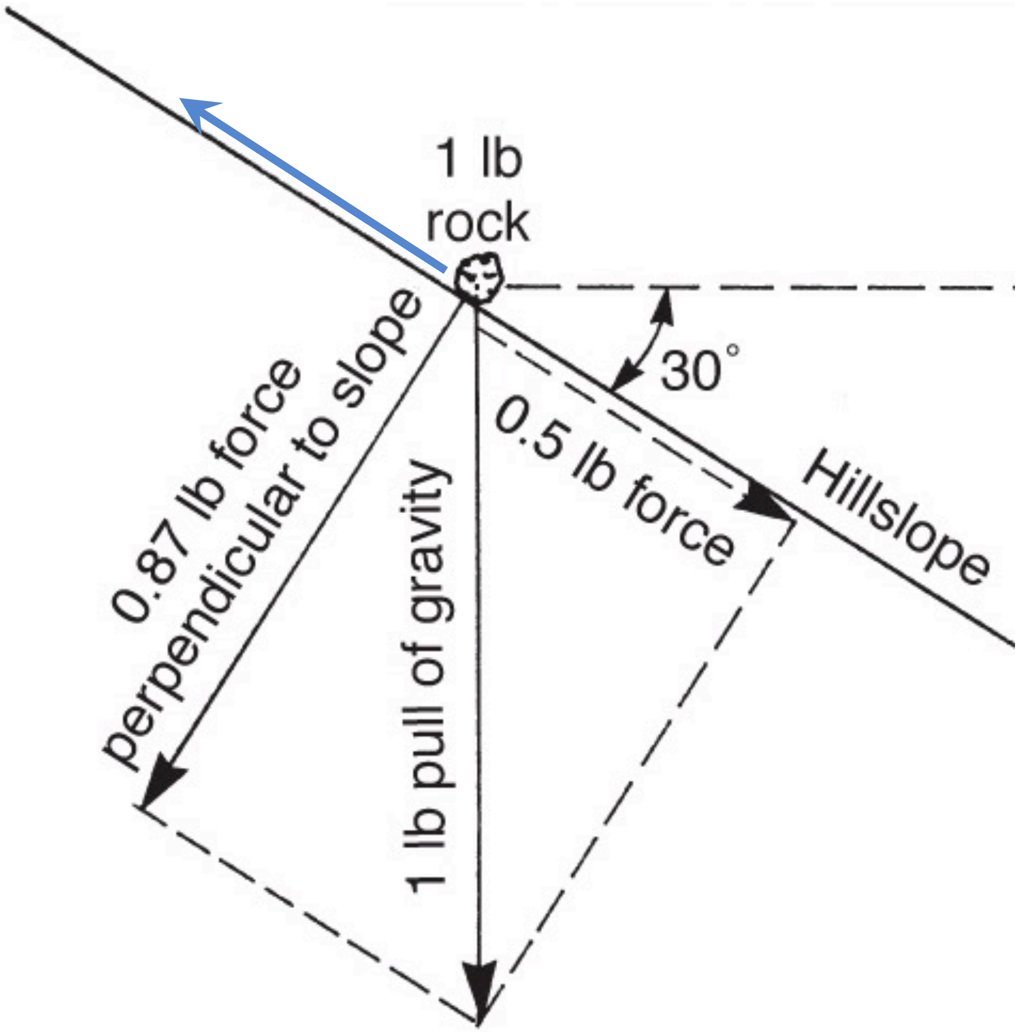
How to cause a landslide: 1) Water decreases soil cohesion and strength

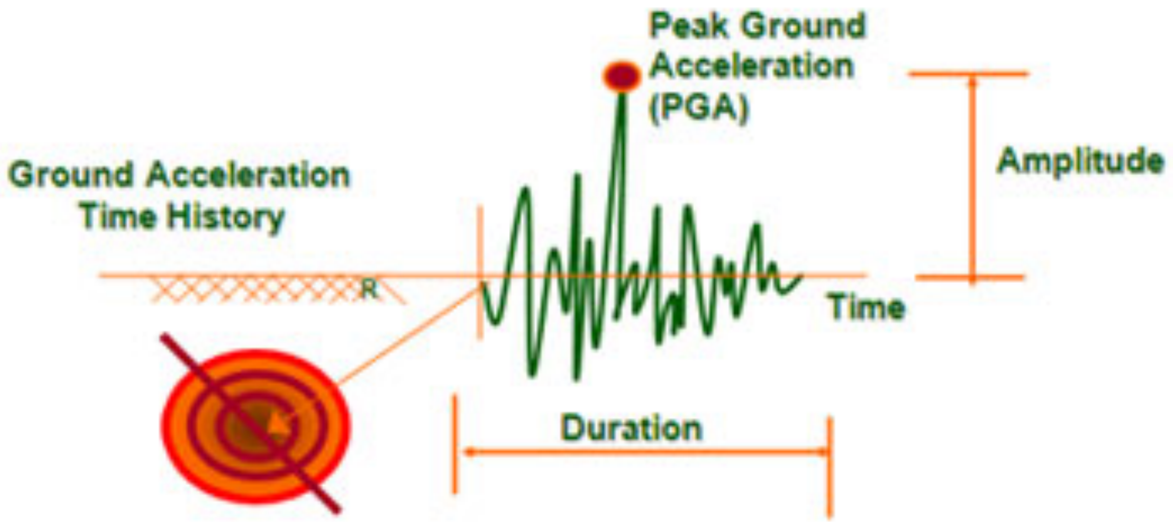


A. Dry soil–high friction

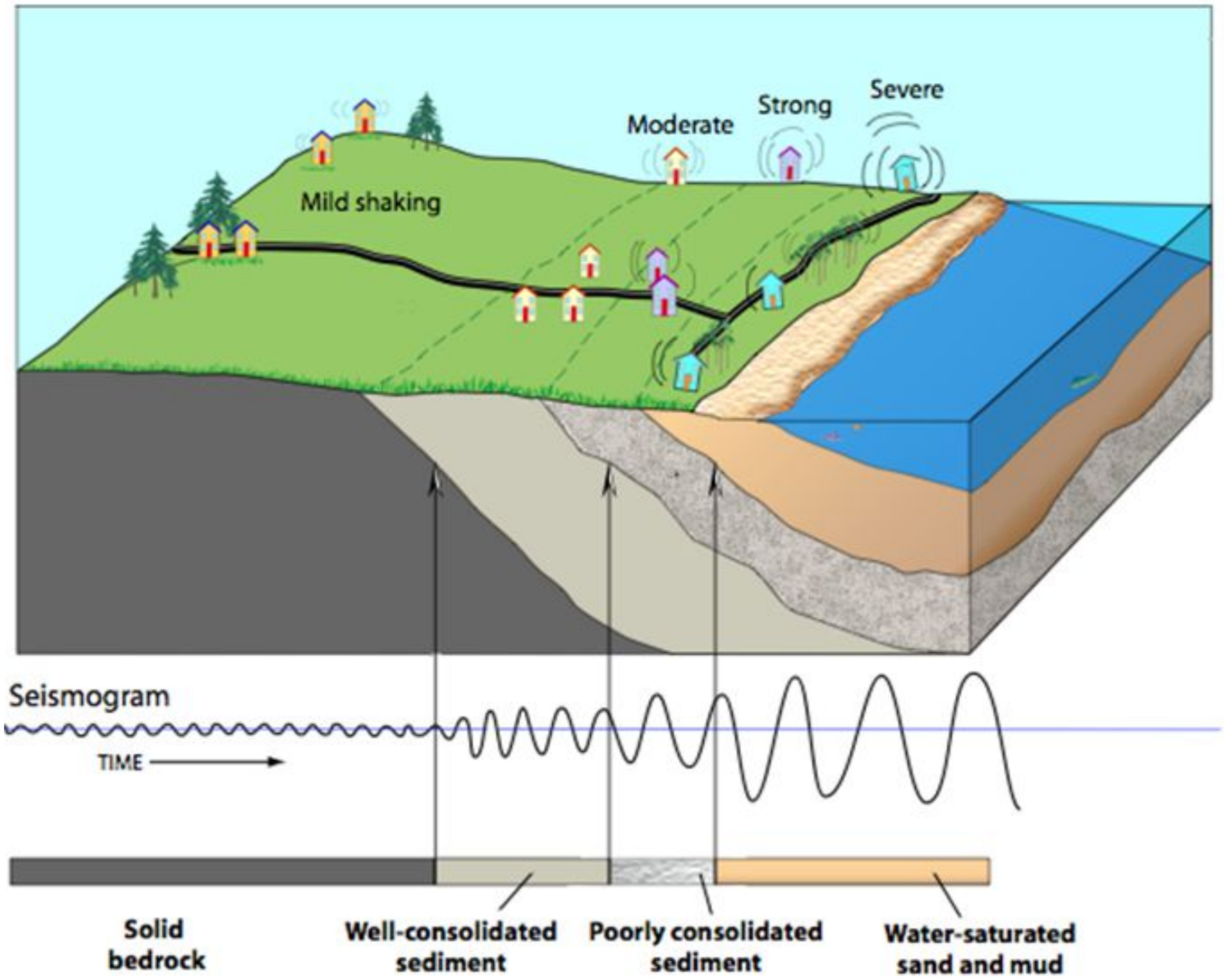
B. Saturated soil

How to cause a landslide: 2) ground shaking

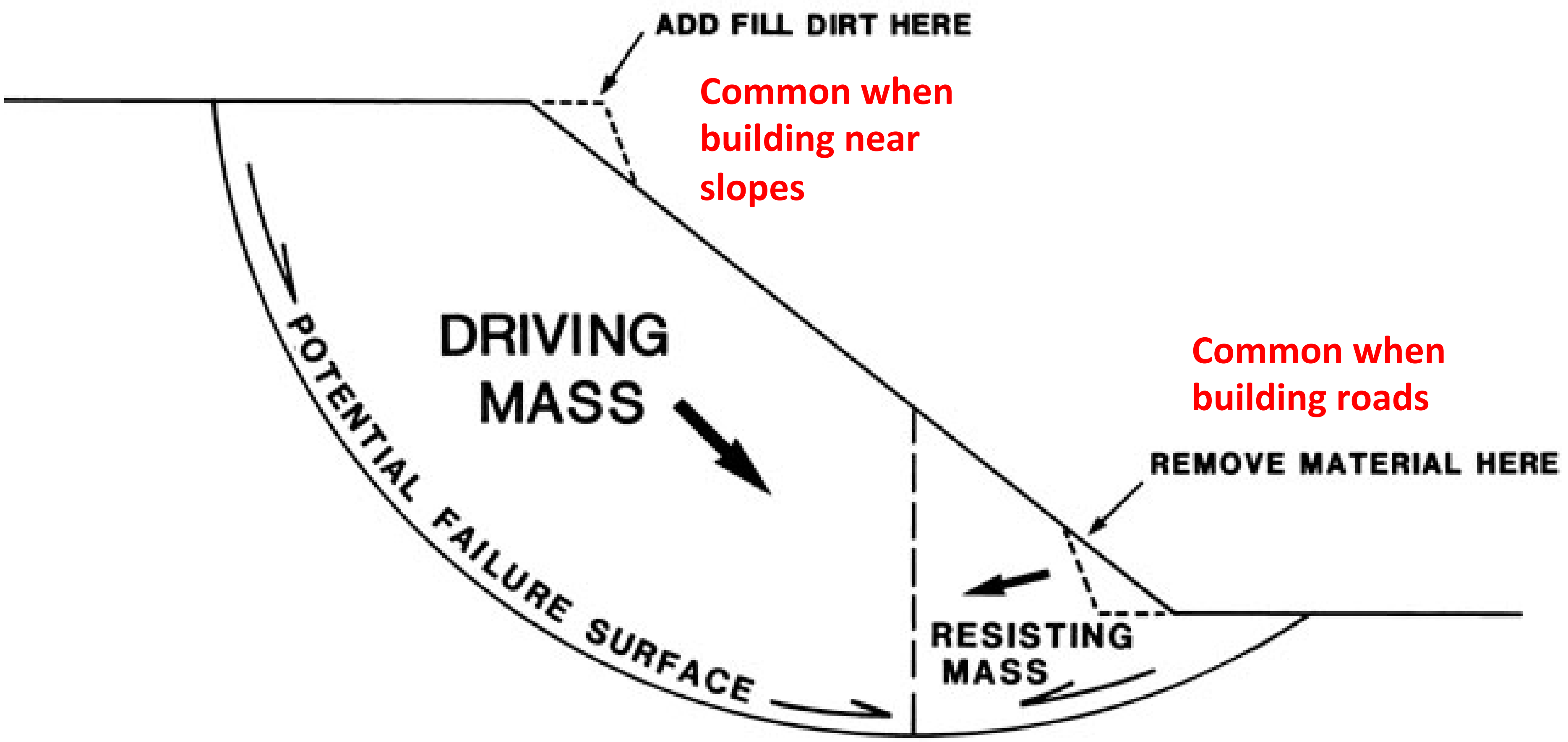




How to cause a landslide: 2) ground shaking

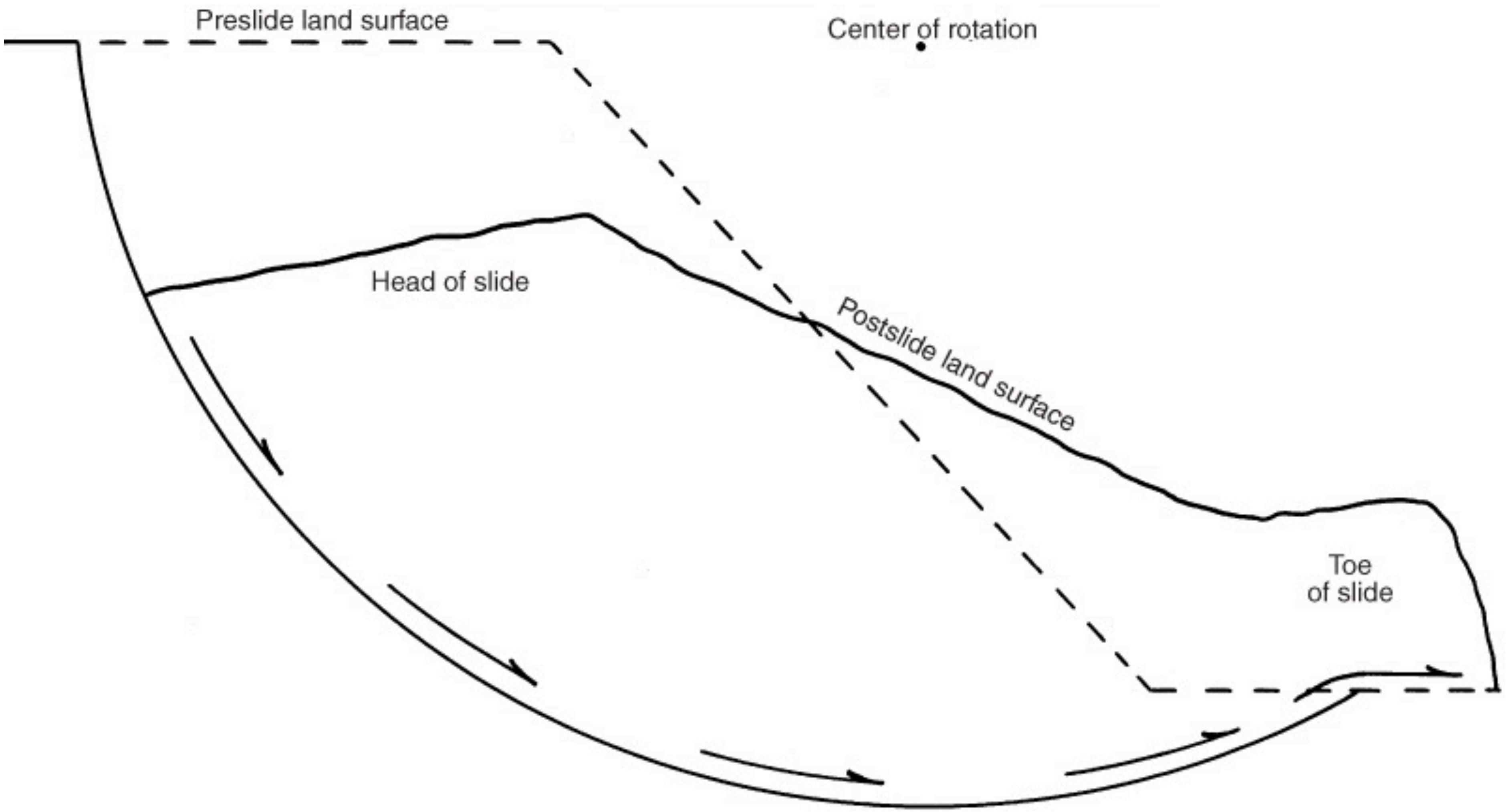


How to cause a landslide: 3) add or remove mass in the wrong place

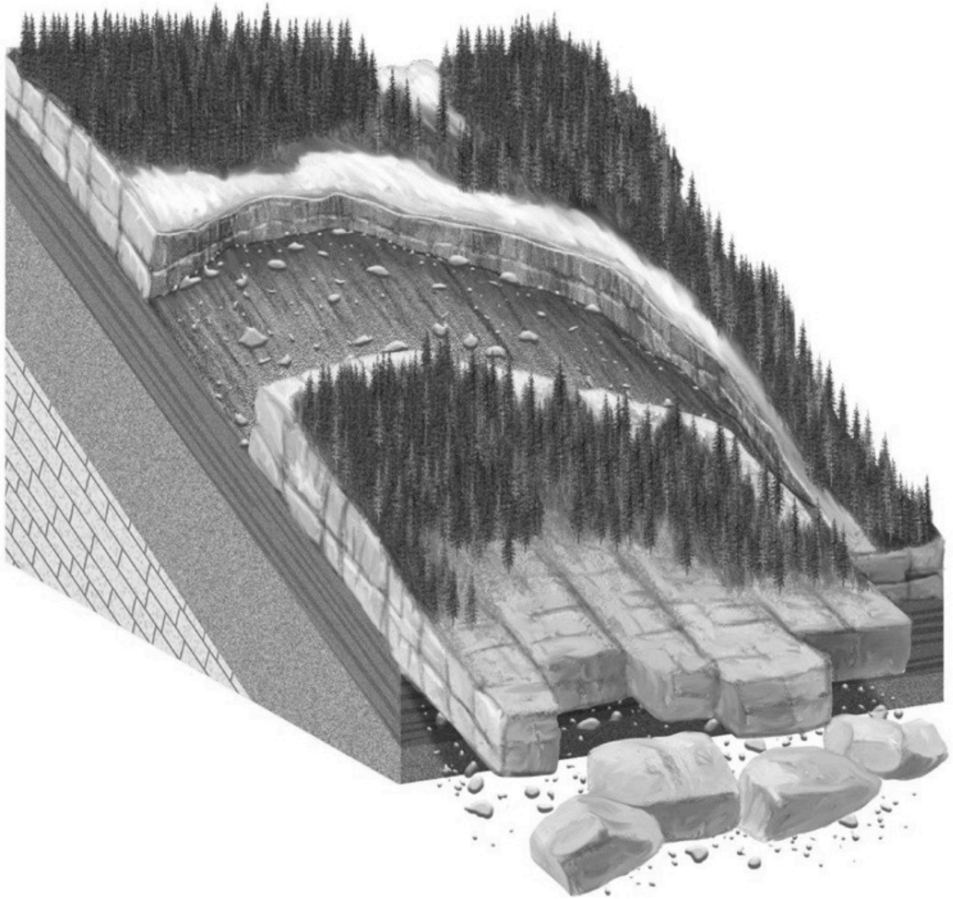


How to cause a landslide: (1) Load the head, (2) Reduce the toe

How to cause a landslide: 3) add or remove mass in the wrong place

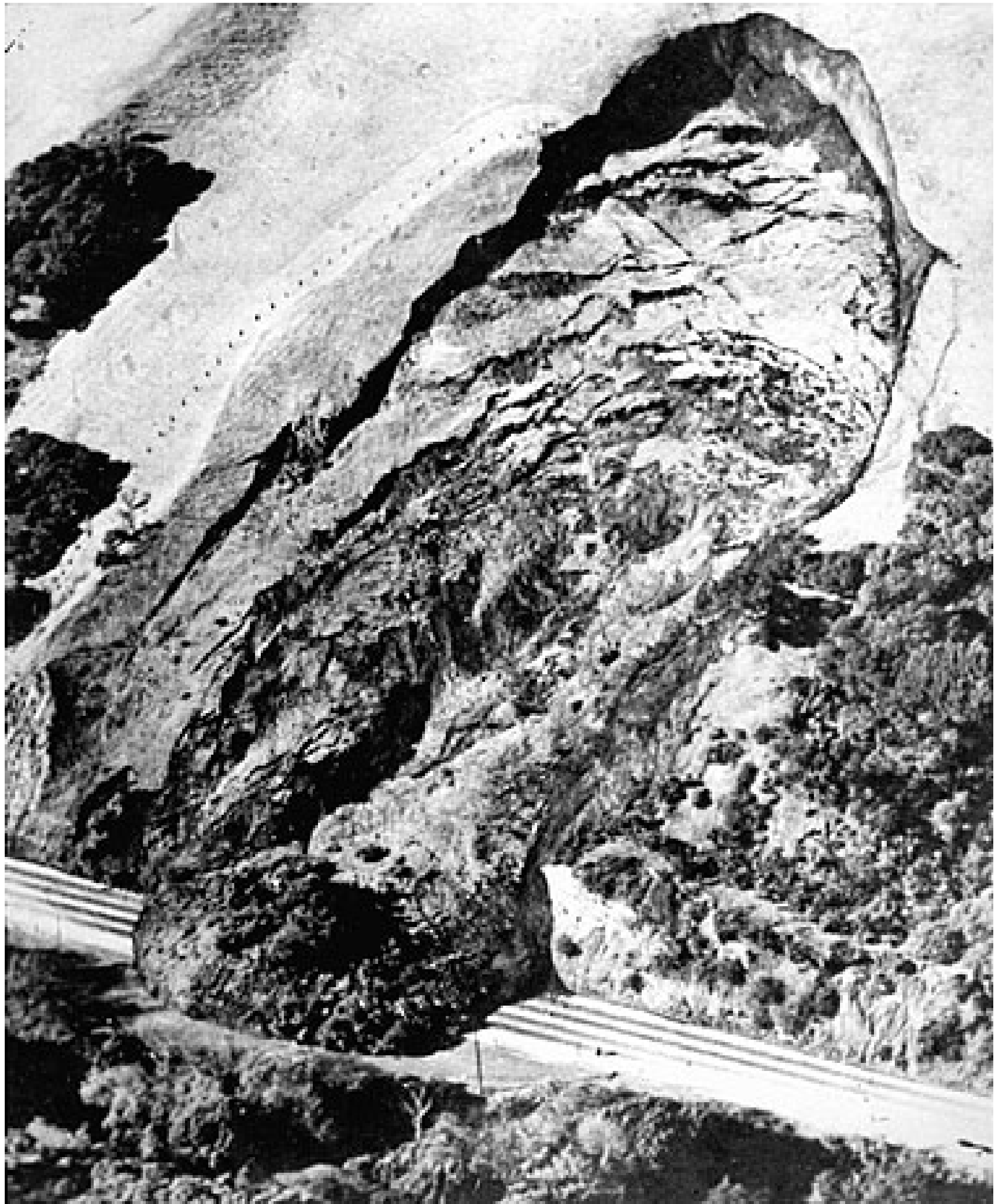


Geomorphic features associated with translational landslides

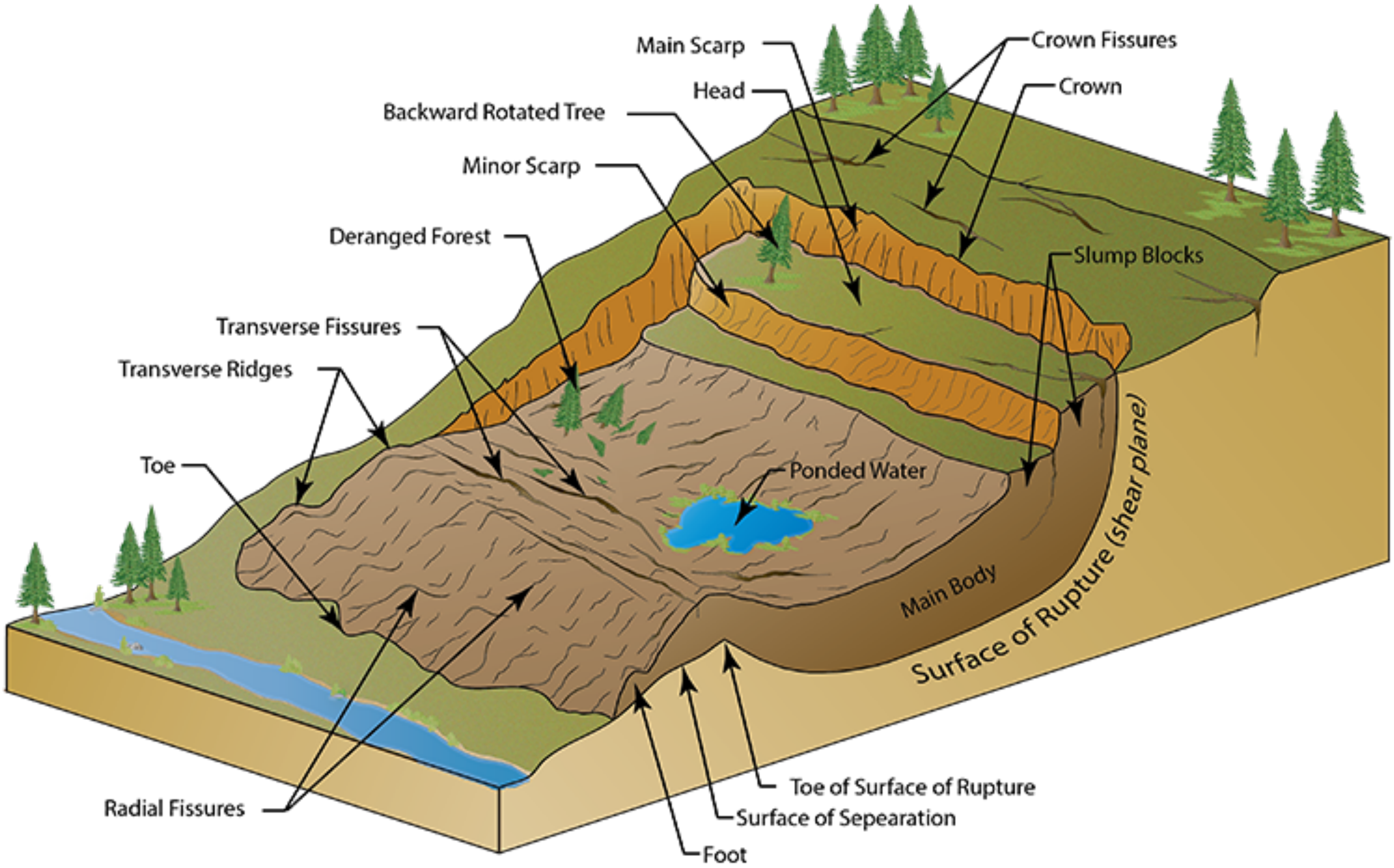


Estatal 101, Queretaro, Mexico

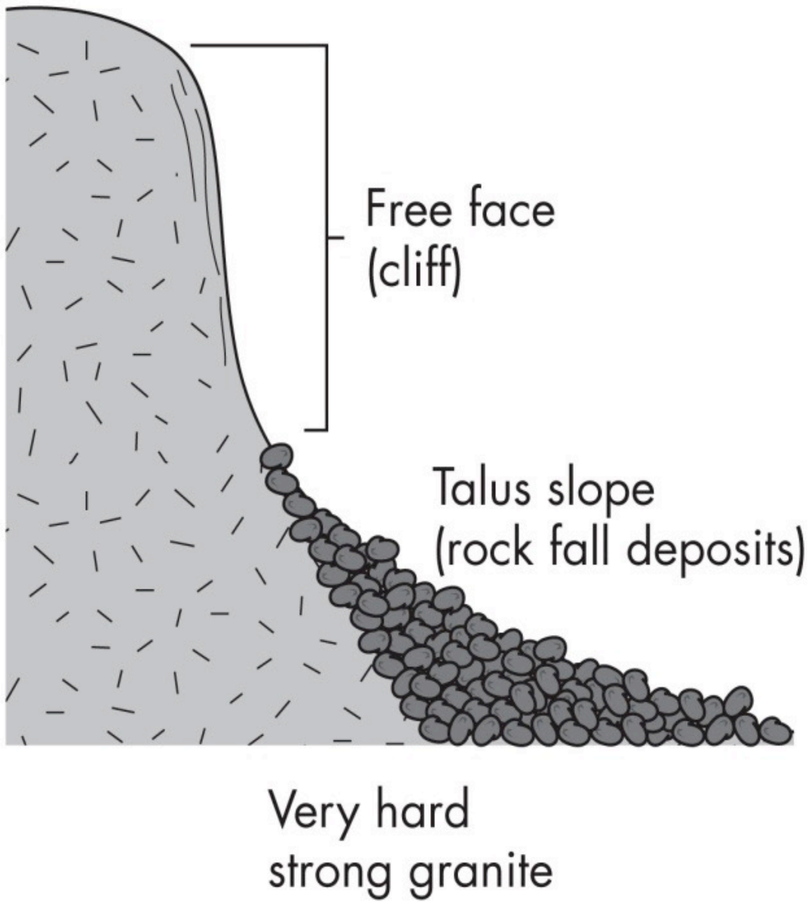
Geomorphic features associated with a rotational landslide



Geomorphic features associated with a rotational landslide

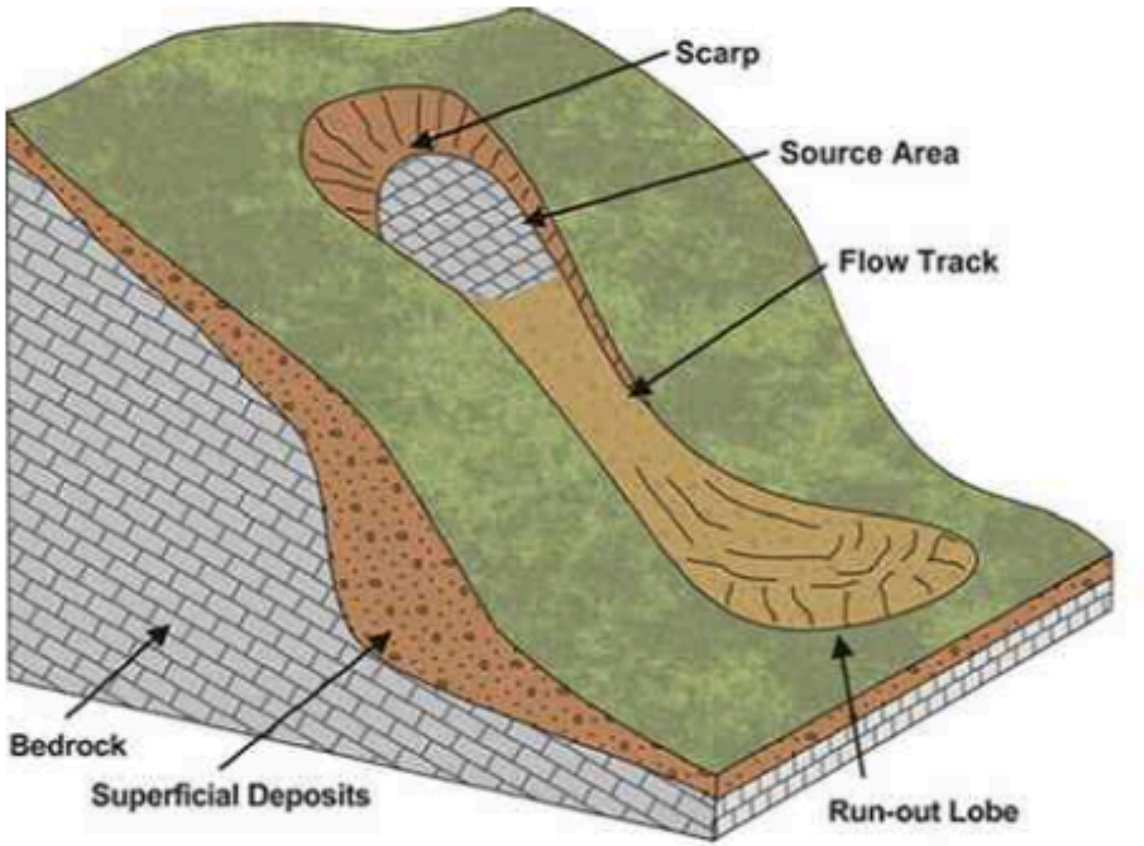


Geomorphic features associated with rockfalls

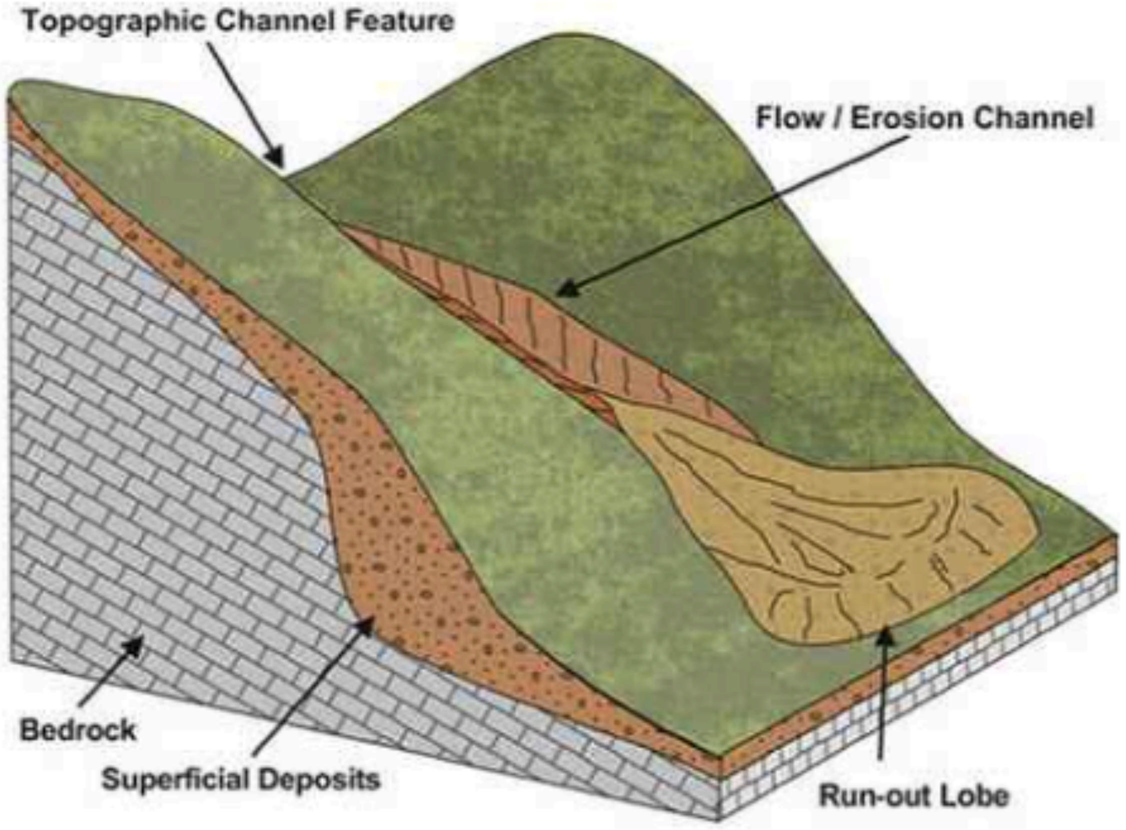


Geomorphic features associated with flows

Hillslope debris flow



Channelized debris flow



Geomorphic features associated with flows

Hillslope debris flow (Vergas State, Venezuela)

Channelized debris flow (Gadria, Italy)

Channelized flow typologies

Debris flow *is a very rapid to extremely rapid flow of saturated non-plastic debris in a steep channel. (Plasticity Index < 5% in sand and finer fractions)*

Debris fan features

LEVEE

LARGE CLAST

Channelized flow typologies

(Photo H. Hubl, Vienna)

QUINDICI, Italy

Mud flow ***is a very rapid to extremely rapid flow of saturated plastic debris in a channel, involving significantly greater water content relative to the source material (Plasticity Index > 5%)***

Debris flood ***is a very rapid, surging flow of water, heavily charged with debris, in a steep channel.***

Some reaL cases...

August 14, 2017

A hillside in the Regent area, near Sierra Leone capital, Free Town, collapsed early on Monday following heavy rains, leaving many houses covered in mud. Many people may have been asleep when the mudslide occurred.

August 6, 2016

Several homes were buried in Coscomatepec (Veracruz), and at least 45 people have died in landslides triggered by the Tropical Storm Earl in the whole Mexico.

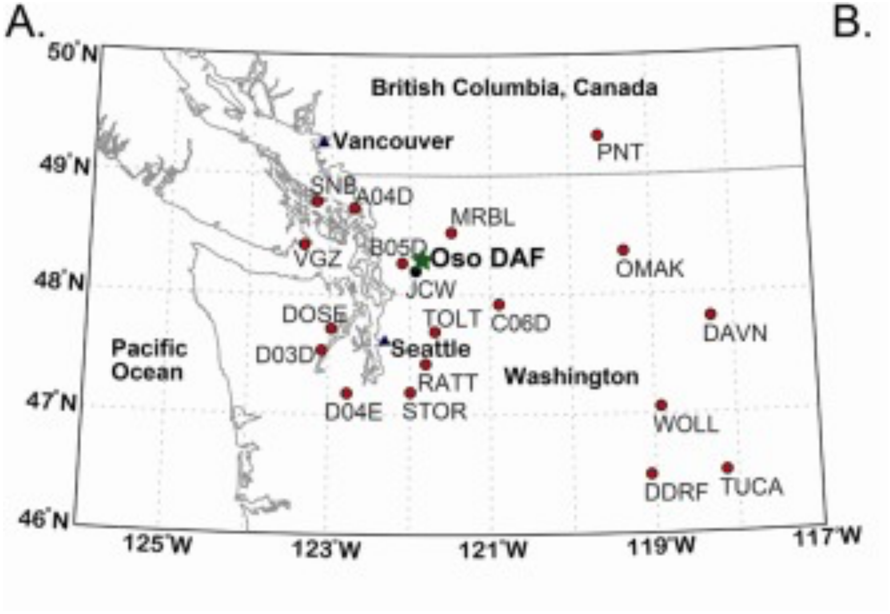
The Burma jade mine landslide disaster, 2015

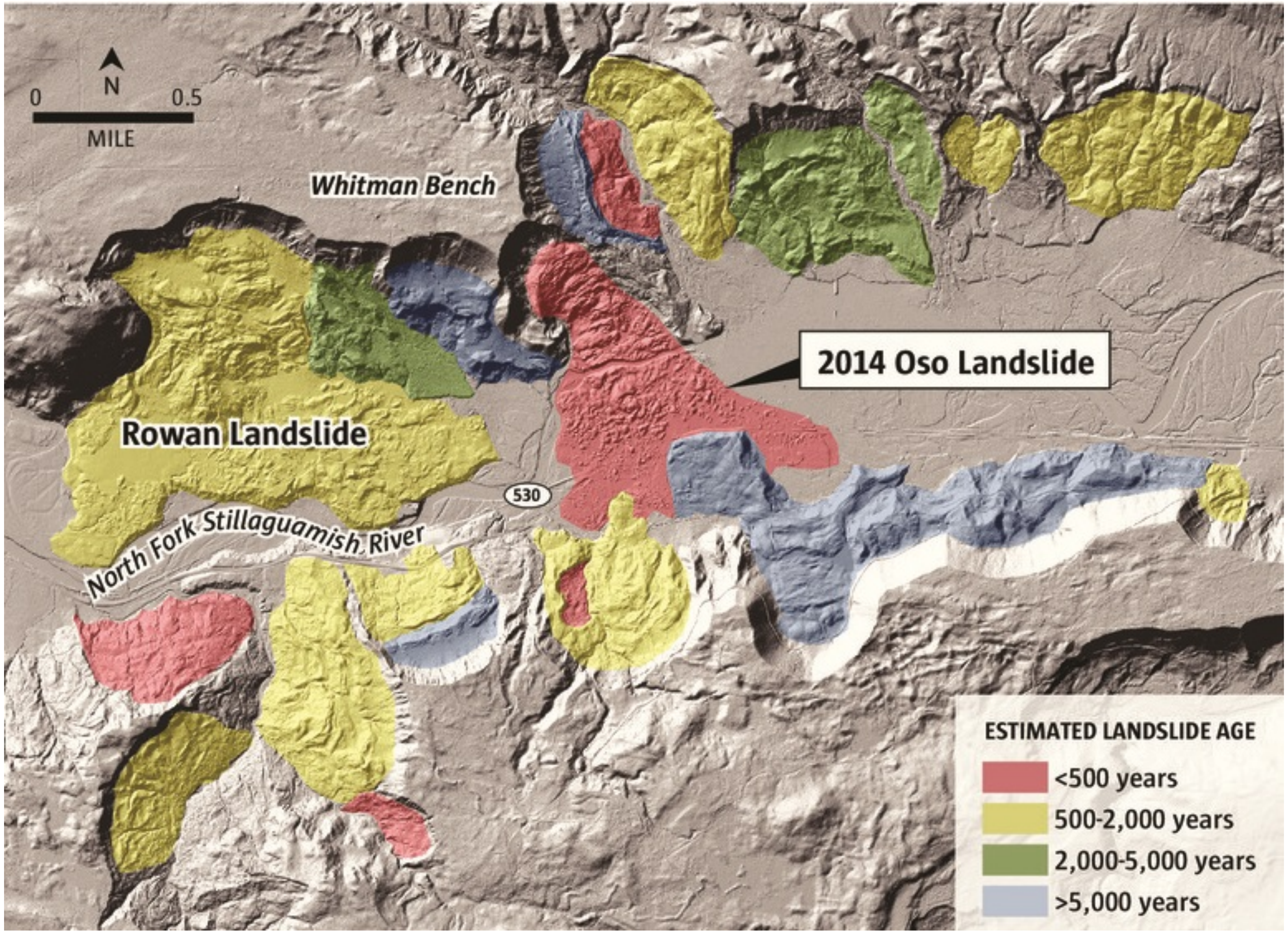
This landslide at a jade mine has killed at least 200 people in northern Myanmar. The victims were buried when a vast heap of waste material, discarded by the mining companies, collapsed in Kachin state. Many of the dead were scavengers living on or near the waste dumps, who search through the debris in the hope of finding fragments of jade to sell.

March 22, 2014

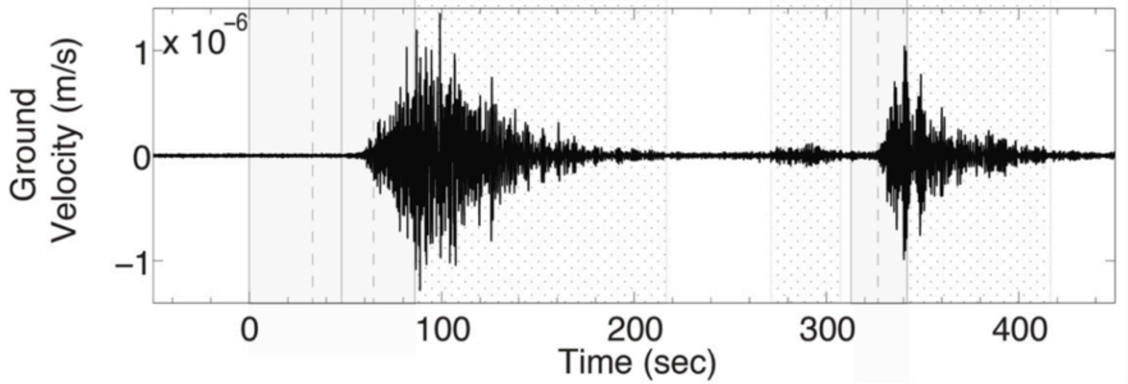
A portion of an unstable hill collapsed 6.4 km east of Oso, Washington, USA, sending mud and debris to the south across the Stillaguamish River, engulfing a rural neighborhood, covering an area of approximately 2.6 km^2, and killing 34 people.

Oso landslide, Washington (USA) - March 22, 2014





R.M. Iverson, D.L. George, K. Allstadt, M.E. Reid, B.D. Collins, J.W. Vallance, S.P. Schilling, J.W. Godt, C.M. Cannon, C.S. Magirl, R.L. Baum, J.A. Coe, W.H. Schulz, J.B. Bower (2015). Landslide mobility and hazards: implications of the 2014 Oso disaster, Earth and Planetary Science Letters, 412, 197-208.



Oso landslide, Washington (USA) - March 22, 2014

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