COURSE: GEO-INFORMATICS IN EARTH SCIENCE, TECTONIC HAZARD AND INFRASTRUCTURE MANAGEMENT

LECTURE 5 – The Science of Liquefaction and Site Soil-Geology

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What is Liquefaction

- These strong buildings in Niigata, Japan, fell over when the sediments below them liquefied during the 1964 earthquake.

Source: Hyndman. D., and Hyndman. D., (2007), National Geographic Data Center, NOAA.

What is Liquefaction

- Stuck in the mud? Sinkholes and subsidence caused by liquefaction caused widespread damage in Christchurch.

Source: news.com.au.

Online: https://temblor.net/earthquake-insights/liquefaction-leaning-tower-san-francisco-1048/

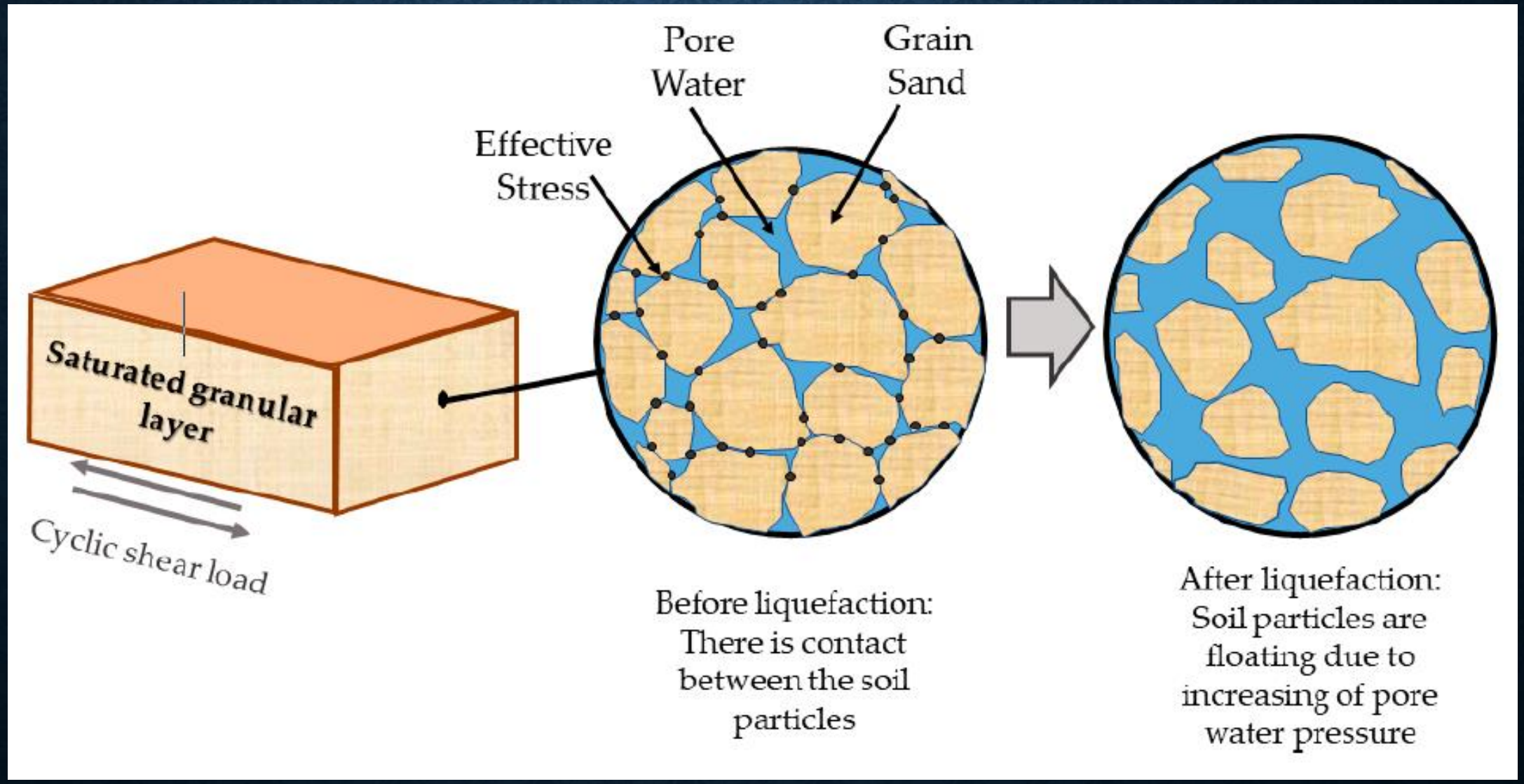
What is Liquefaction

Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading.

Possibility of Liquefaction to occur

Liquefaction is more likely to occur in loose to moderately saturated granular soils with poor drainage, such as silty sands or sands and gravels that are capped or contain seams of impermeable sediments

Possibility of Liquefaction



Source: Araujo. W., and Ledezma. C., (2020)

Possibility of Liquefaction to occur

- The water exerts a pressure on the soil particles that influences how tightly the particles themselves are pressed together.
- Water Pressure was low at First.
- Earthquake shaking cause the water pressure to increase to the point where the soil particles can readily move with respect to other.

Factors Affecting Liquefaction

Soil Type:

- The type of soil plays a significant role. Loose, cohesionless soils such as sands and silts are more susceptible to liquefaction than cohesive soils like clays.

Saturation Level:

- The degree of soil saturation with water is crucial. Fully saturated soils are more susceptible because water cannot escape as easily.

Factors Affecting Liquefaction

Grain Size Distribution:

- Fine-grained soils (silt and clay) tend to be less prone to liquefaction than coarse-grained soils (sand and gravel) due to smaller pore spaces and greater interlocking of particles.

Silt Content:

- Higher silt content can hinder the movement of water within the soil and reduce the potential for liquefaction.

Factors Affecting Liquefaction

Intensity and Duration of Shaking:

- Strong ground shaking during earthquakes generates increased pore water pressure, promoting liquefaction. Longer durations of shaking can further exacerbate this effect.

Earthquake Magnitude:

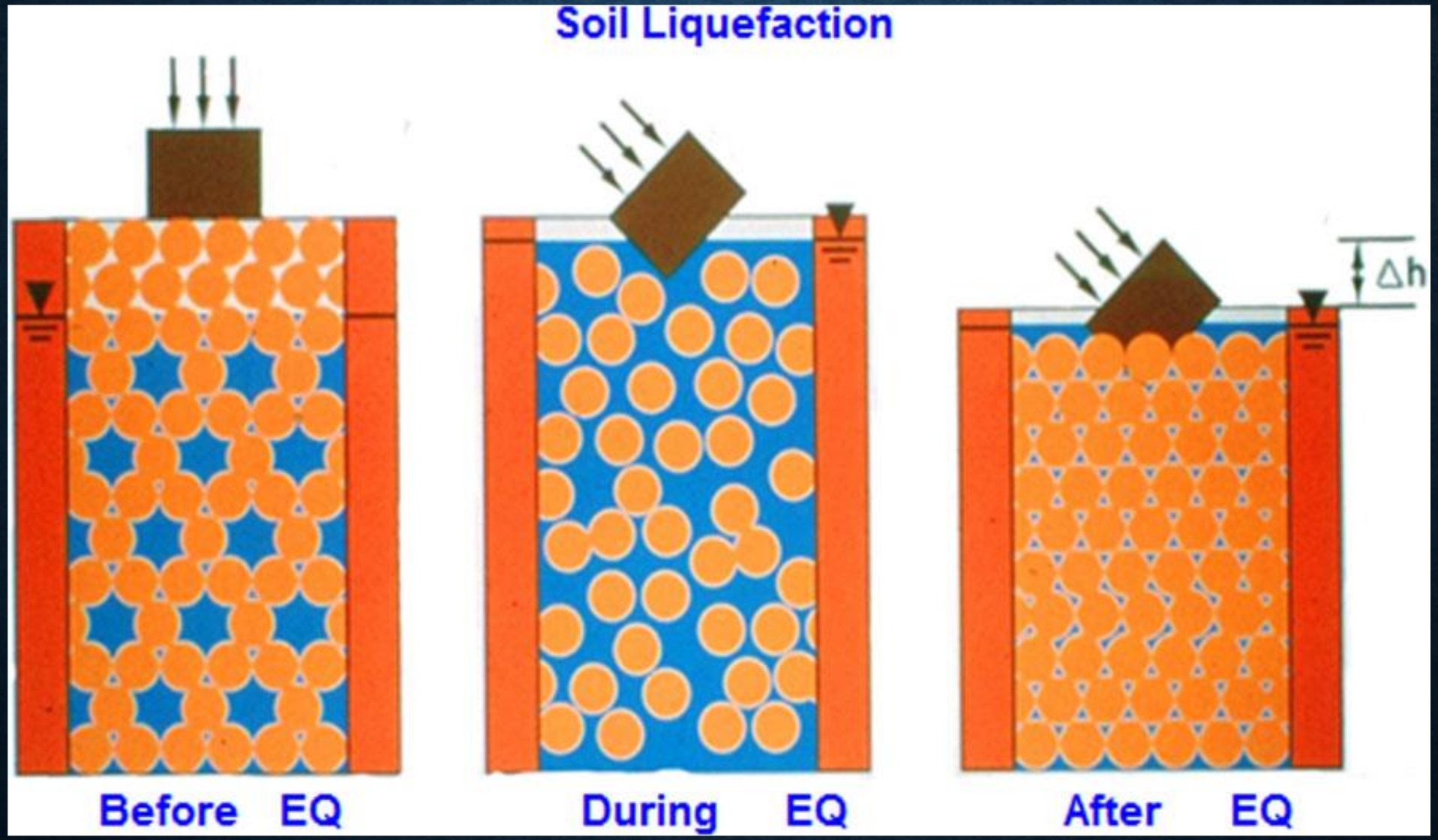
- Larger earthquakes generate more intense shaking, increasing the potential for liquefaction.

Factors Affecting Liquefaction

Geological and Geographical Setting:

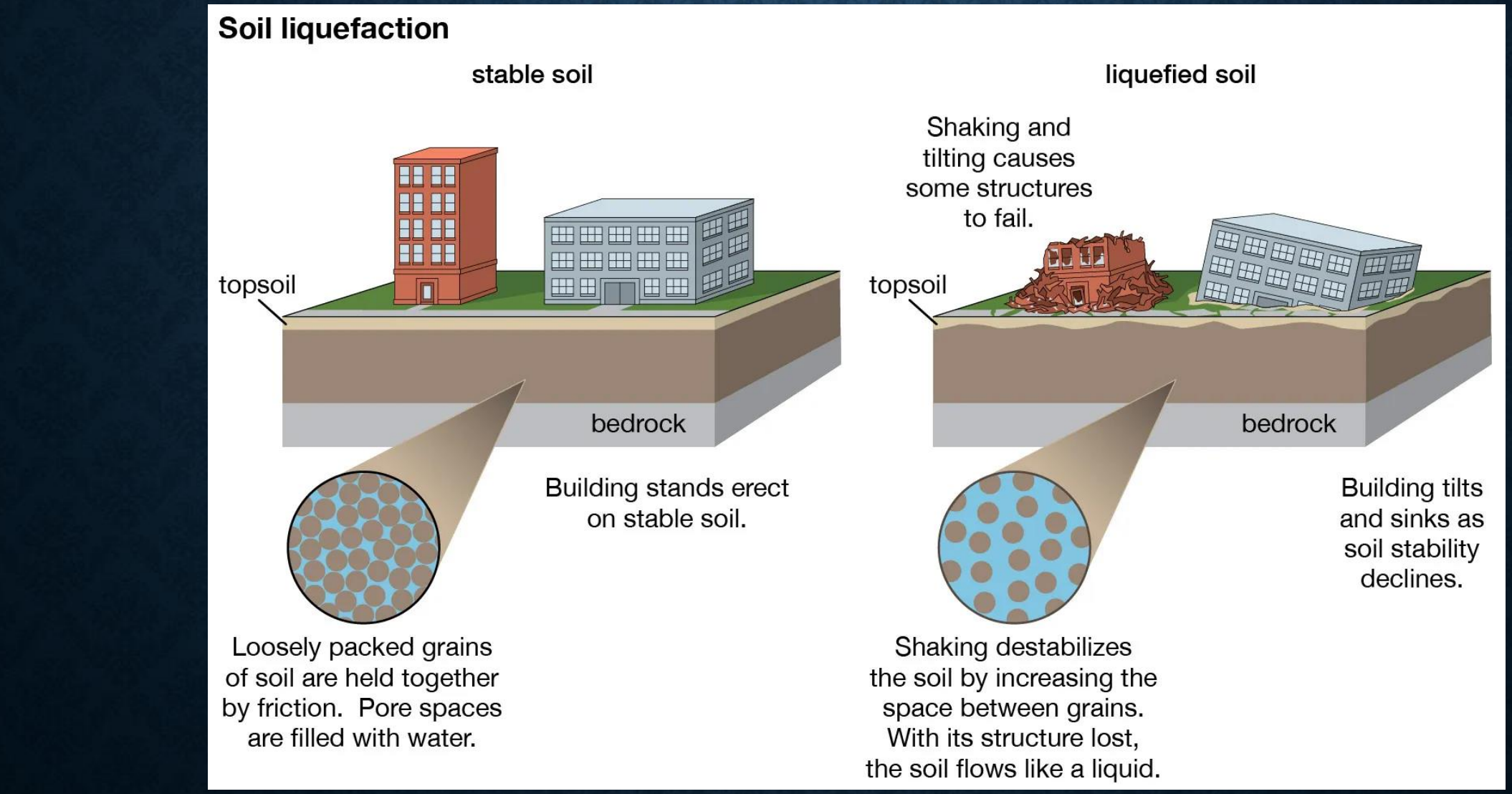
- Local geological conditions, topography, fault/lineaments and proximity to water bodies can affect soil properties and the likelihood of liquefaction.

Possibility of Liquefaction to occur



Source: Nath et al, (2017), After Nath (2011),

Possibility of Liquefaction to occur



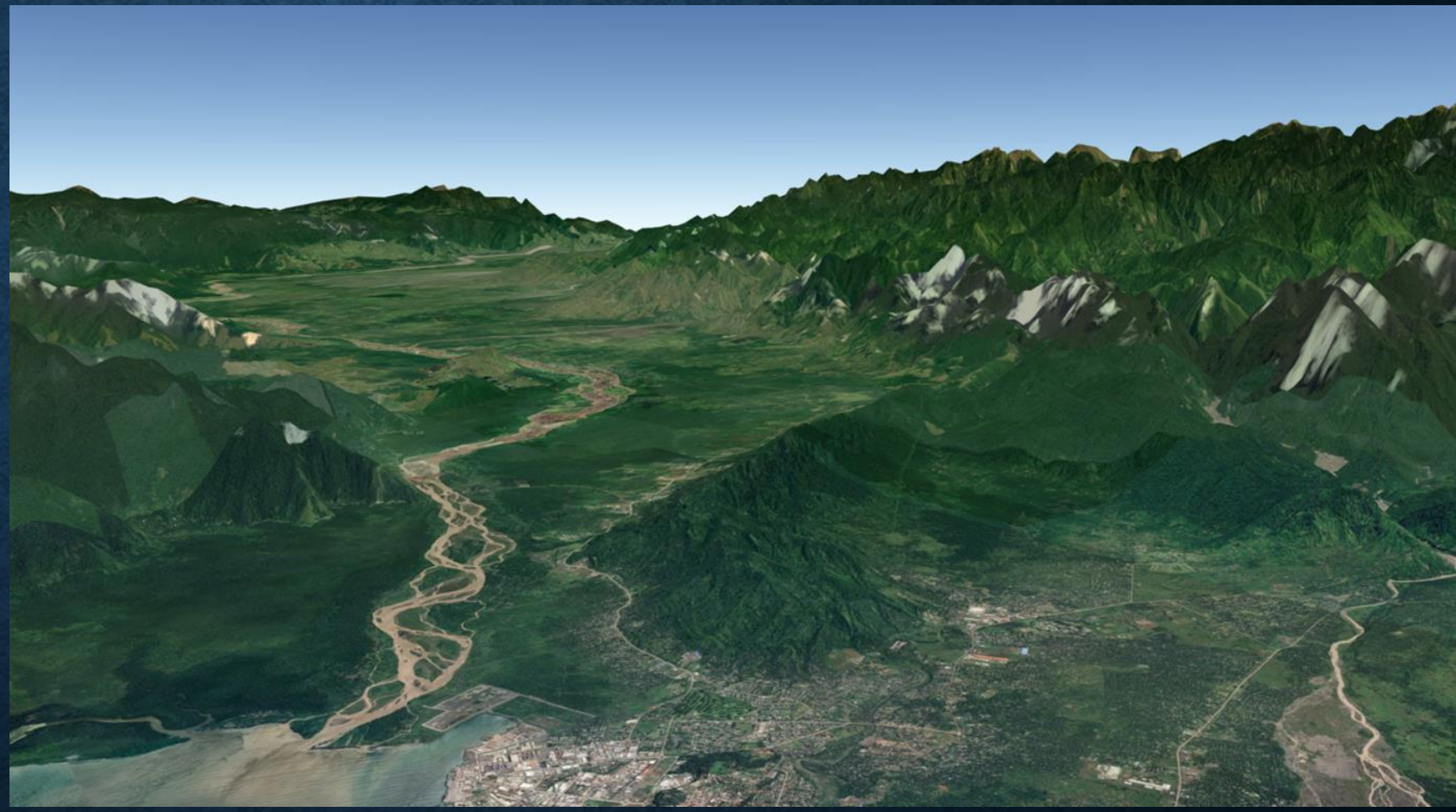
Source: Encyclopaedia Britannica, Inc, 2012 https://www.britannica.com/science/soil-liquefaction#/media/1/1775711/167786

Possibility of Liquefaction to occur

- ❖ Liquefaction Mostly occurs in low lying areas that are near to waterbodies:

- Lakes
- Rivers
- Ocean

- ❖ In this place there could be existence of ground water within and surrounding



Mechanics of Liquefaction:

- Seismic waves propagate through soil layers.
- This propagation generates shear deformations within the layer.
- Shear deformations lead to the collapse of the loose granular soil structure.
- The collapse of the granular structure results in the transfer of stresses from particle contacts to the pore water.

Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

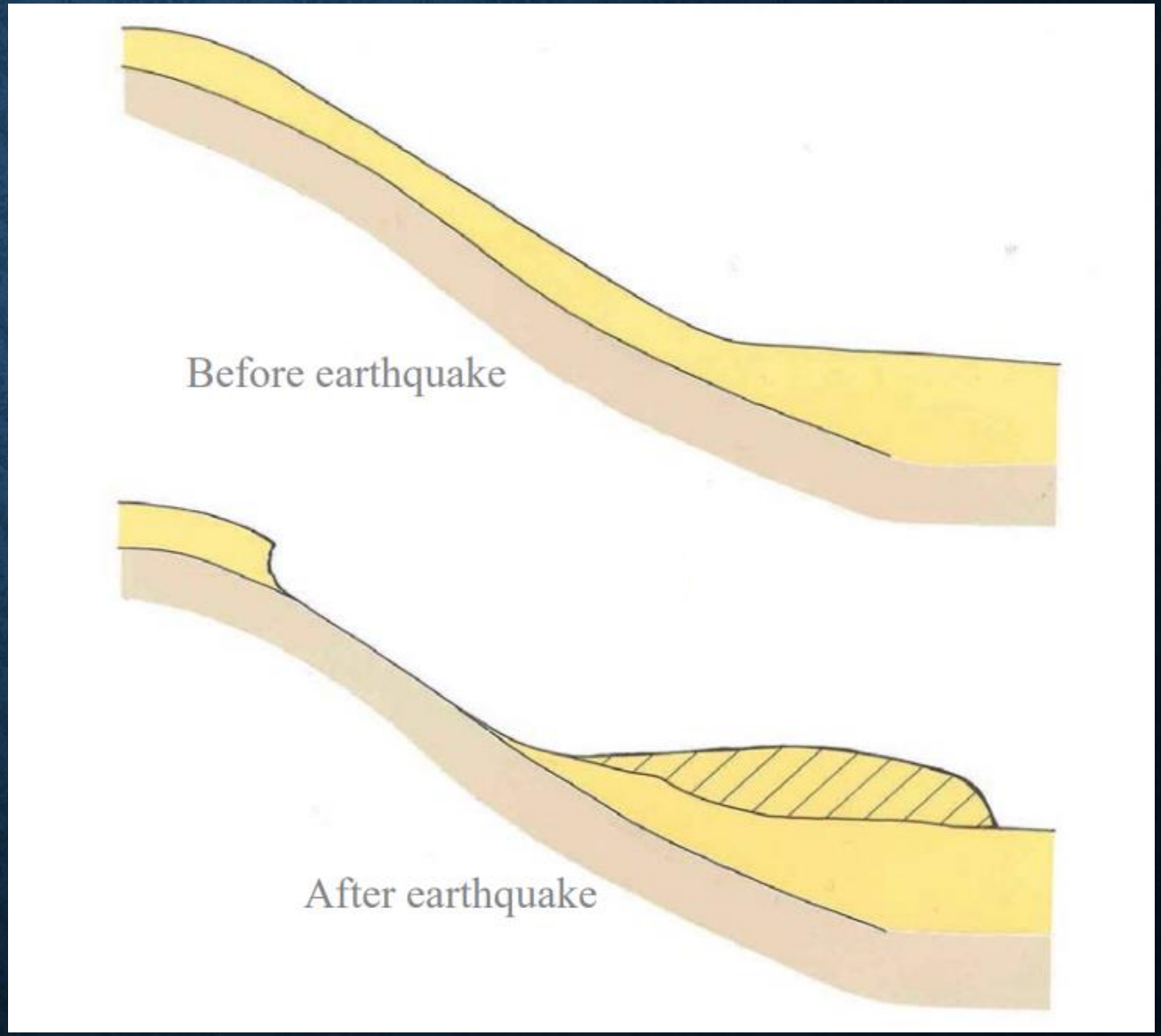
- Sand boils
- Flow failure
- Lateral spread
- Ground oscillation
- Loss of bearing strength
- Ground settlement

Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

- Flow failure

- Very disastrous ground failures takes place by liquefaction.
- This failures generally flow large masses of soil laterally.
- It takes place in loose saturated sands or silts on comparatively steep slopes

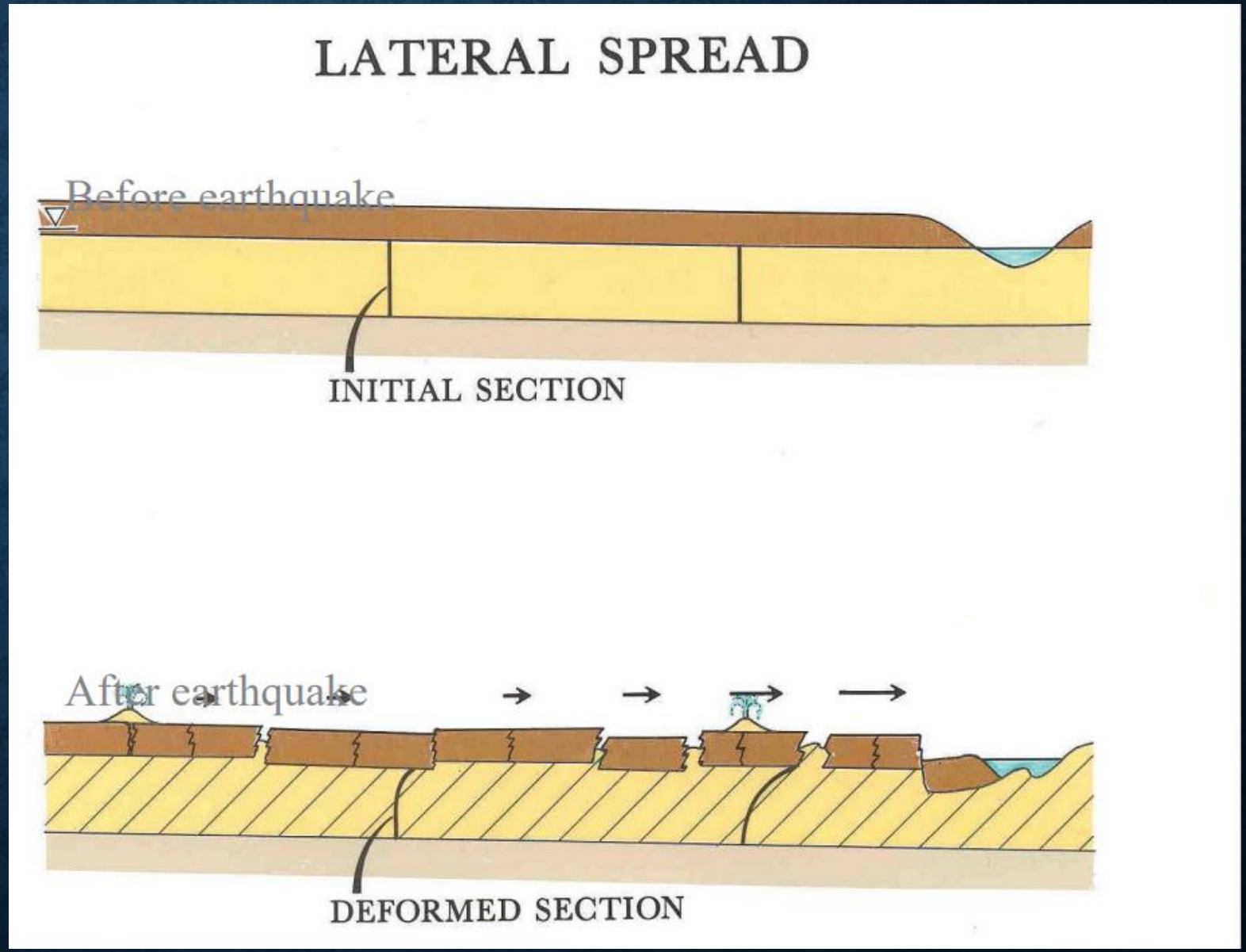


Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

❖ Lateral Spread

- The ground can slip down on very small slopes
- Lateral spreads involve lateral displacement of large, superficial blocks of soil as a result of liquefaction in a subsurface layer
- Movement occurs in response to the combined gravitational and inertial forces generated by an earthquake.

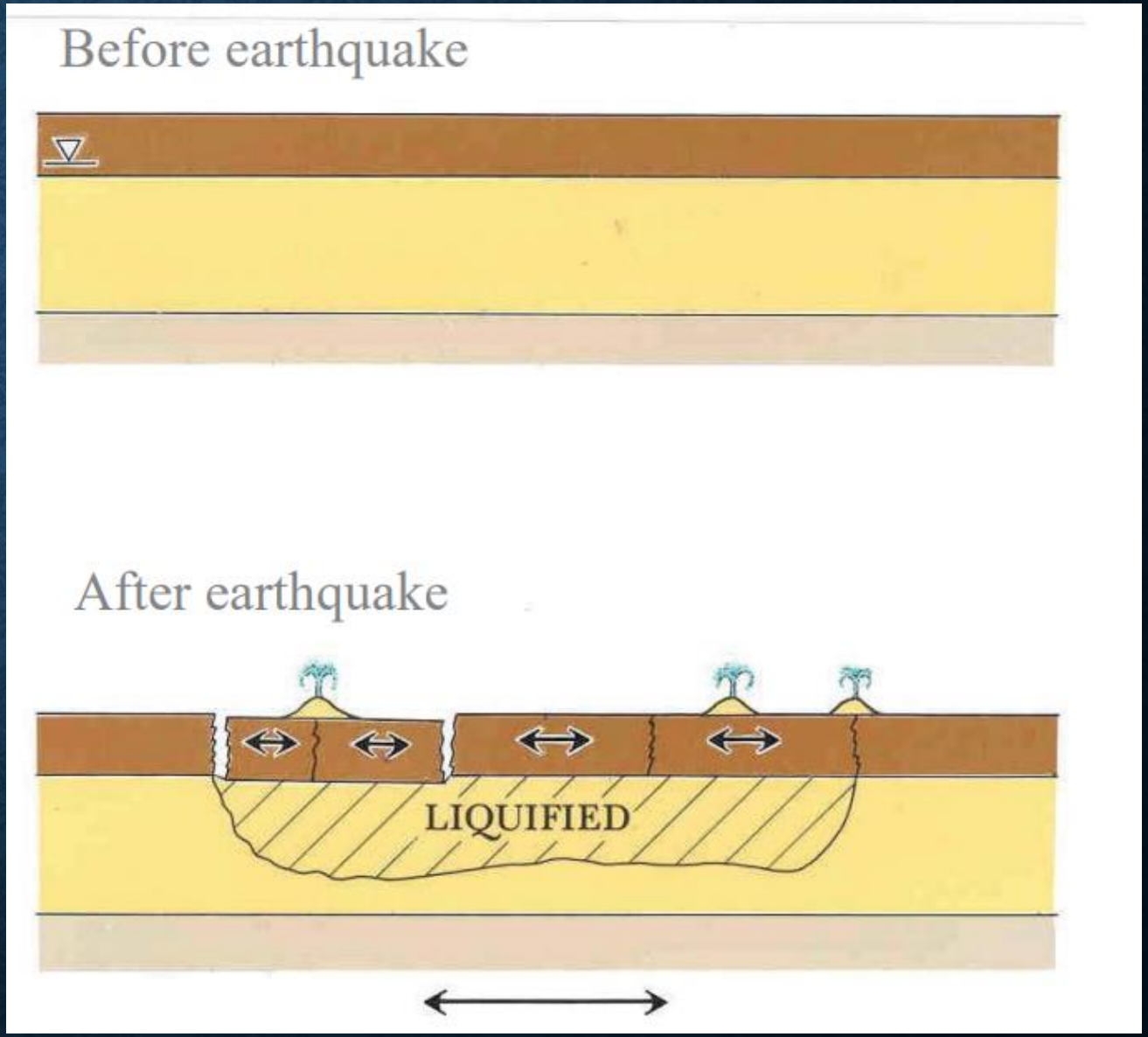


Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

❖ Ground Oscillation

- ❖ Where slopes are too gentle to allow lateral displacement, liquefaction at depth commonly decouples overlying soil blocks, allowing them to jostle back and forth on the liquefied layer during an earthquake.
- ❖ This jostling of blocks produces an oscillation often seen by observers as ground waves.



Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

- Ground Oscillation
  - Walk and Curb Damage Caused by Ground Oscillation (1989 Loma Prieta, Calif. Earthquake)

Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

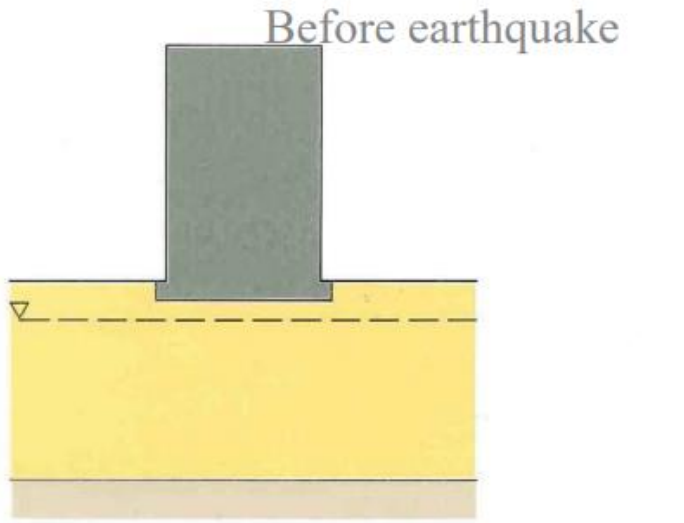
- Ground Oscillation
  - Pavement and Curb Damage Caused by Ground Oscillation during 1989 Loma Prieta, Calif. Earthquake

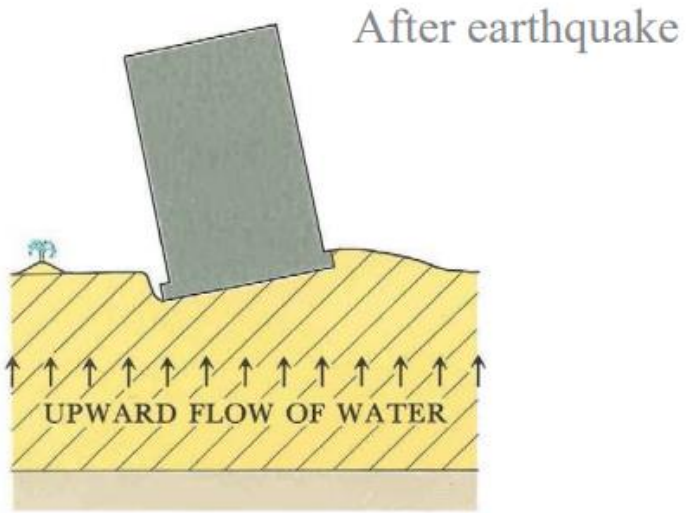
Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

- Loss of Bearing Capacity

- When the soil supporting a building or other structures liquefies and loses strength, large soil deformations can occur, allowing the structure to settle and tip





Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

- Loss of Bearing Capacity

Source: Hyndman. D., and Hyndman. D., (2007), National Geographic Data Center, NOAA.

Consequences of Liquefaction

- Loss of Bearing Capacity

Tipped Building in Adapazari, Turkey, Caused by Liquefaction-Induced Loss of Bearing Strength during 1999 Koaceli, Turkey Earthquake.

Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Consequences of Liquefaction

- Ground Settlement

Liquefaction ground reconsolidates during an earthquake, the ground surface may settle and the underlying liquefied soil becomes dense

Source: A. Elgamal, Chicago, Illinois, 2013, Courtesy of Professor T. L. Youd

Site Soil and Geology

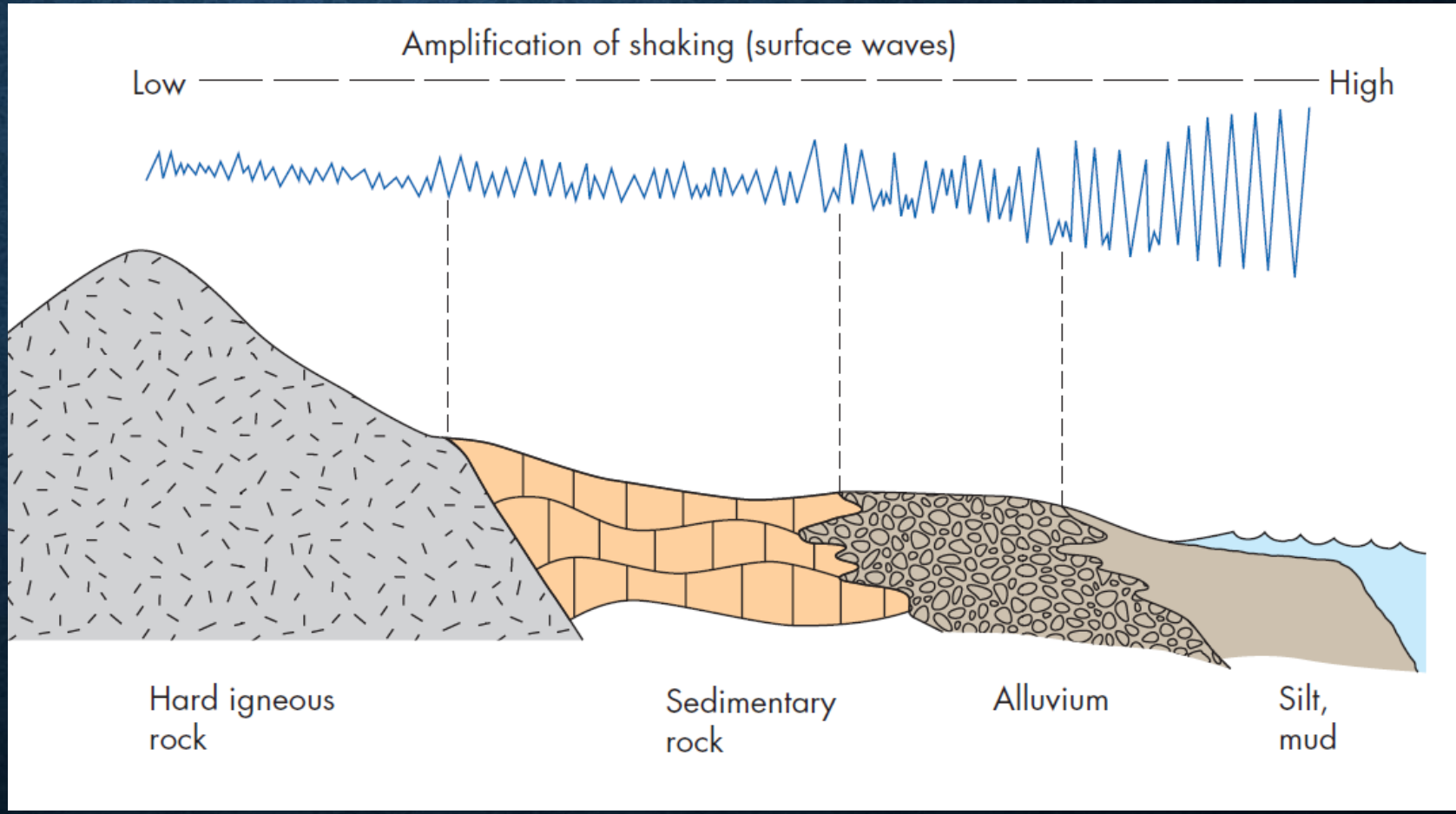
The composition and characteristics of the soil and geological formations at a particular location can significantly influence how seismic waves are amplified or attenuated.

Soft, loose soils like clay and sand tend to amplify seismic waves because they have a low shear modulus and can undergo significant settlement during shaking.

Hard, dense rocks, on the other hand, generally transmit seismic waves efficiently with minimal amplification.

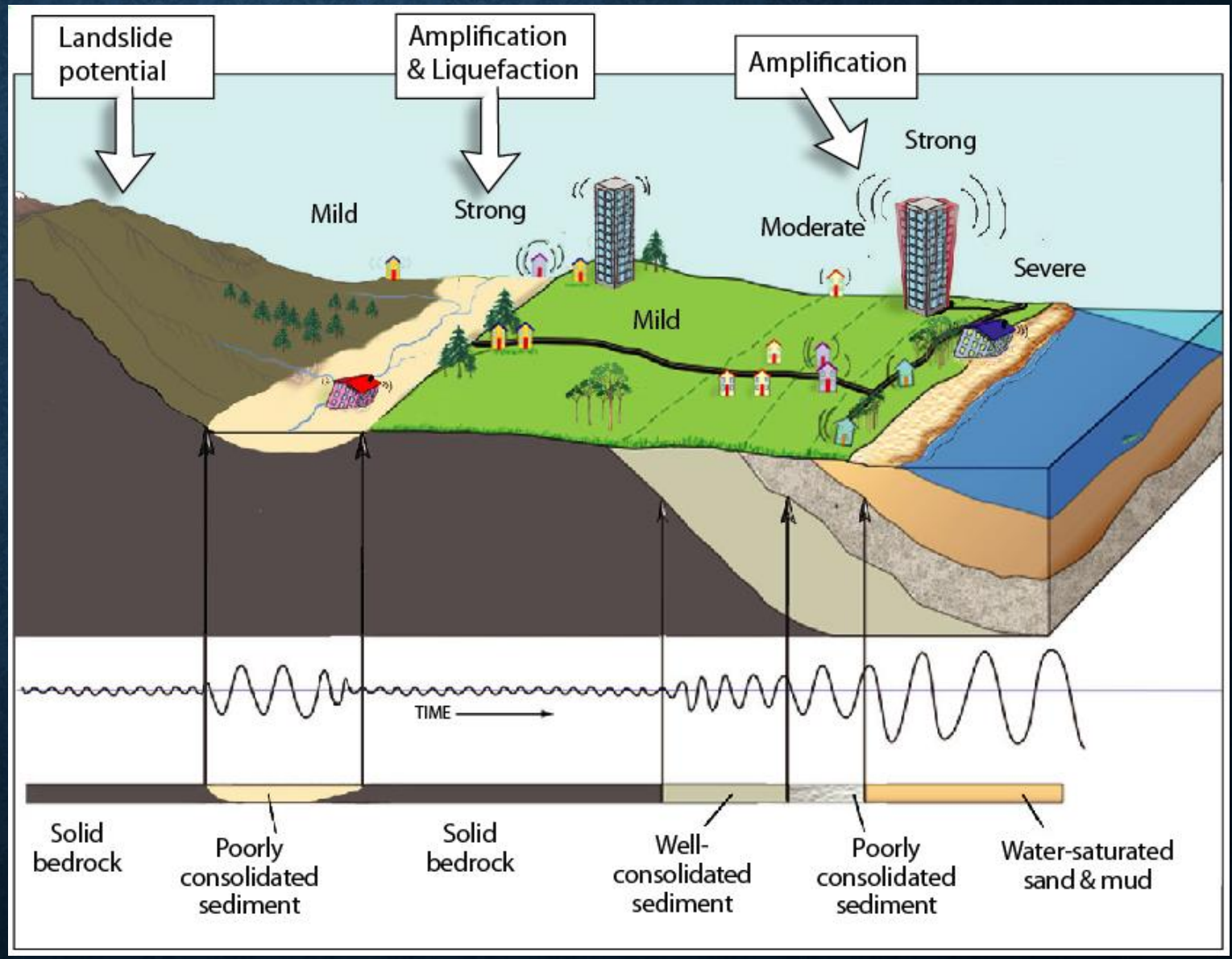
Seismic Waves Amplification With Site Soil and Geology

- Seismic waves from an earthquake can be amplified when they encounter certain soil conditions.
- This is known as "site response" or "site amplification."



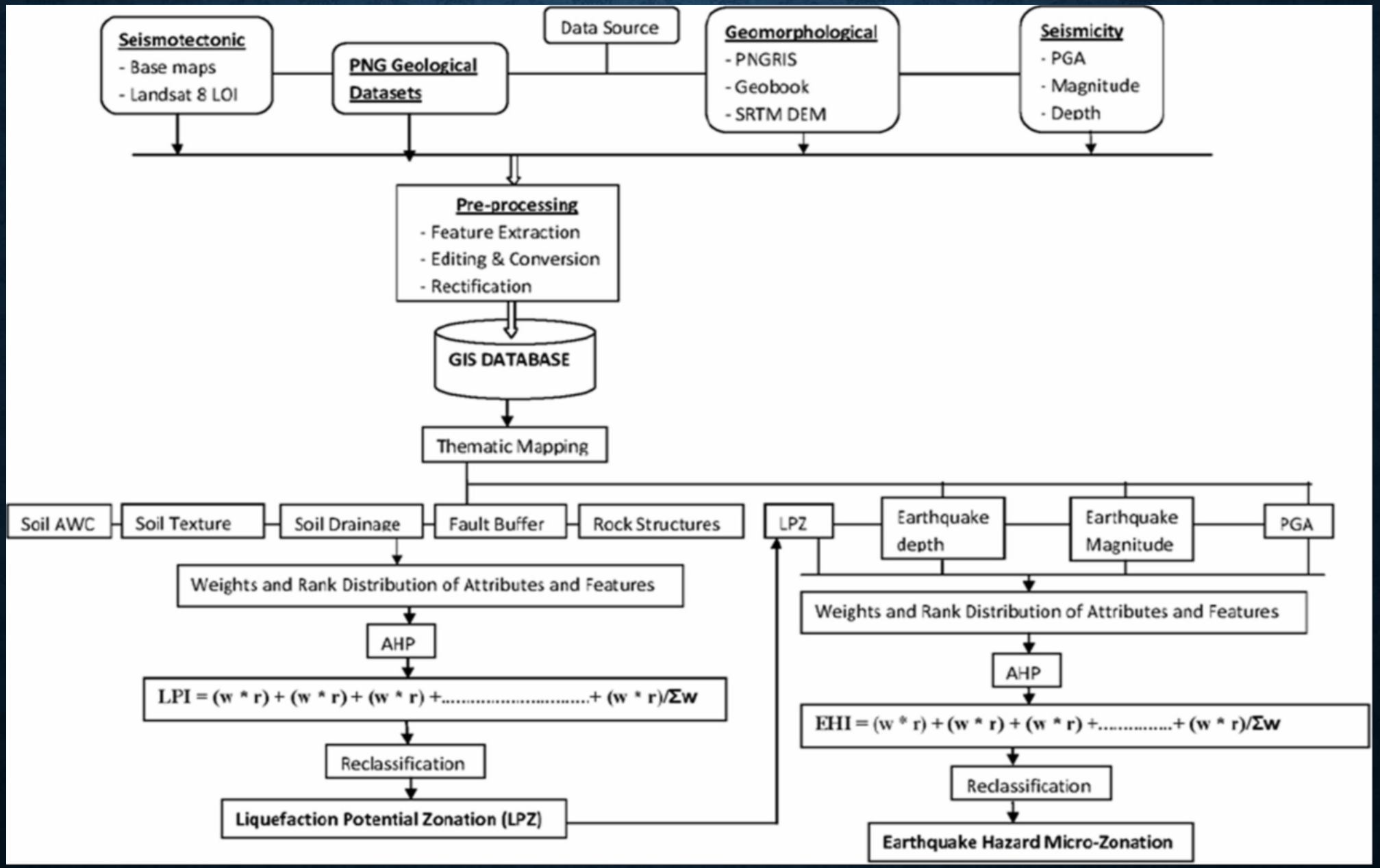
Source: Edward A. Keller, Duane E. Devecchio, Robert H. (CON) Blodgett, 2012, 3rd edition

Seismic Waves Amplification With Site Soil and Geology



Source: https://serc.carleton.edu/ANGLE/educational_materials/activities/205530.html

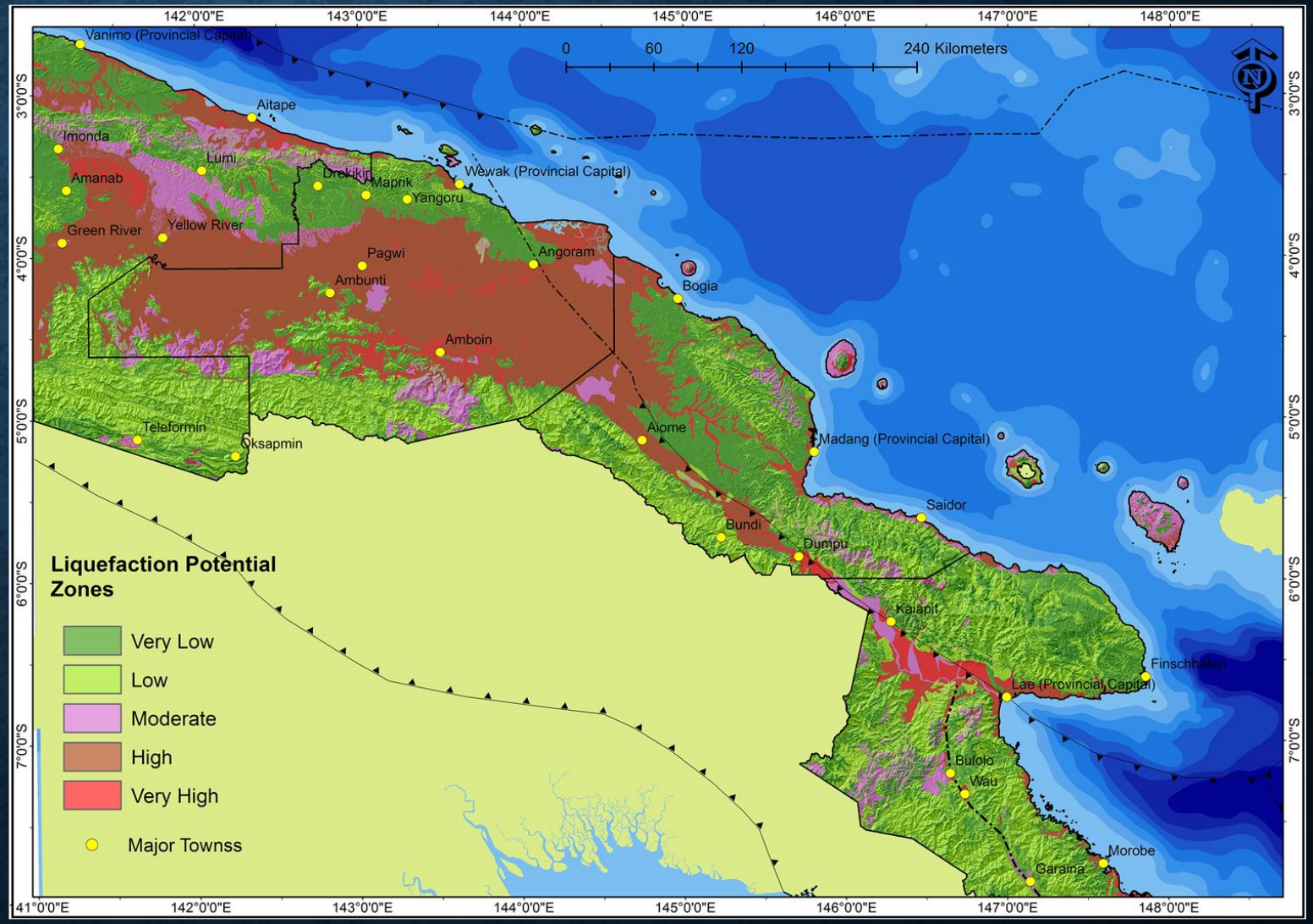
Liquefaction Potential Zonation.



Liquefaction Potential Zonation.

Factors assessed for LPZ,

- Rock types in the form of consolidation statues,
- soil texture,
- soil AWC,
- soil drainage,
- fault buffer zones,
- slope factor



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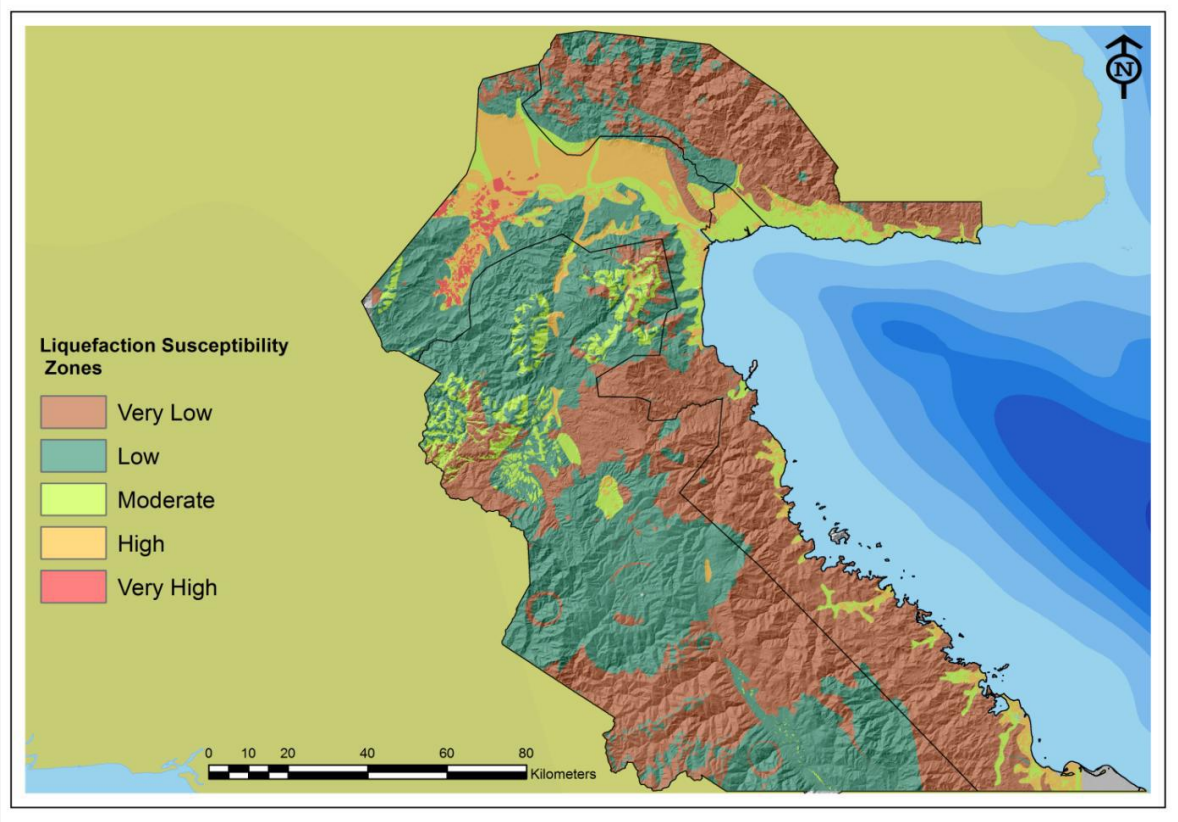

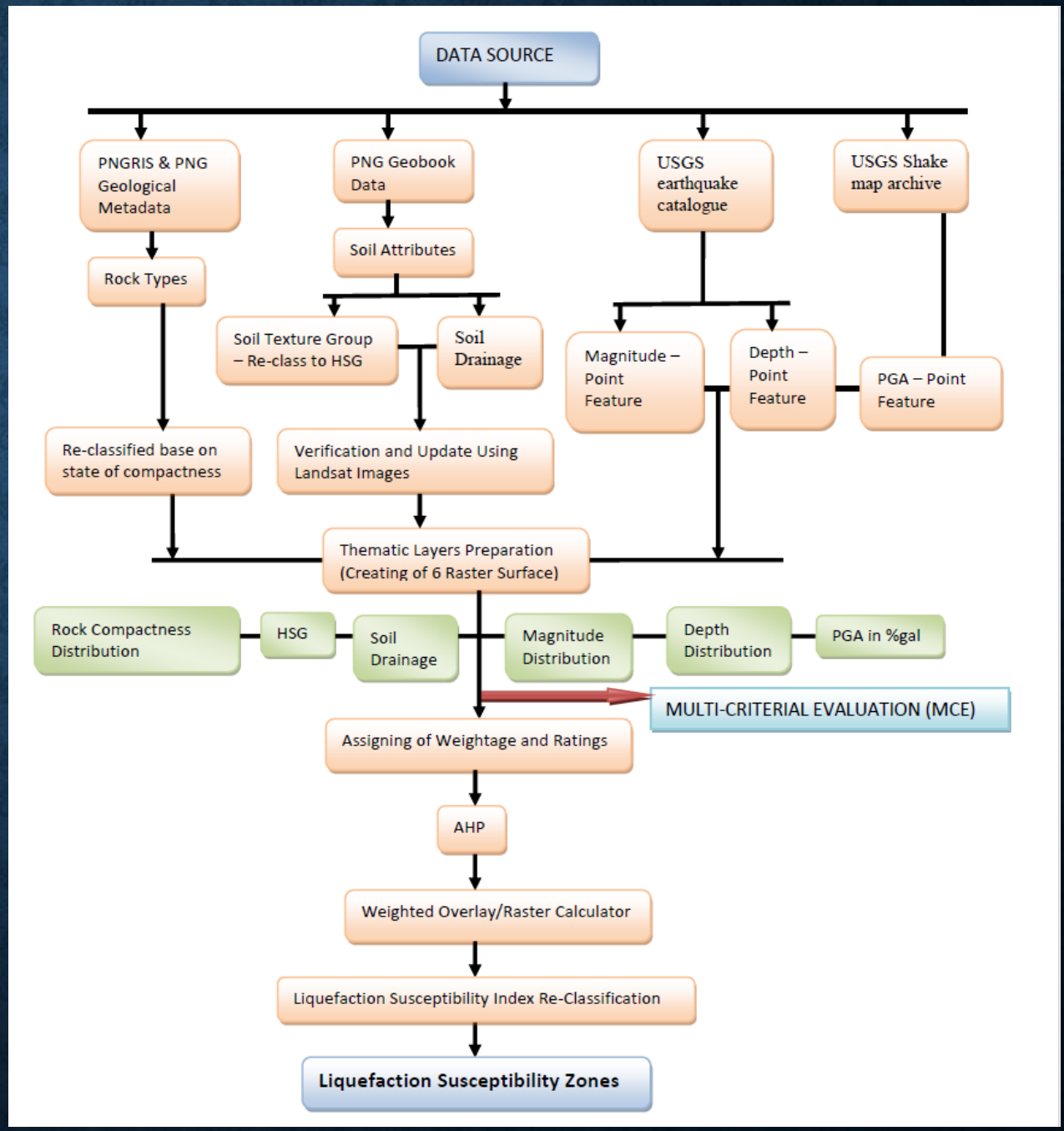

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