Geotechnical Hazards in Alabama

Presented by: Rodney Collins, Ph.D., P.E.

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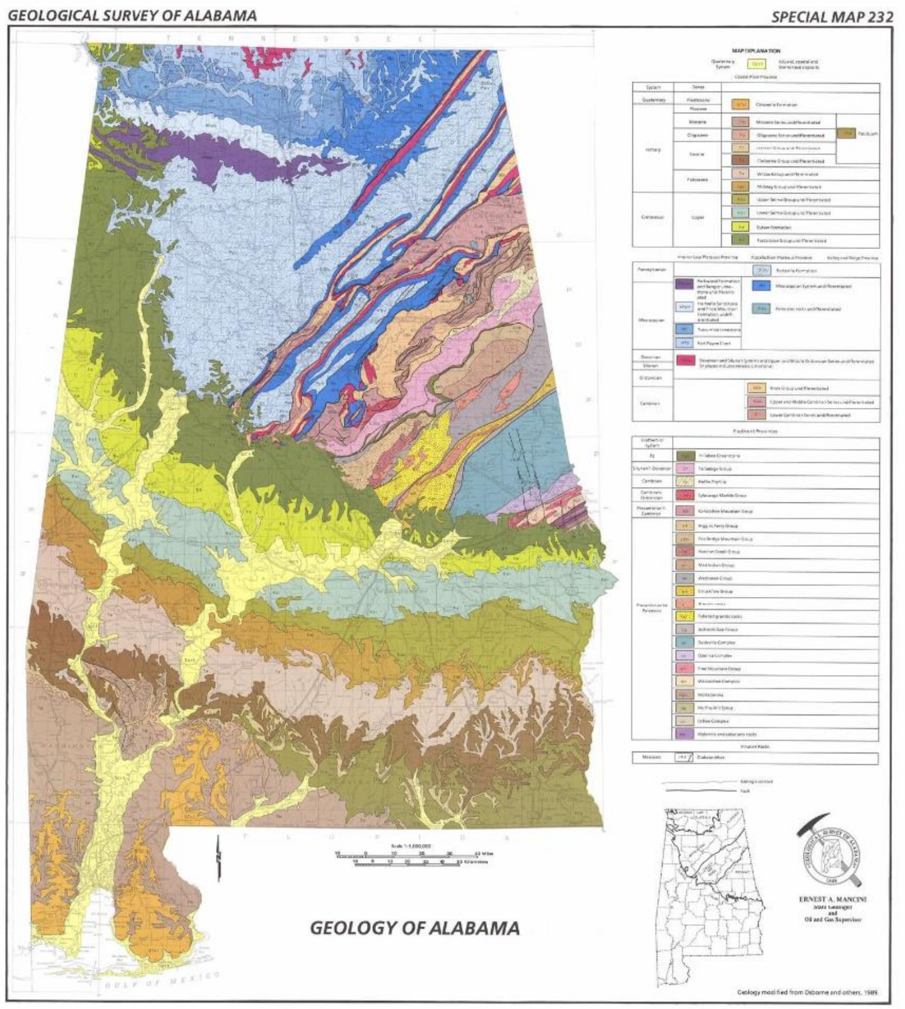
Presentation Summary

- Alabama's Geology
- Sinkholes
- Slope Failures/Landslides
- Shrink and Swell

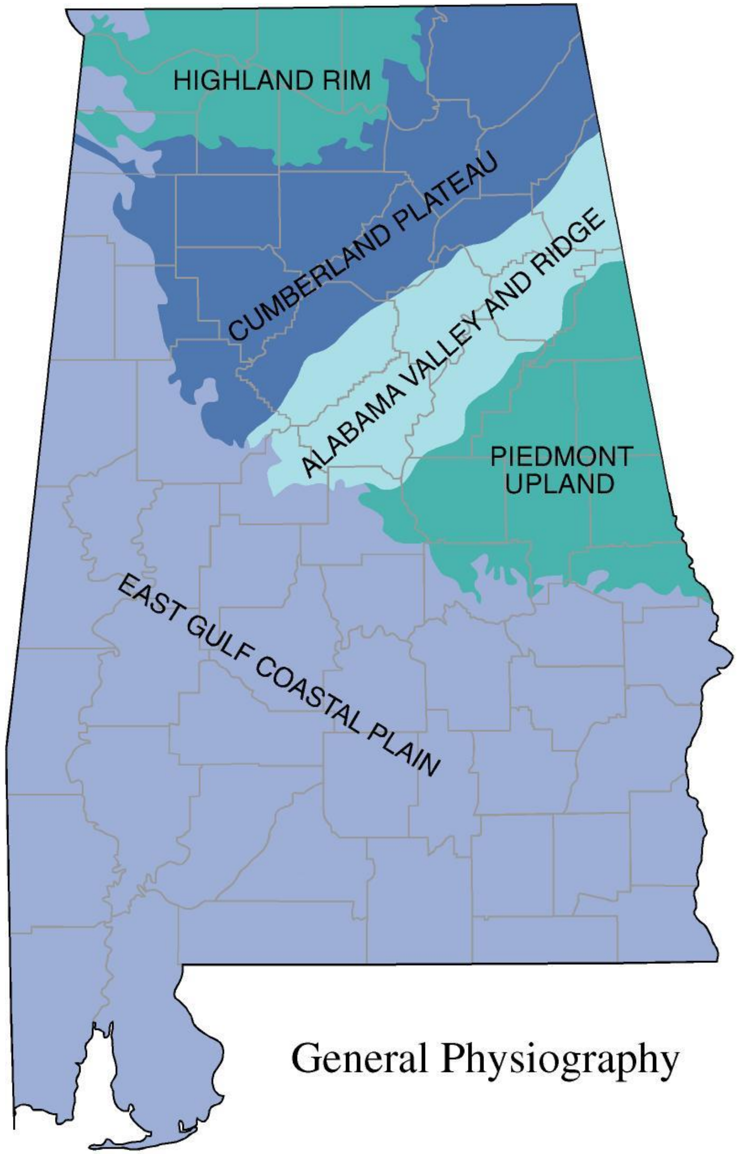
Geology of Alabama

- Geologically Diverse State
- Continental collision and mountain building
- Folded and faulted sedimentary rocks of Tennessee Valley and Ridge
- Metamorphic rocks Piedmont Upland
- Coal beds of north-central Alabama
- Formation and evolution of Gulf of Mexico



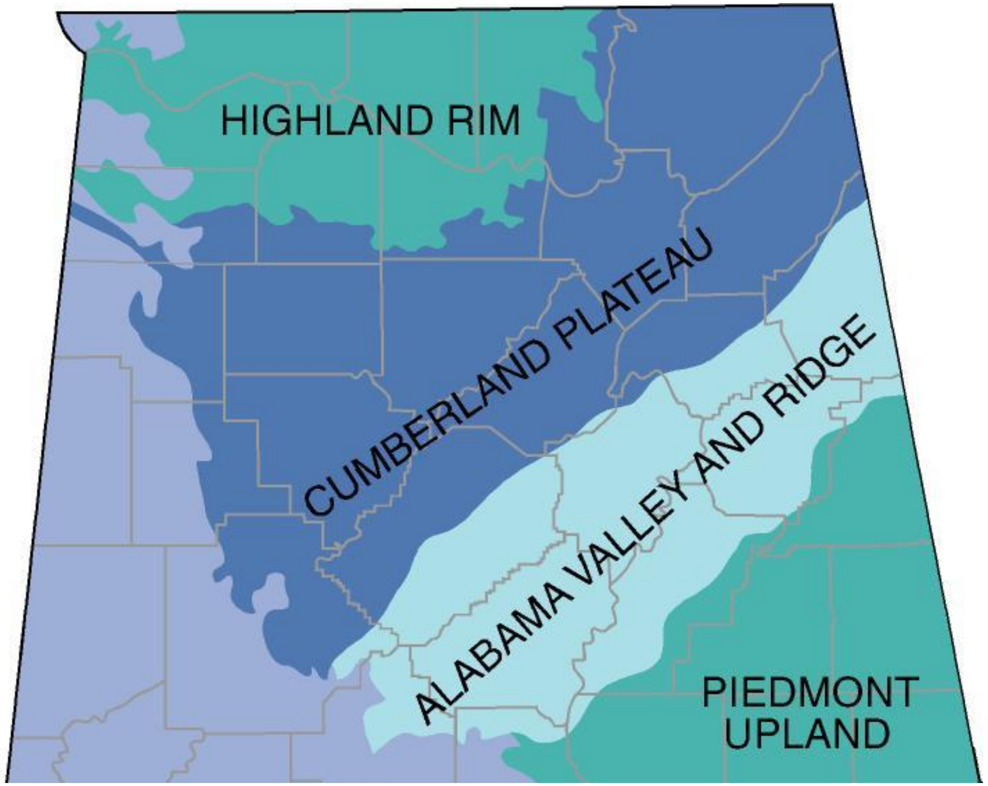
Physiographic Sections

- Divided into five sections:
  - Highland Rim
  - Cumberland Plateau
  - Alabama Valley and Ridge
  - Piedmont Upland
  - East Gulf Coastal Plain



Highland Rim

- Soils formed by residuum weathered from limestone
  - Limestone (clays)
  - Chert (clay)



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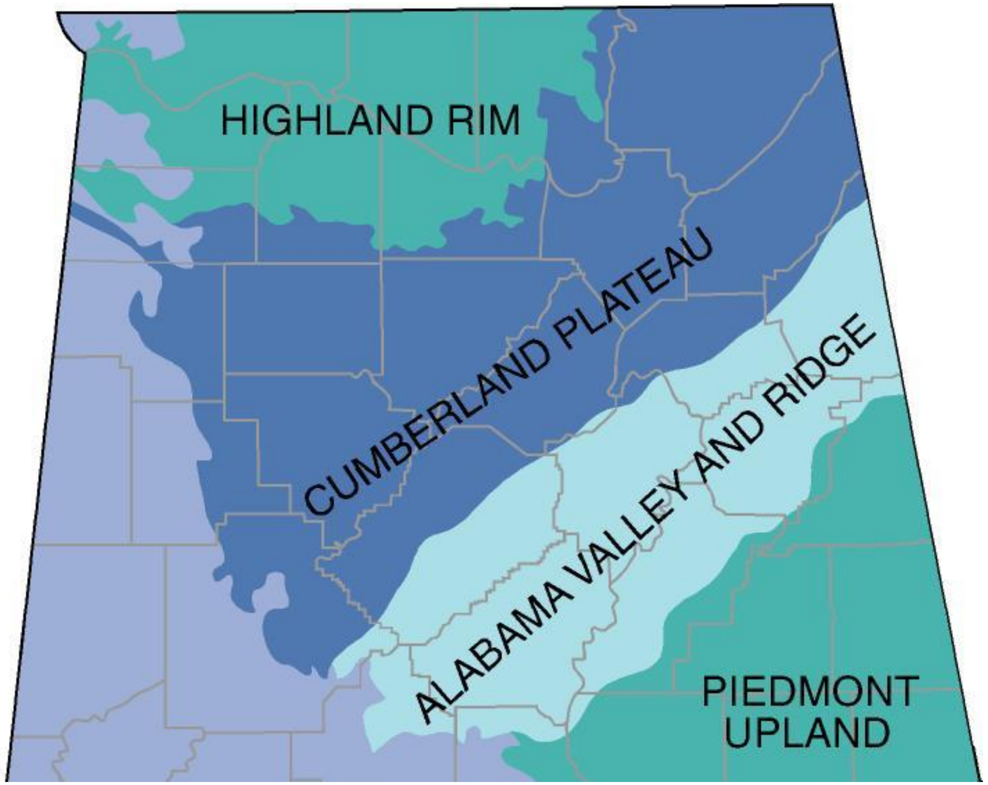
Cumberland Plateau

- Mountainous Region
  - Sandstone (sands)
  - Shale (clays)
  - Limestone (clays)



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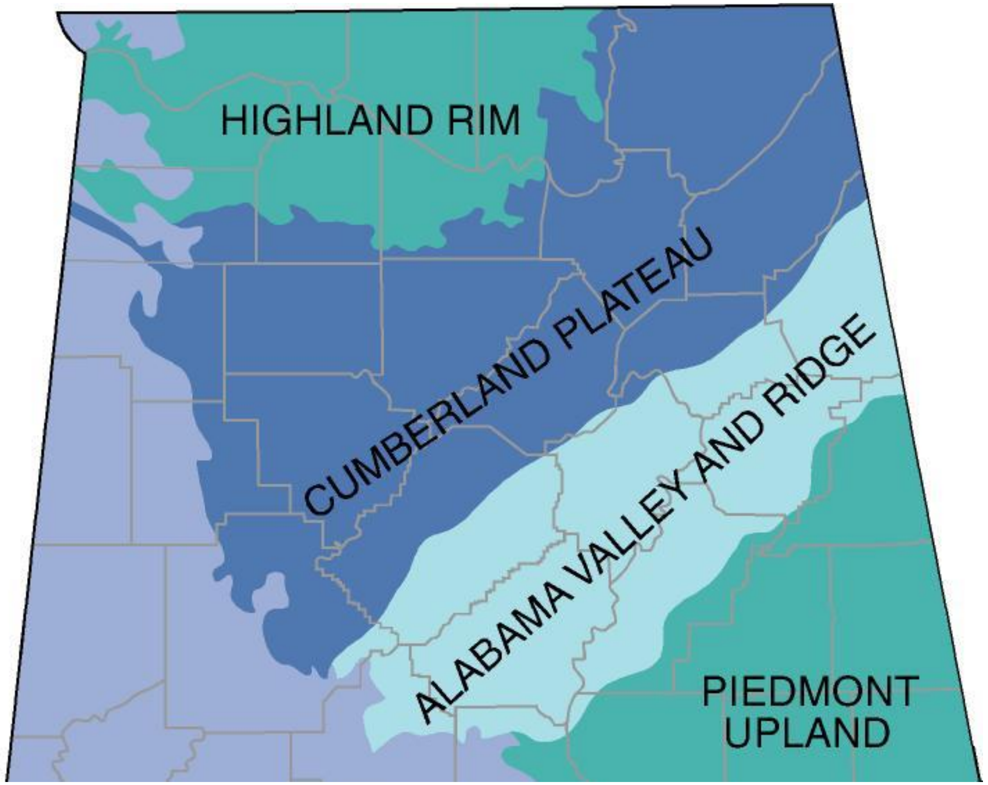
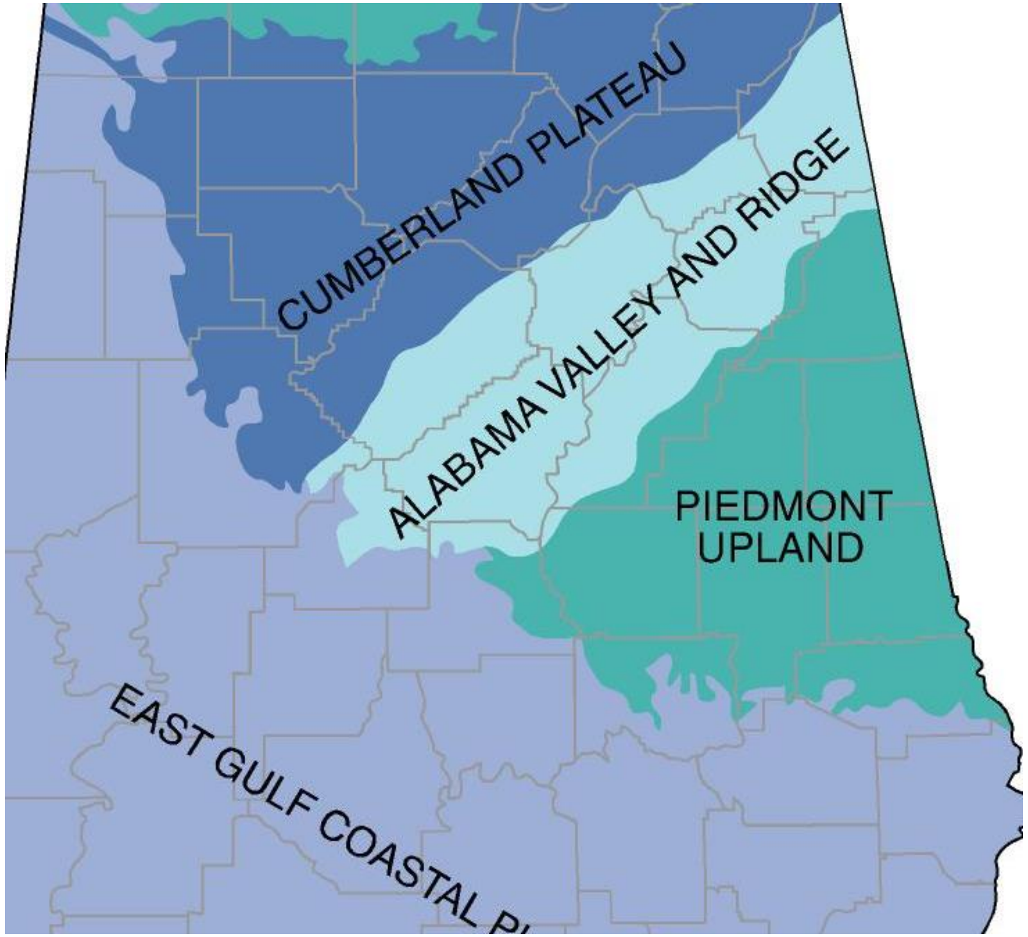
Alabama Valley and Ridge

- Diverse sedimentary rocks
- Sands
- Clays
- Shallow rock



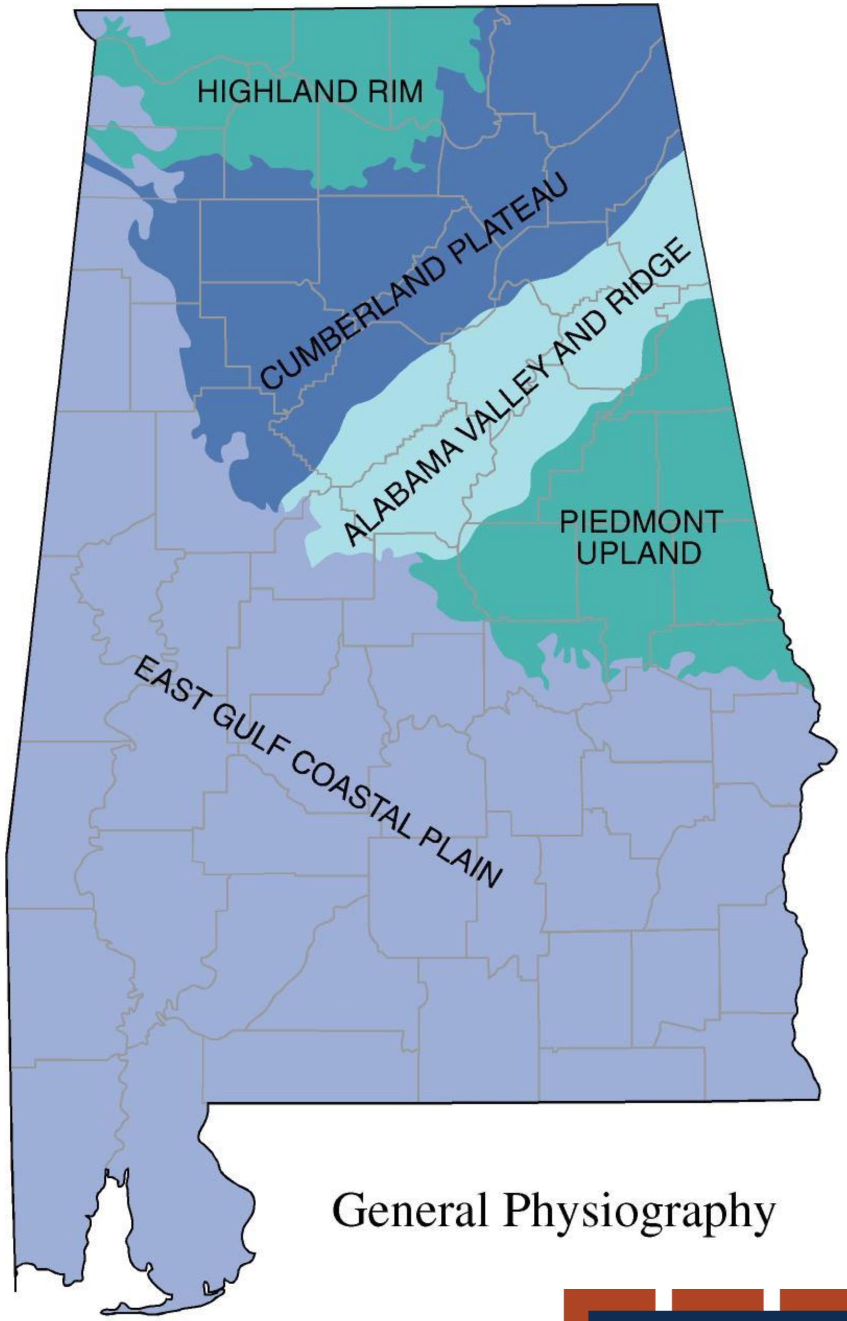
Piedmont Upland

- Soils primarily weathered from the minerals:
  - granite, hornblende and mica schists
    - Silts
    - Sands
    - Clays



East Gulf Coastal Plain

- Derived from marine and fluvial sediments
- Deep unconsolidated sediments (sands, clays)
- Also includes “Black Belt”
  - Soils derived from alkaline, Selma chalk or acid marine clays
  - Highly plastic clay soils



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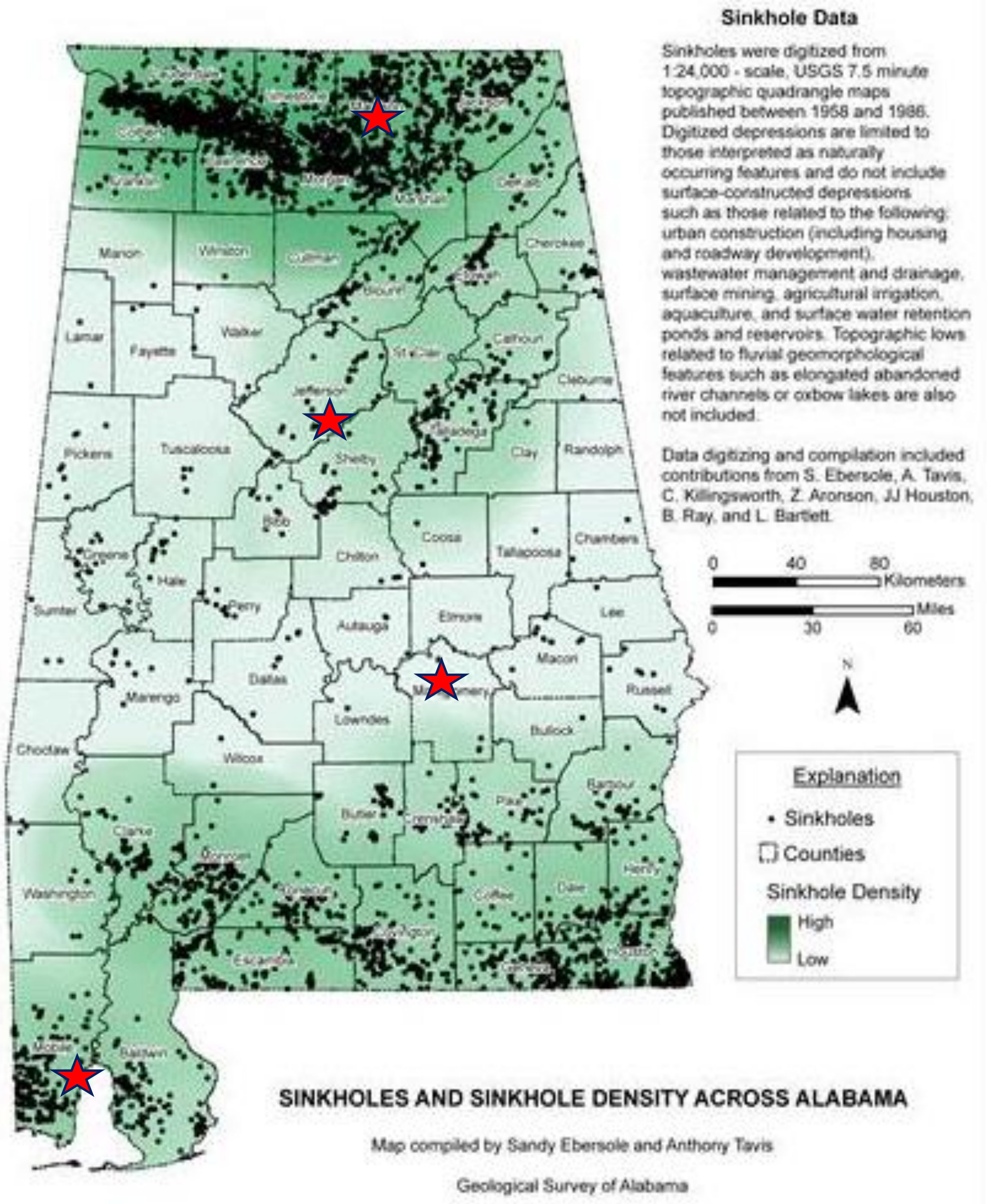
Sinkhole Map of Alabama



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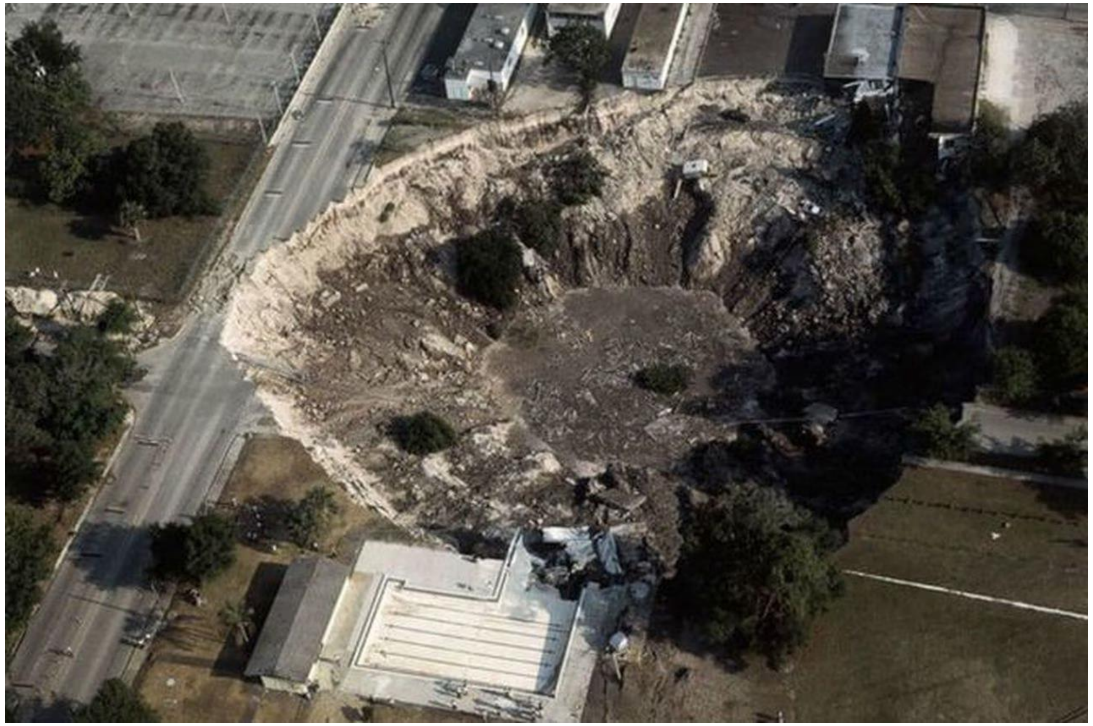
Sinkholes



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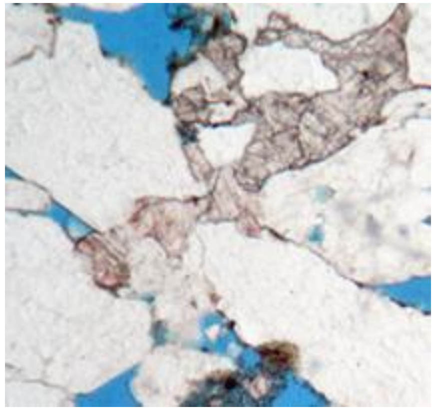
Sinkhole Rock Types

- Limestone, dolomite contain Calcite
- Calcite
  - Composed of calcium carbonate ($CaCO_3$)
  - Dissolves when acid added
- Some sandstones which contain Calcite can be susceptible to sinkholes



Dissolution

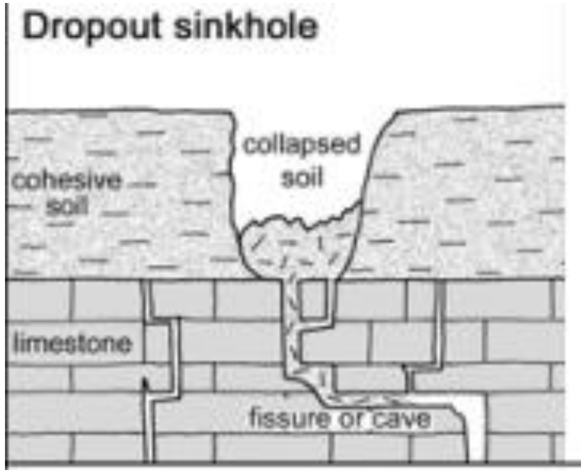
- Rainwater is naturally acidic
  - Rain absorbs carbon dioxide and sulfide from atmosphere
  - More acidic during interaction with vegetation
- Rainwater infiltrates rock through cracks and crevices

Collapse

- Roof of cave too thin to support weight of ground above results in subsidence

Man's Influence on Dissolution and sinkholes

- Increased drainage flows washing soil down into cavernous karst
- Pumps decline groundwater level
- Redirected and concentrated flows of stormwater run-off
  - Leaking pipelines
- **4,000 sinkholes documented in Alabama caused by human activity, most of these since 1950**
- **Shelby County 1,000 sinkholes developed between 1958 and 1973 in an area of 10 square miles**
  - Wells, quarrying and mining
  - **Only China has a greater record of artificially induced sinkholes**



Formation process	Soil collapse into soil void formed over bedrock fissure
Host rock types	Cohesive soil overlying limestone, dolomite, gypsum
Formation speed	In minutes, into soil void evolved over months or years
Typical max size	Up to 50 m across and 10 m deep
Engineering hazard	The main threat of instant failure in soil-covered karst
Other names in use	Subsidence s/h, cover collapse s/h, alluvial s/h

Evaluation and Detection of Sinkholes

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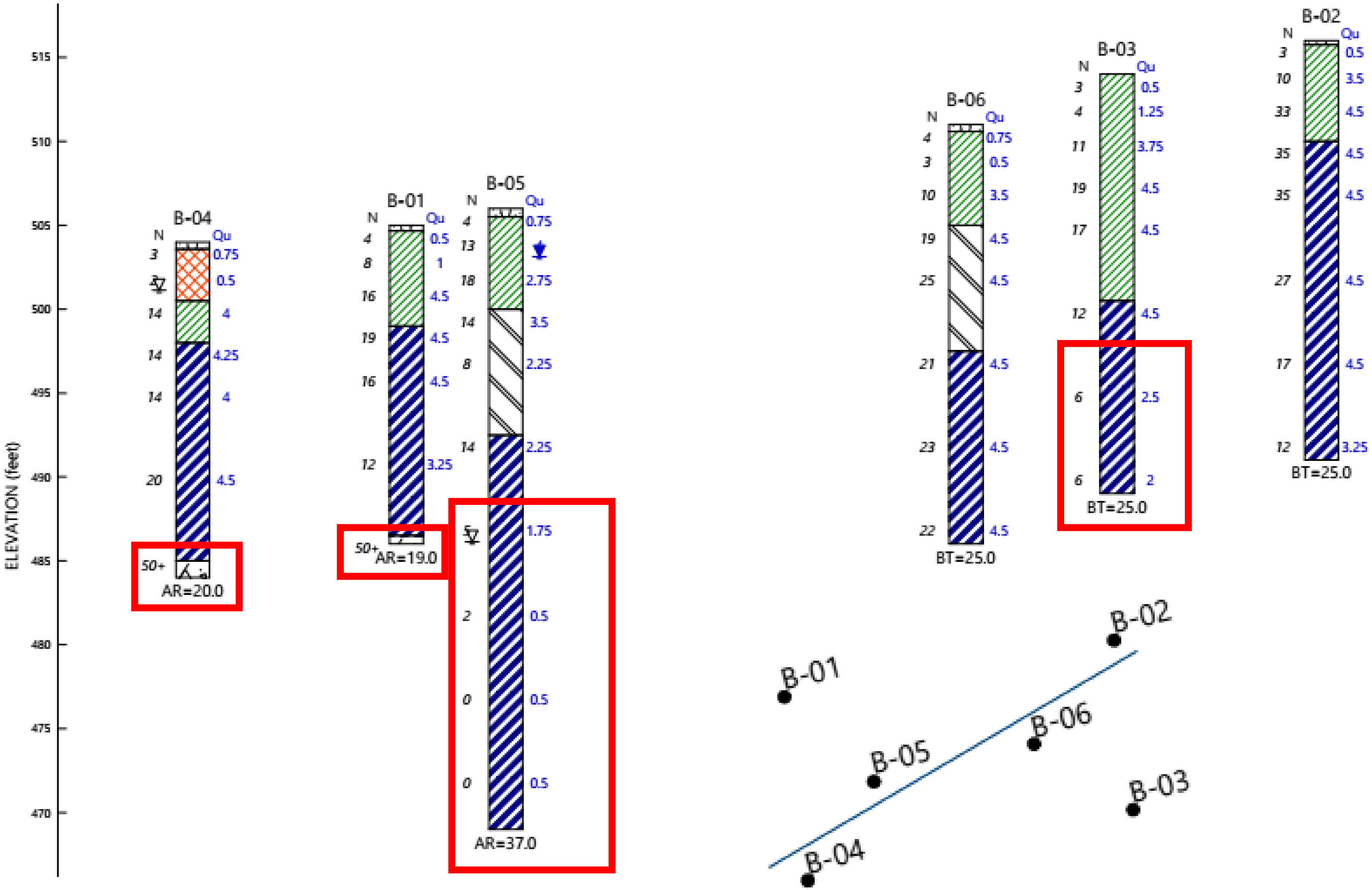
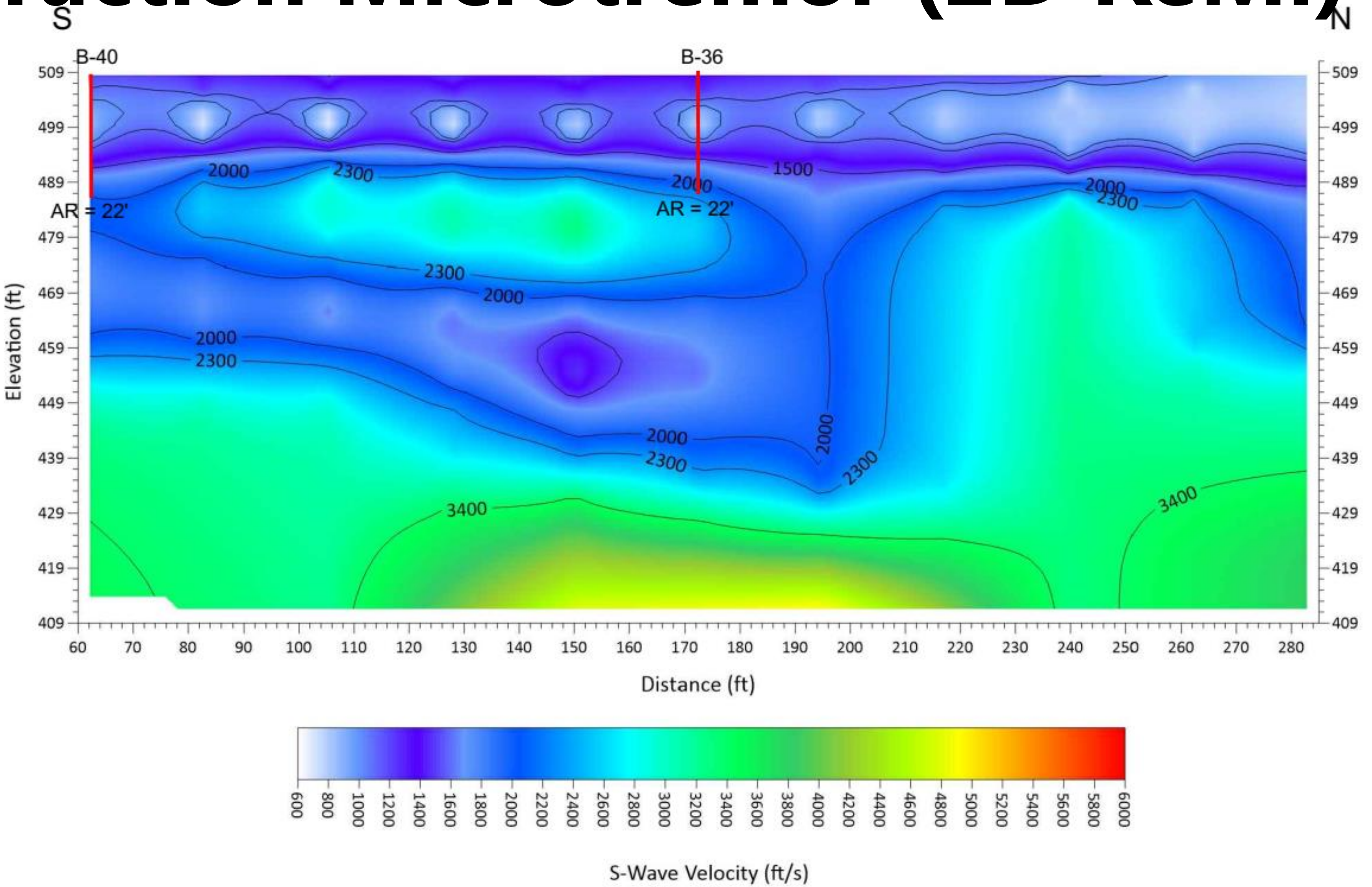
Sinkhole detection using borings



2-D Subsurface Profile using Refraction Microtremor (2D ReMi)



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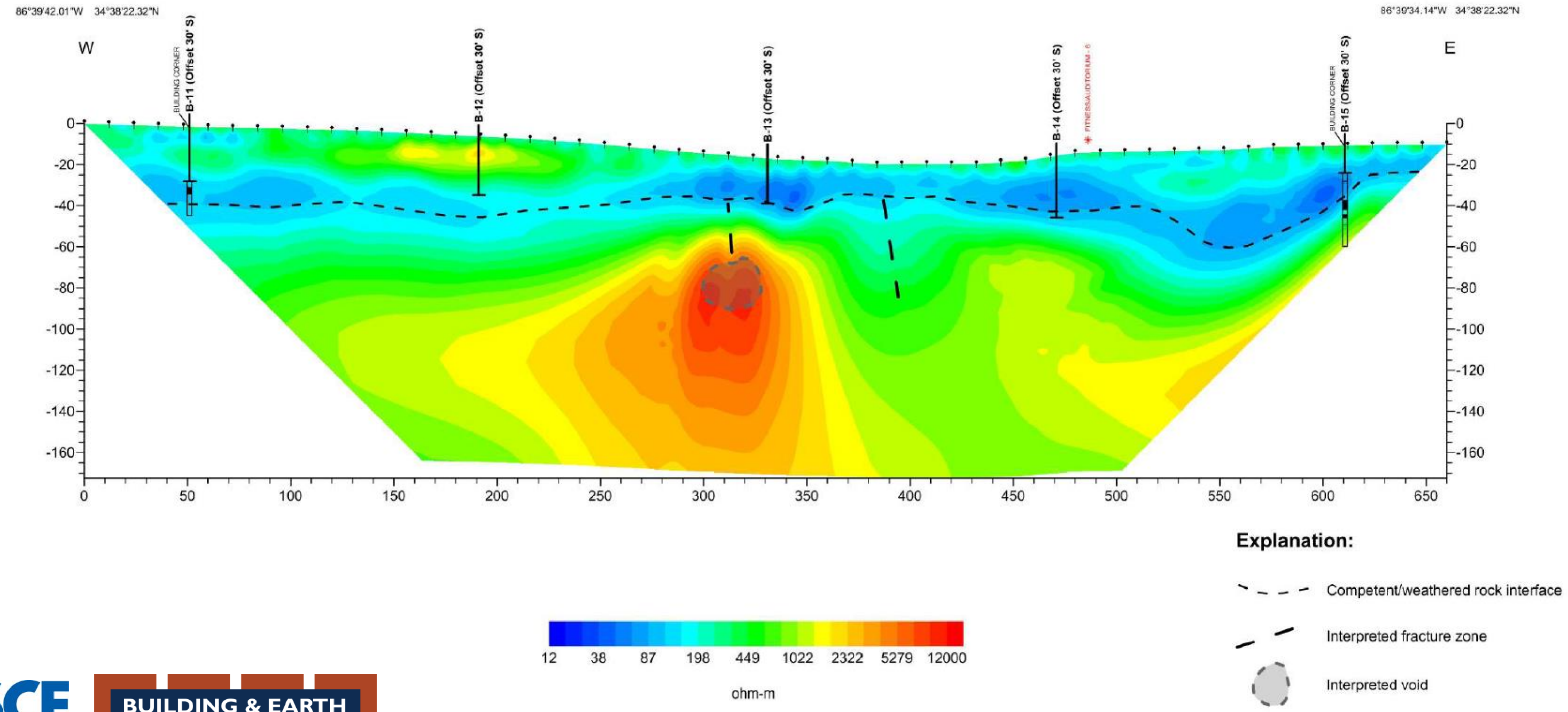
Electrical Resistivity (ERI)



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Remediation

- Relocation of Structure
- Low mobility grouting
- Reverse filter
- Deep Foundations

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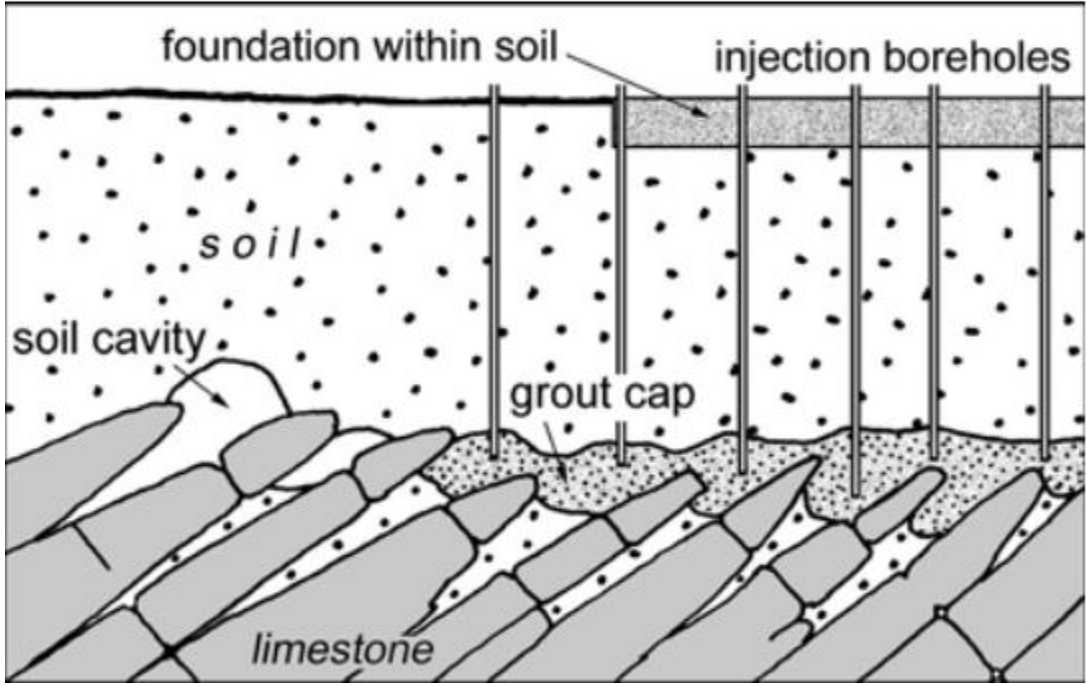
Low Mobility Grouting



- Staged injection of low slump grout to improve soil properties
- Uses highly viscous grout mixture to displace and compress loose soil around expanding grout bulb

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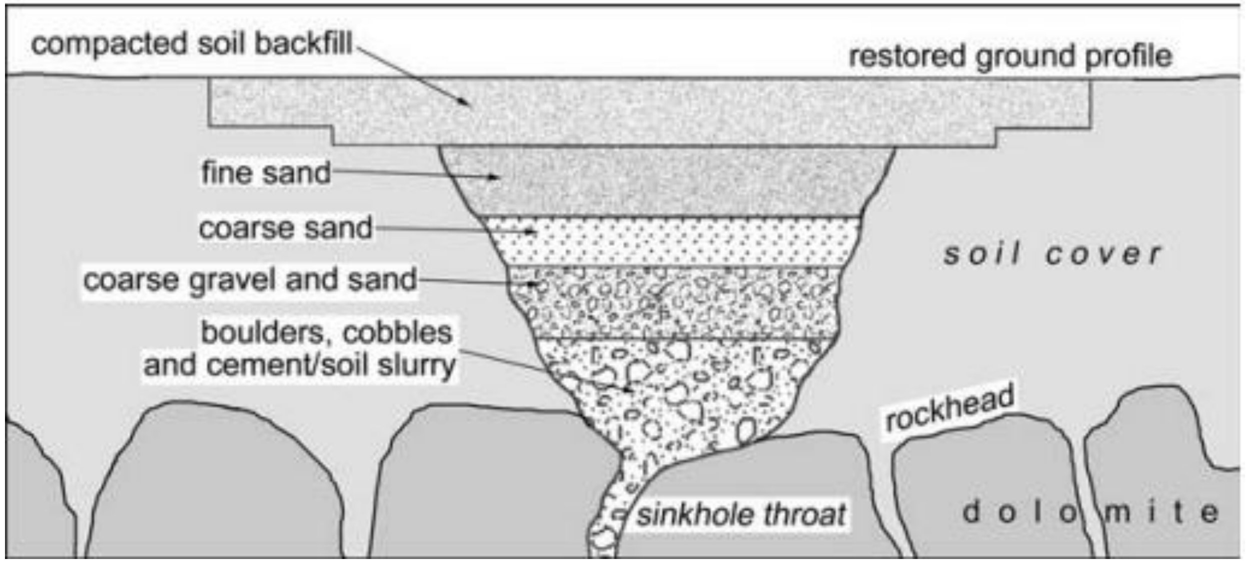
Reverse Filter

- Allows for continuation of moisture drainage
- Best for small sinkholes where throat can be excavated



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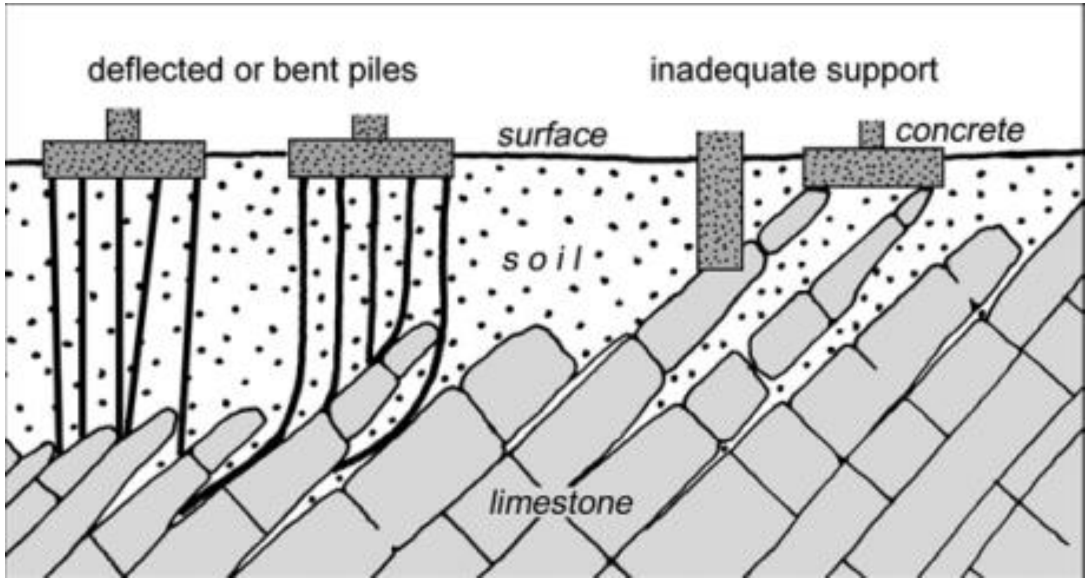
Deep Foundations

- Allows for dropout to occur without hazard to the structure
- Piles can be bent or crushed during placement PDA can help interpret



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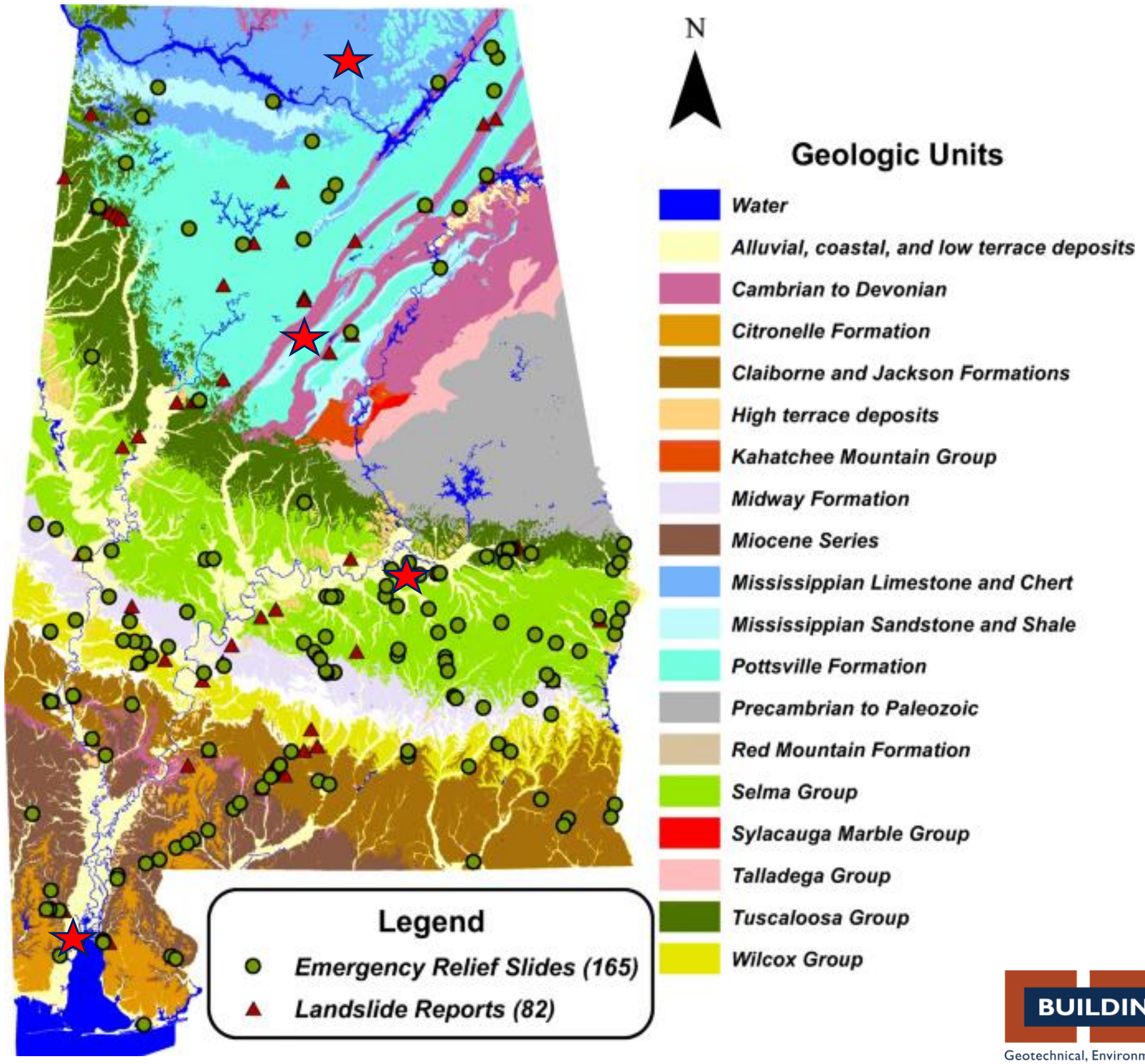
Alabama Landslide Database



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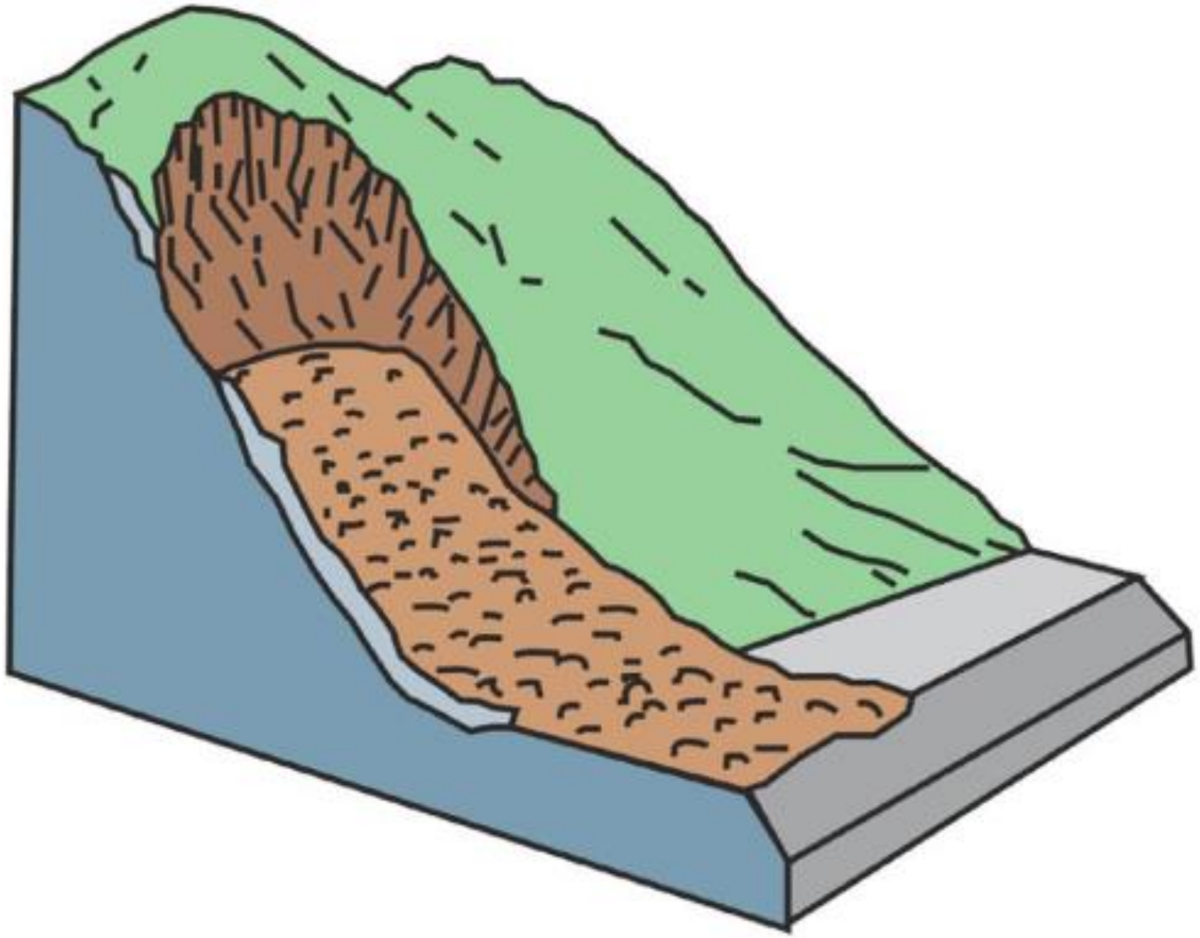
Types of Landslides

- Rotational
- Translational
- Rock Fall
- Topple
- Surface Erosion
- Flow



Triggering Mechanisms

- Shear strength of soil must be greater than shear stress required for equilibrium
  - Can occur:

Decrease in Shear Strength	Increase in the shear strength required for equilibrium
Increase in pore pressure (reduces effective stress)	Loads at top of slope
Cracking	Water pressure in cracks at top of slope
Swelling	**Increase in soil weight due to increase in moisture**
Slickensides	Excavation at bottom of slope
Decomposition of clayey rock fills	Drop in water level at the base of a slope
Creep under sustained loads	Earthquakes
Leaching	$\text{Factor of Safety} = \dfrac{\text{Resisting Forces}}{\text{Driving Forces}}$
Strain Softening	
Weathering	**F. S. > 1 keeps slope from sliding**
Cyclic Loading	

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Slope Failures

- Fill slopes during construction
  - Relatively high shear strength, stiff consistency
  - Stable slopes
- Cyclic wetting and drying results in net increase in soil moisture and decrease in shear strength
- Slope failures usually triggered by rainfall event

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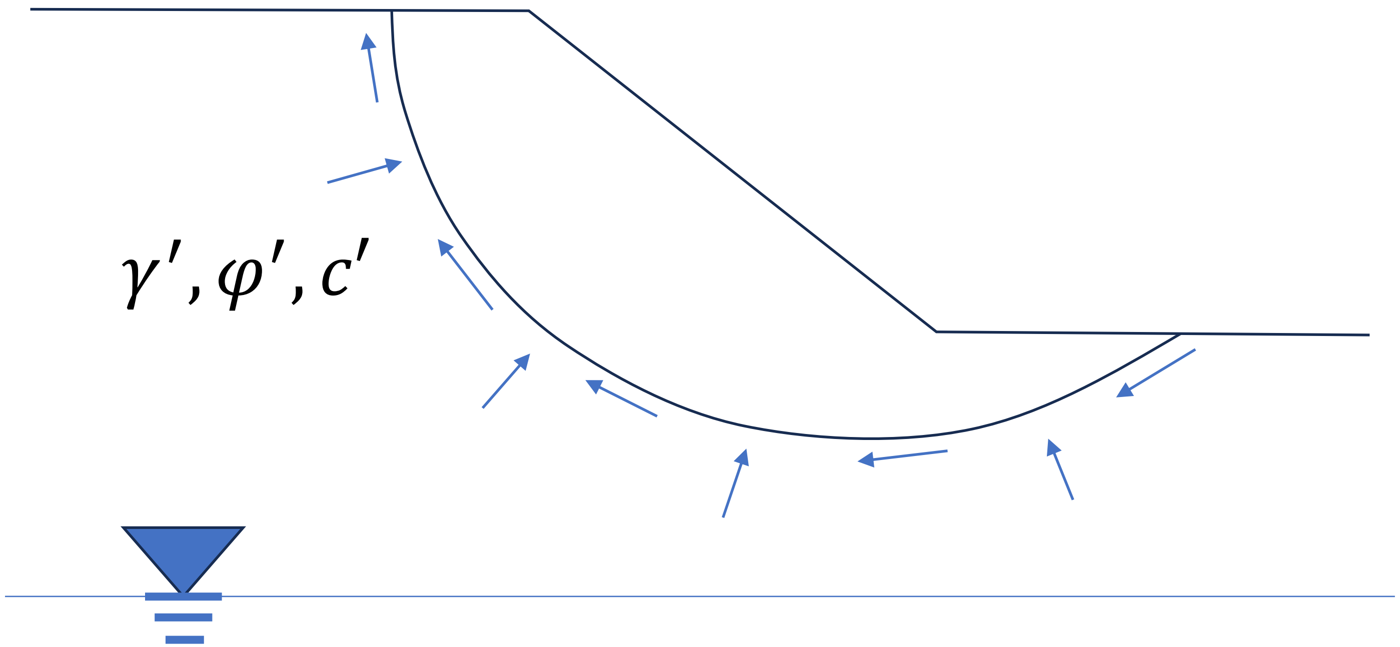
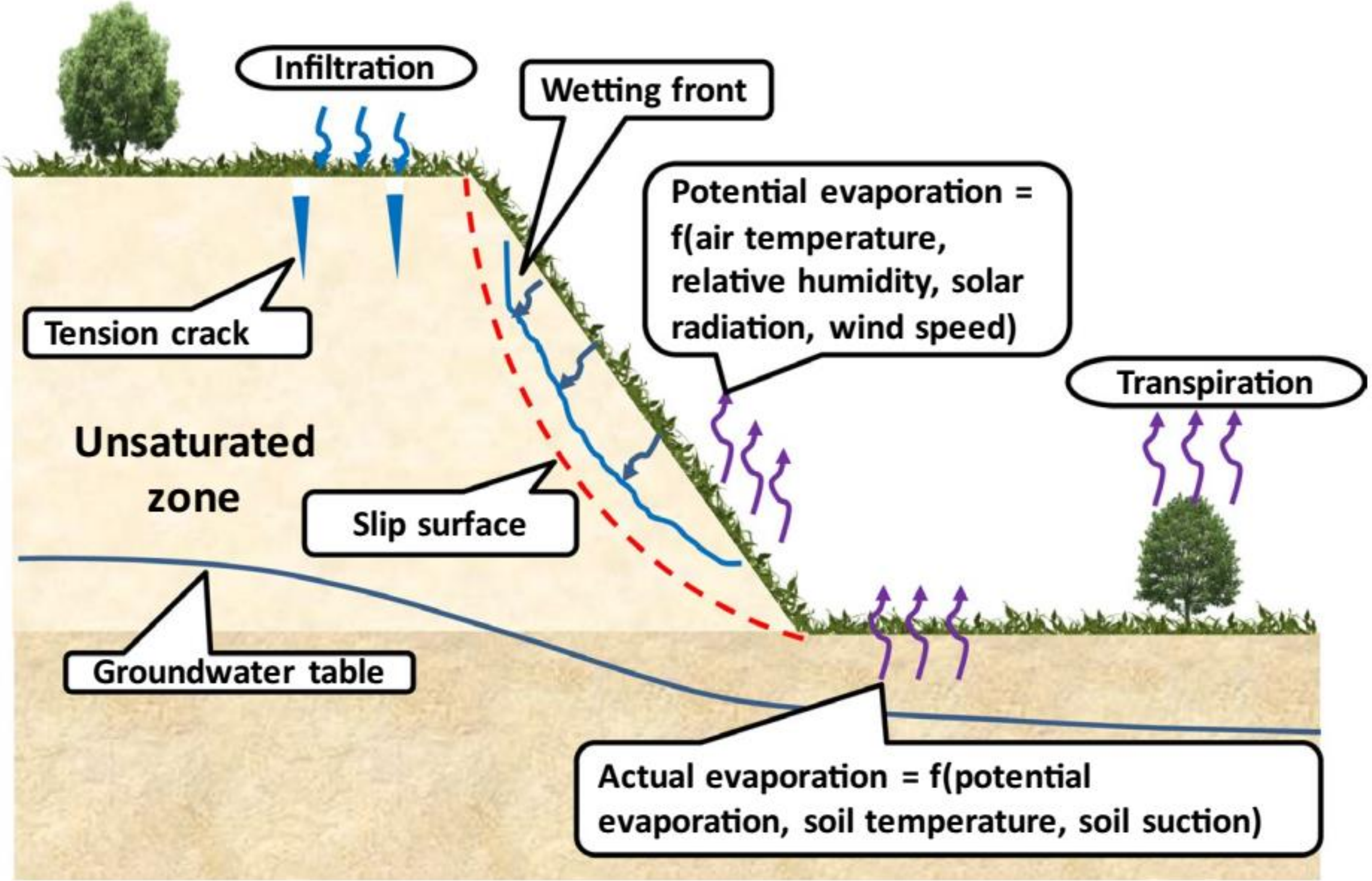
Slide Mechanics

- Resistance is a combination of shear resistance from the soil and normal stresses
- Soil shear strength dependent on unit weight, friction angle and cohesion
- Soil moisture typically assumed saturated
  - May not be a realistic condition



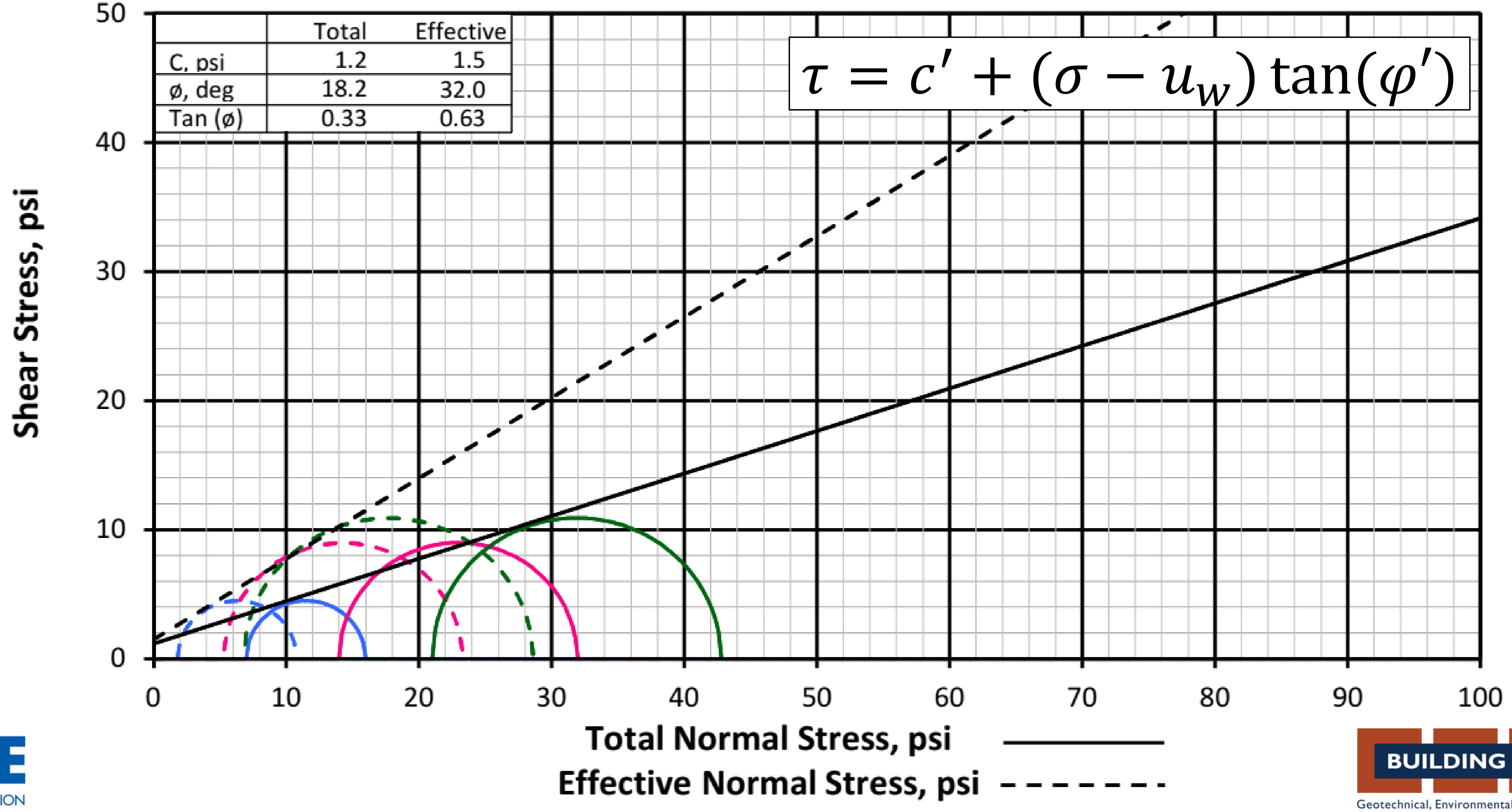
Unsaturated Slide Conditions

- Other factors that influence slide mechanics are unaccounted for in traditional analysis methods
- Severe rainfall events can cause slopes that have a high factor of safety in dry conditions to fail



Traditional Soil Shear Strength

$$\tau = c' + (\sigma - u_w)\tan(\varphi')$$



	Total	Effective
C, psi	1.2	1.5
ø, deg	18.2	32.0
Tan (ø)	0.33	0.63

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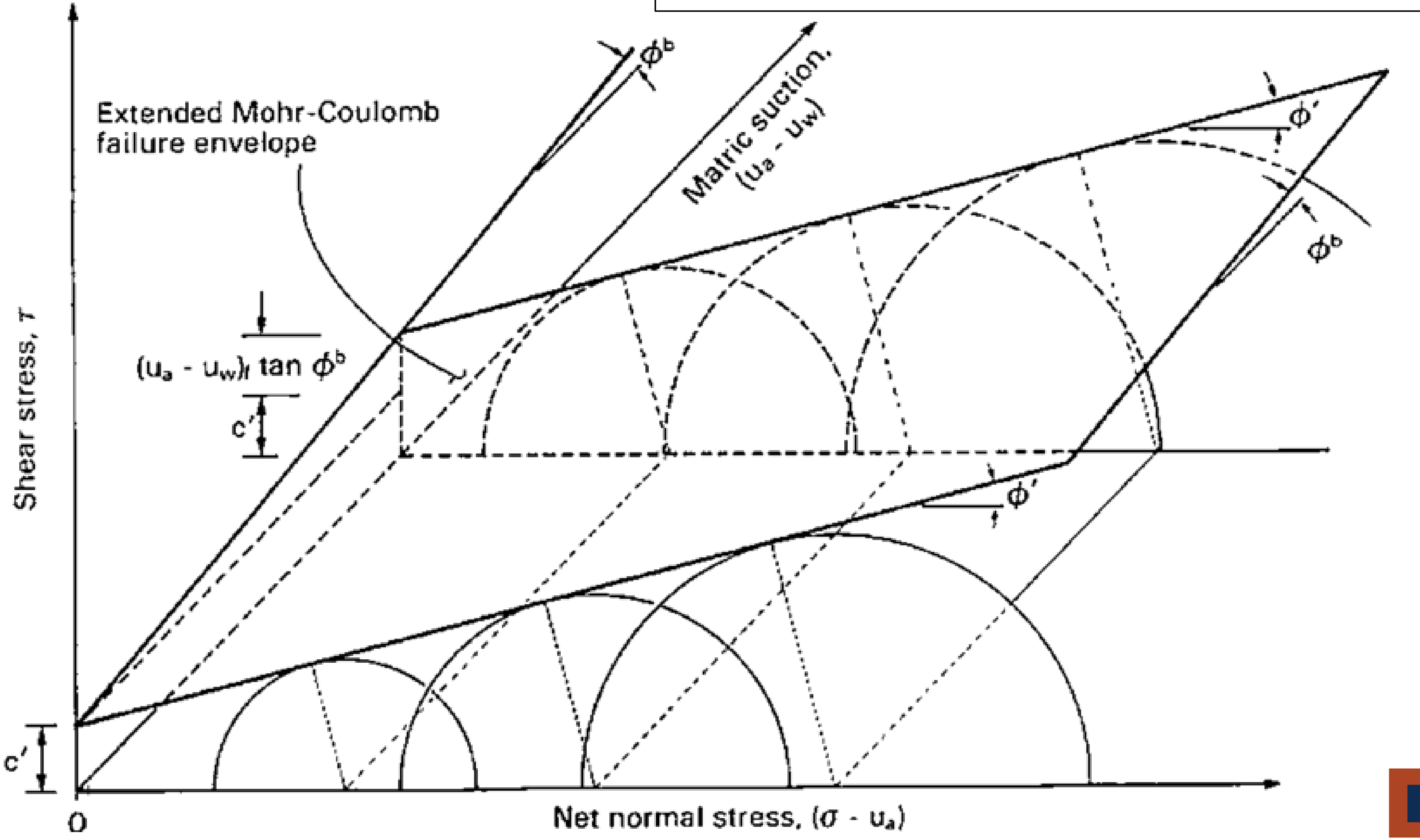
Unsaturated Soil Mechanics

$$\tau = c' + (\sigma_n - u_a)\tan\phi' + (u_a - u_w)\tan\phi^b$$



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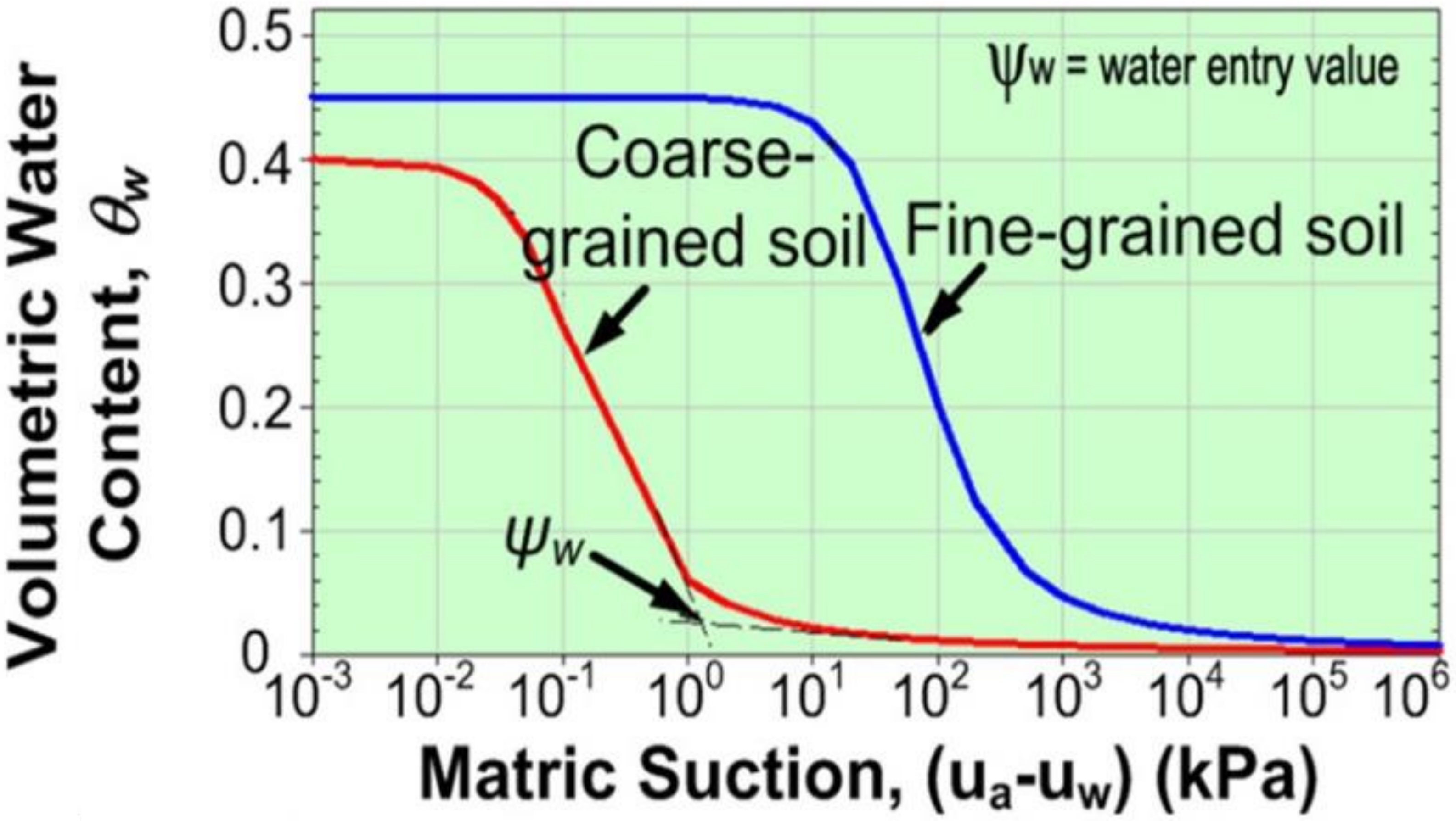
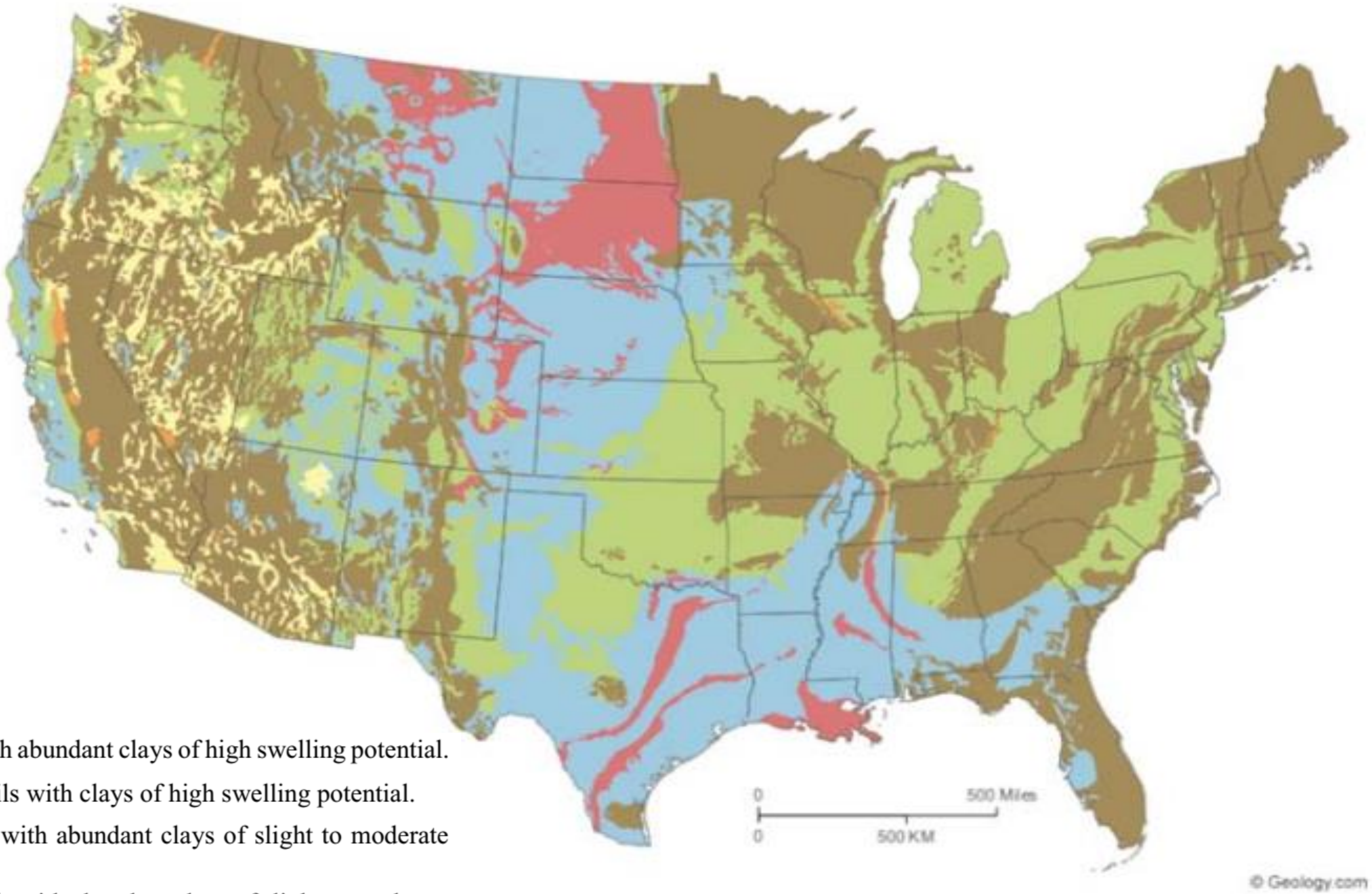
Soil Water Characteristic Curve

- Influence by soil type
- Methods of predictions
- Implementation



Distribution of Expansive Soil



- Over 50 percent of these areas are underlain by soils with abundant clays of high swelling potential.
- Less than 50 percent of these areas are underlain by soils with clays of high swelling potential.
- Over 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.
- Less than 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.
- These areas are underlain by soils with little to no clays with swelling potential.
- Data insufficient to indicate the clay content or the swelling potential of soils.

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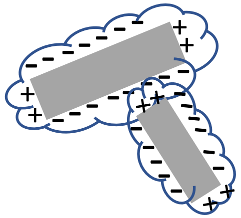
Diffuse Double Layer

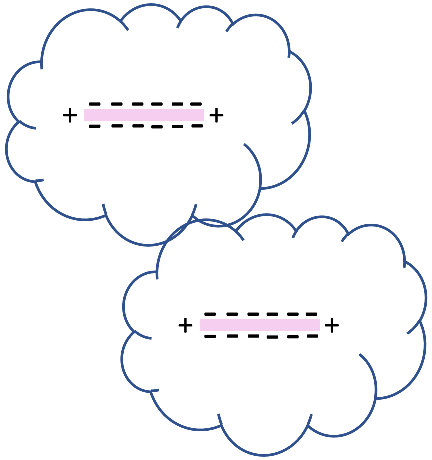
- Clay minerals have net negative charge
- Attracted to positive ion from water molecules
- Forms electron cloud
- Shrink/swell
- Addition of salt or calcium chloride
  - Shrink Diffuse Double Layer
  - Increase interparticle forces



Kaolinite

Strong interparticle forces

Small DDL



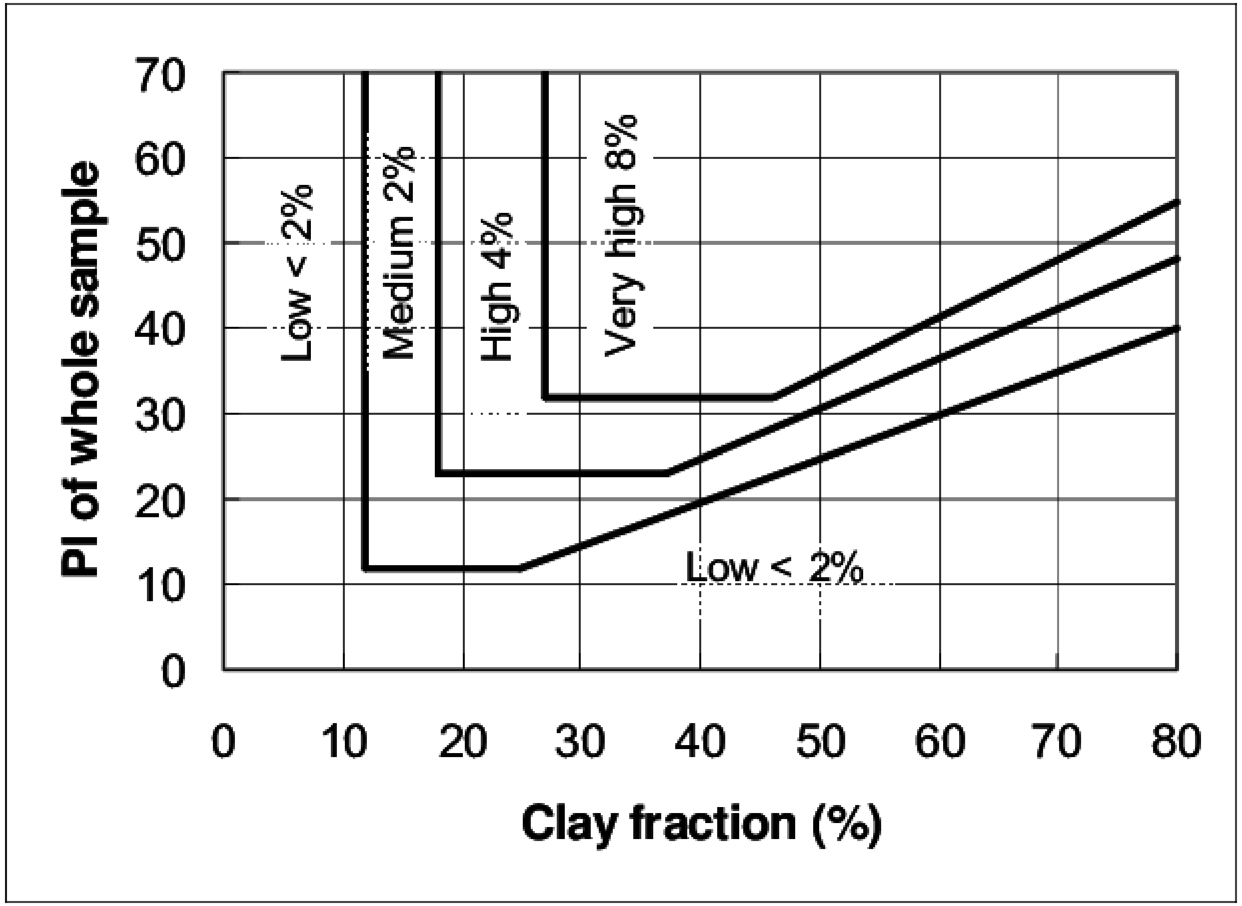
Na Montmorillonite (Bentonite)

Weak interparticle forces

Large DDL

Heave Prediction

- Heave potential depends on clay content, plasticity index and shrinkage limit
- Initial dryness and matric suction influences heave potential



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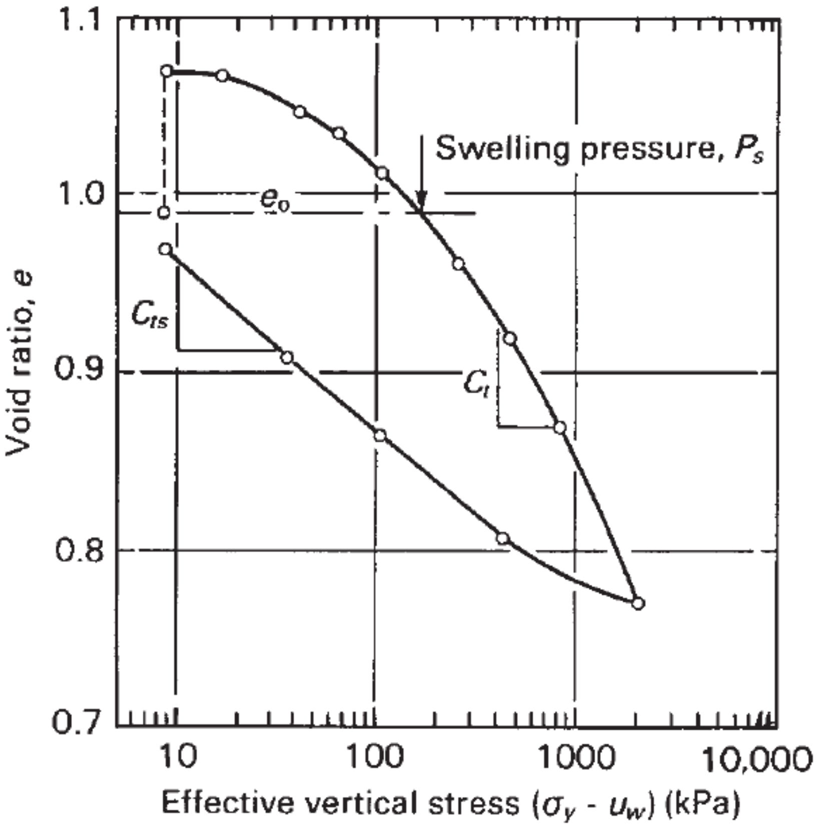
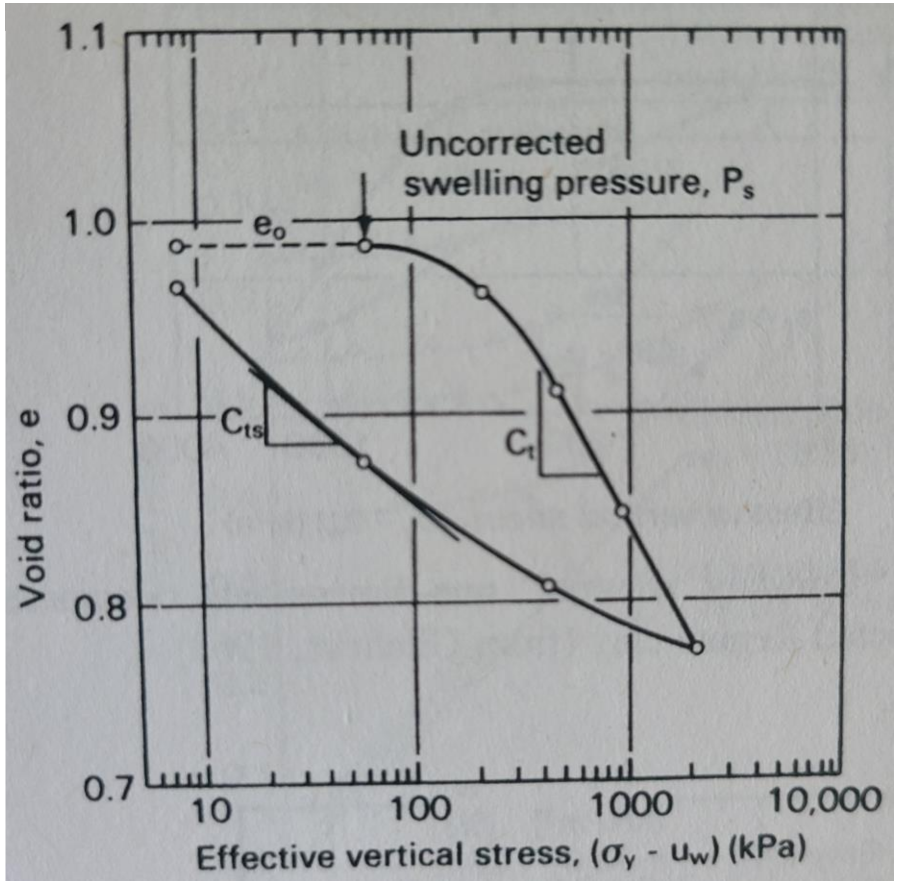
Swell Measurement

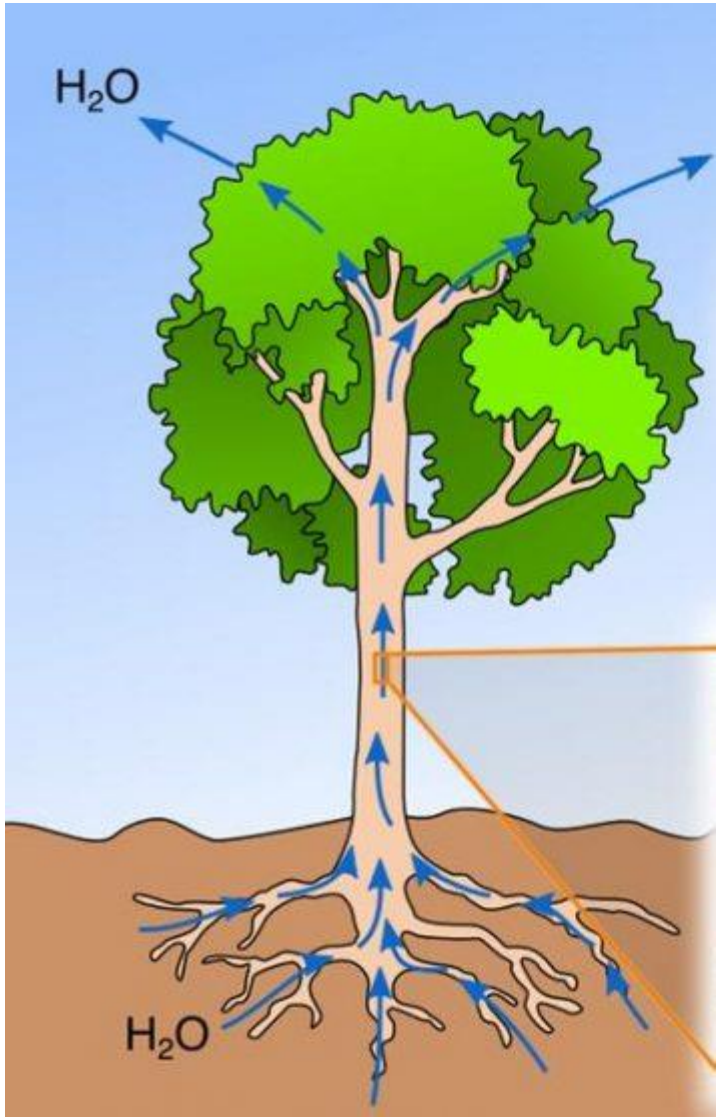
- Free Swell
- Constant Pressure
- Oedometer tests can be used to measure amount of swell and swell pressure





Swell Mitigation

- Undercut
- Moisture condition
- Chemical stabilization
- Deepen footings
- Remove trees or heavy root structures



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Thank you

for your time and attention.