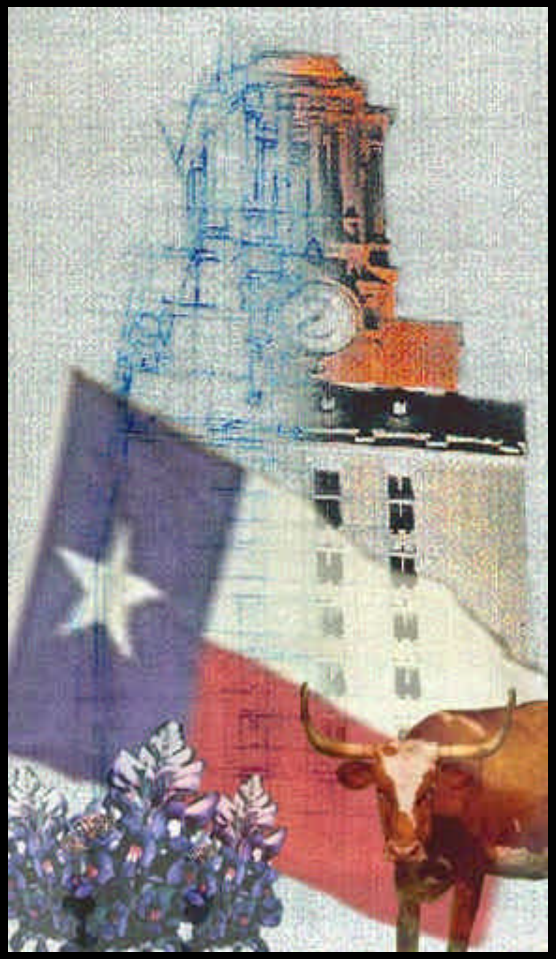
The Increasing Role of Stress Wave Measurements in Solving Geotechnical Engineering Problems



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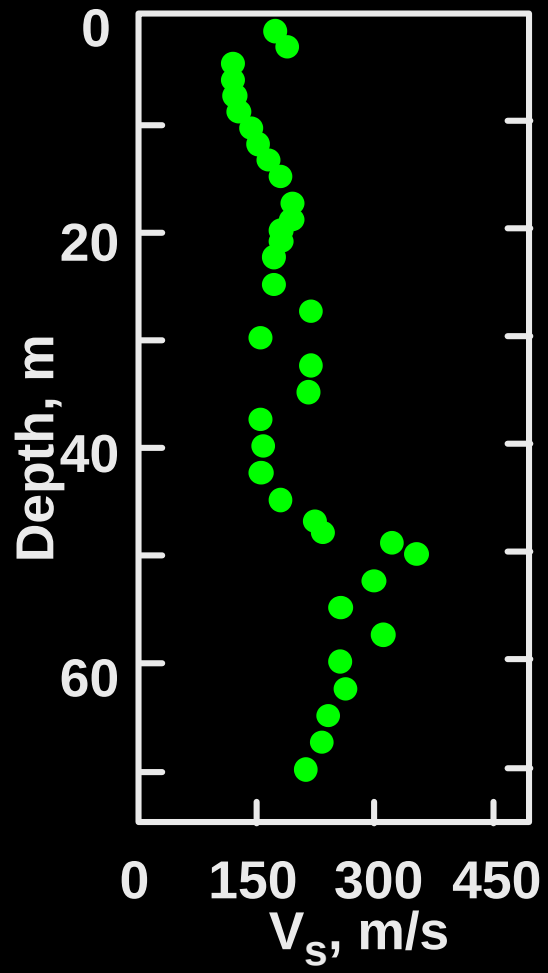
Outline

1. Brief Background
   - emphasis field measurements
2. Present a Number of Applications
   - static and dynamic problems
3. Show Importance of Field Seismic Measurements in Predicting the G – log g and t – g Curves
4. Concluding Remarks

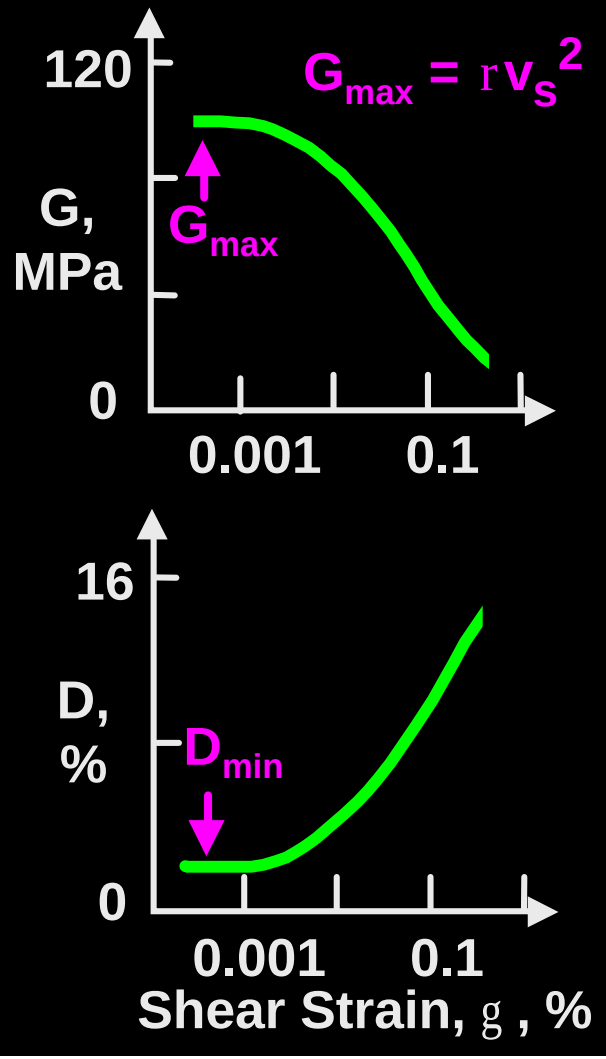
1. Background: Role of Stress Wave Measurements

1. Soil Profile

2. Field: Linear V_s (and V_p)

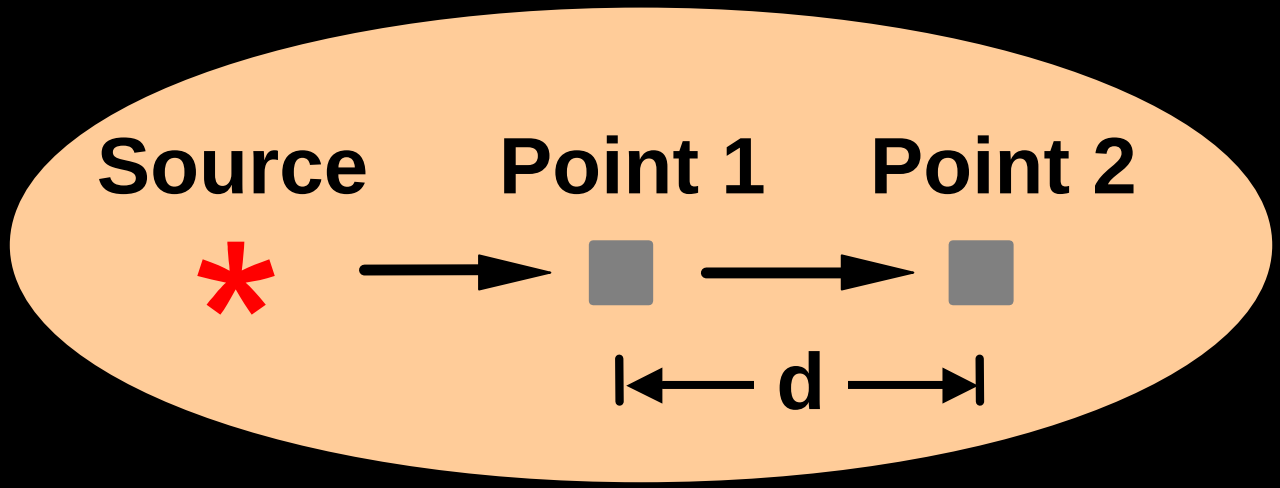


3. Lab: Linear and Nonlinear G and D



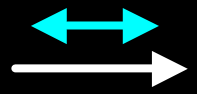
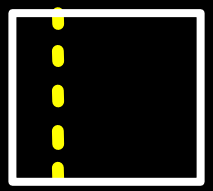
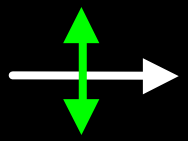
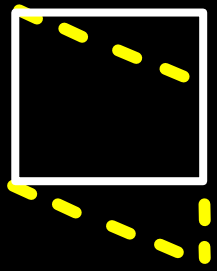
Stress Wave (Seismic) Measurements in the Field

Objective: measure time, t, for a given stress wave to propagate a given distance, d ... then velocity = d/t

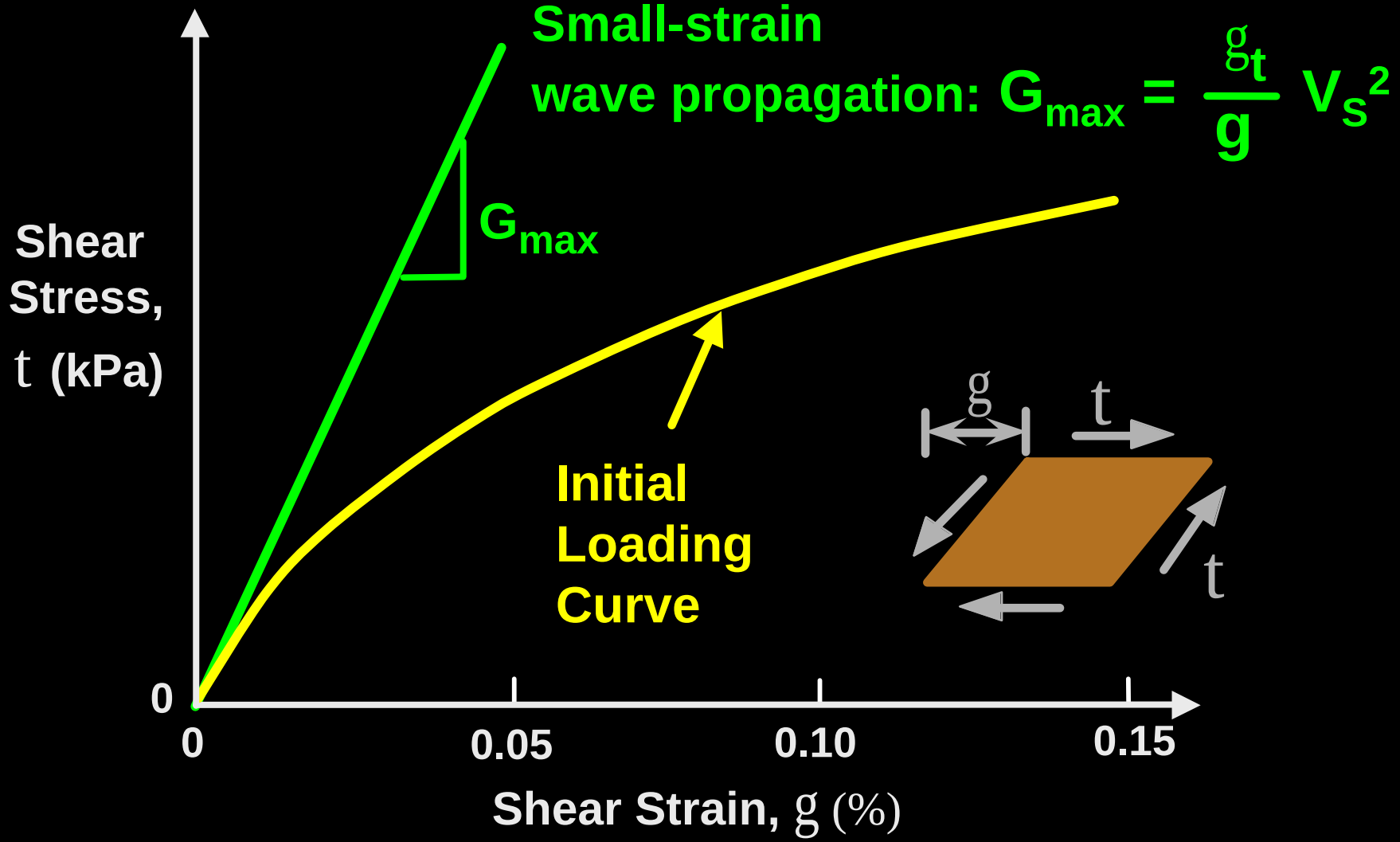


Key characteristic: small-strain (linear) measurements

Field Measurements with Compression (P) and Shear (S) Waves

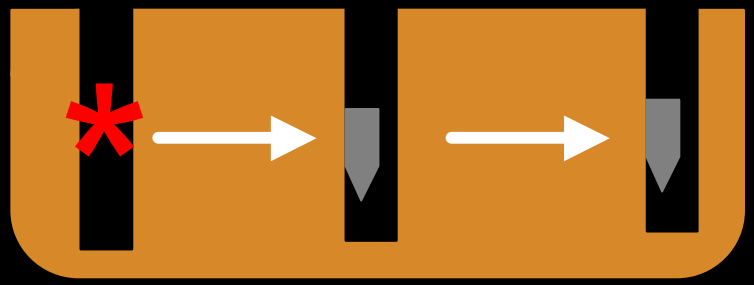
Wave Type	Particle Motion	Distortion	Wave Velocity	Small-Strain Modulus
P			V_p	$M_{max} = \frac{\gamma_t}{g} V_p^2$
S			V_S	$G_{max} = \frac{\gamma_t}{g} V_S^2$

Small-Strain Seismic Measurements

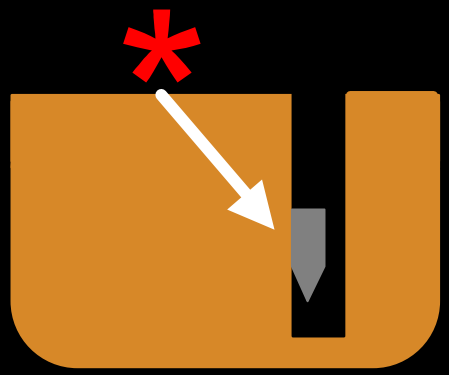


First “Geotechnical” Field Seismic Methods (1970s)

1. Crosshole Test



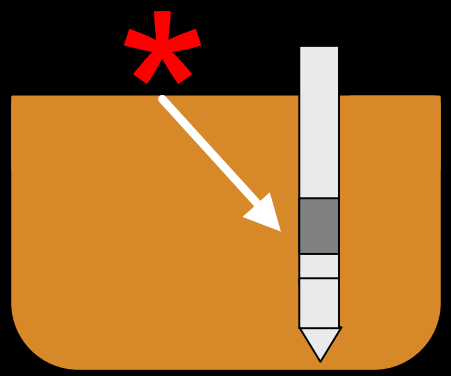
2. Downhole Test



Direct P and S Waves

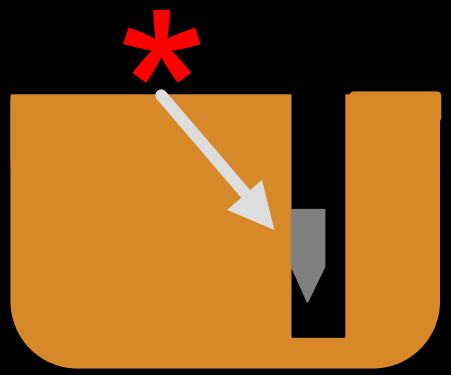
Modified Seismic Method (1980s)

1. Seismic Cone Penetrometer Test (SCPT)



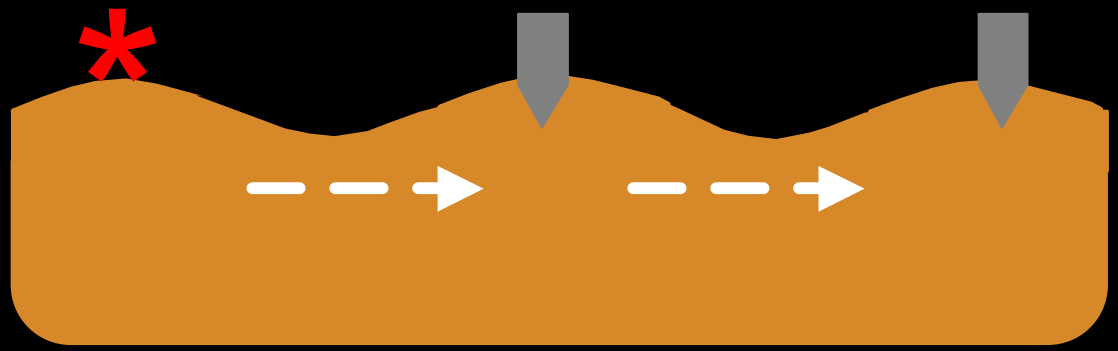
Direct S Wave

SCPT adapted from 1970s Downhole Test



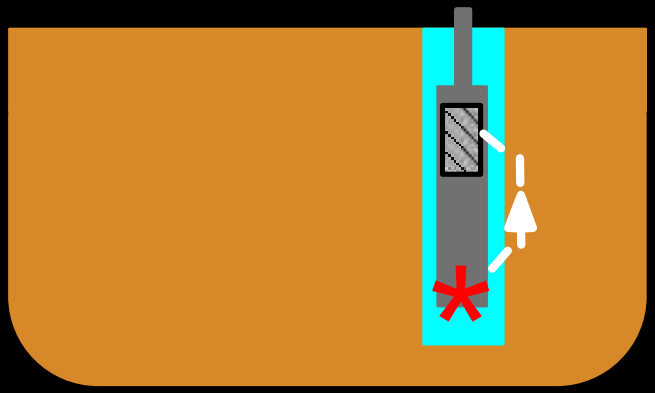
Recent Field Methods (1990s)

1. Surface Wave (SASW) Test



Measure Rayleigh (R) Waves

2. P-S Suspension Logger



Direct P and S Waves

2. Increasing the Role in Solving Geotechnical Engineering Problems

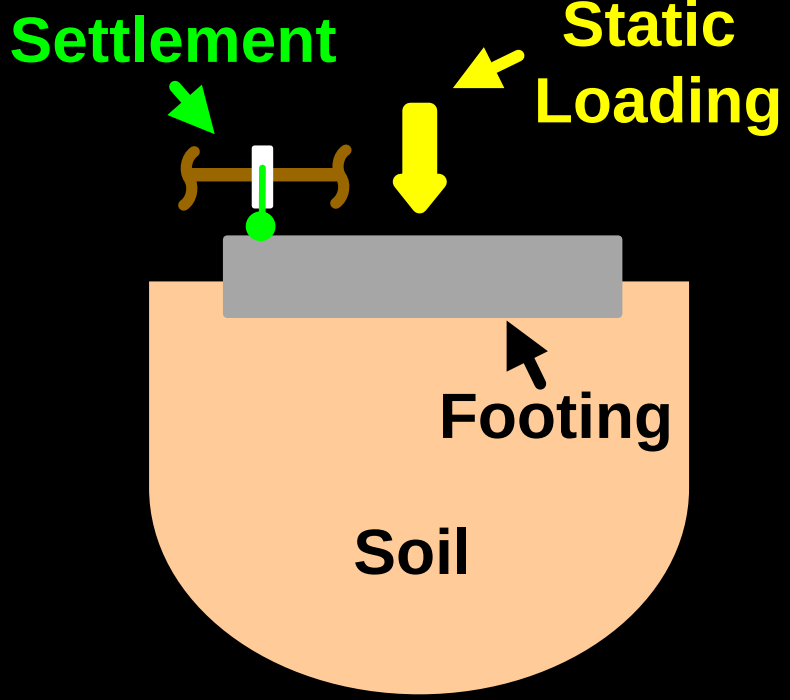
Case Histories and Applications

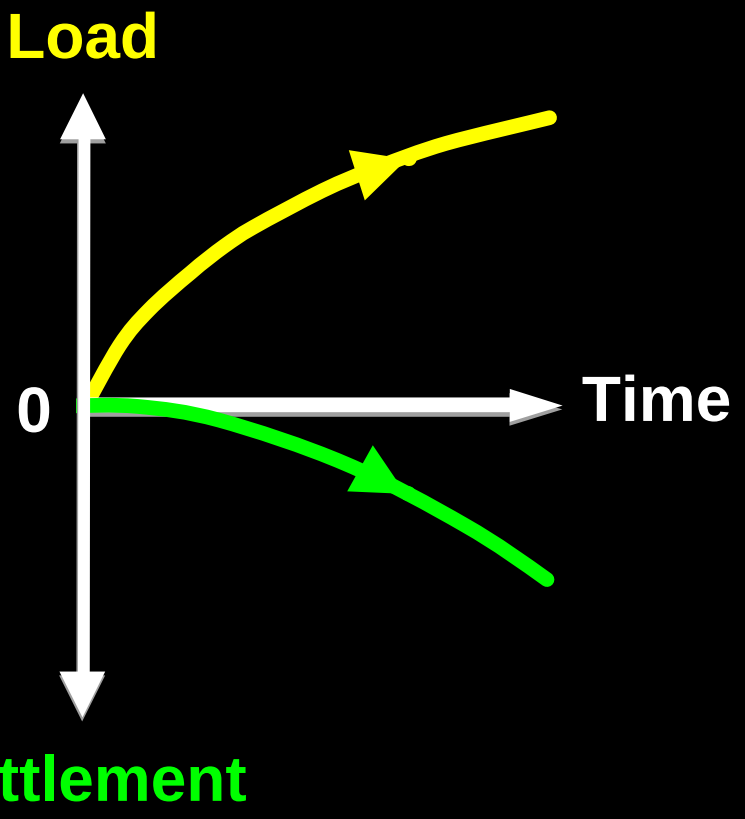
- **static conditions**
- **dynamic conditions**

Solutions - Static Conditions

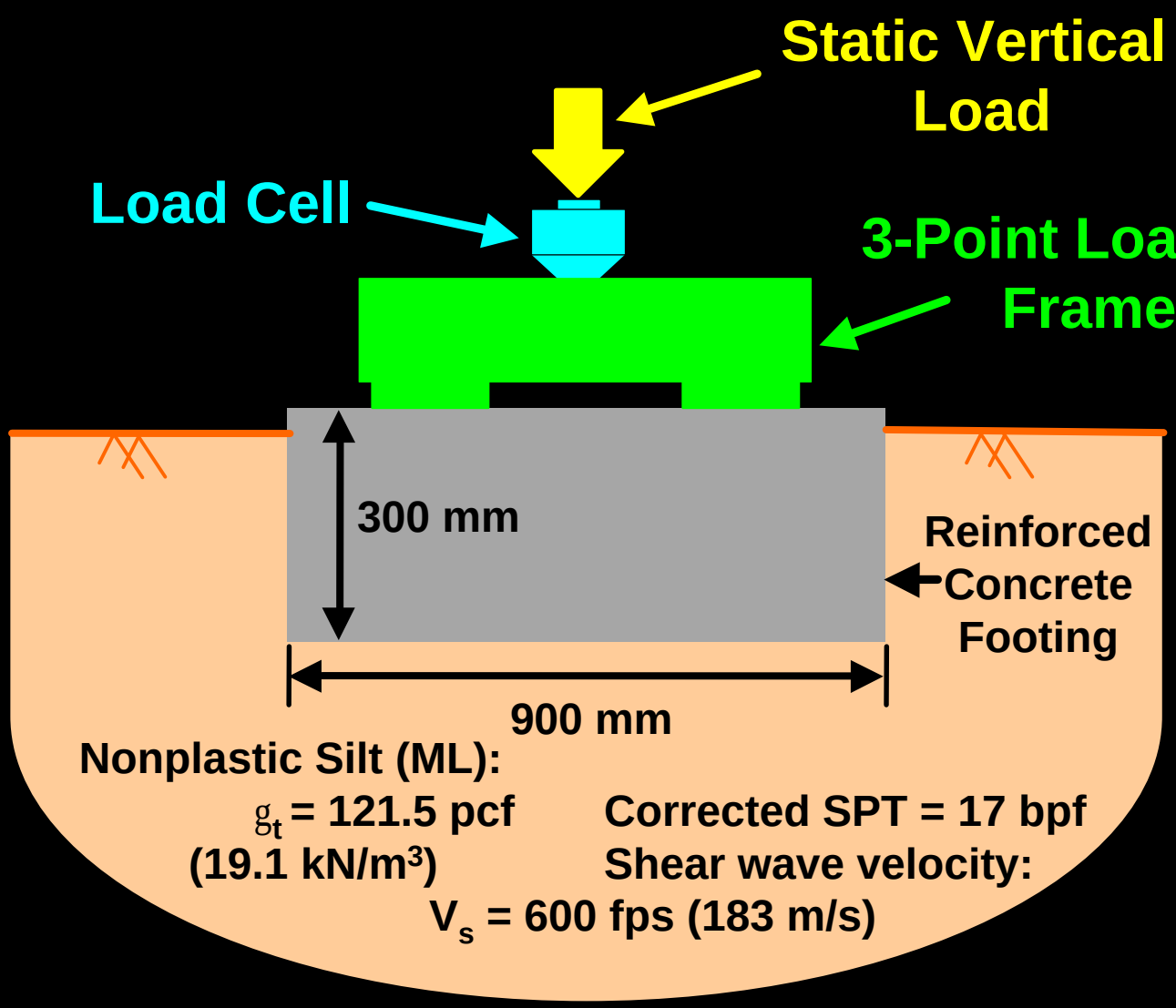
1. Static Loading
    - footing settlements
    - retaining wall movements
2. Site Characterization
    - layering, ground water table, etc.
    - underground cavity detection
    - tunnel investigations
    - pavement studies
3. Process Monitoring
    - grouting evaluations
    - ground improvement studies
    - areas of deterioration
4. Link Between Field and Lab

Static Application #1:
Predicting Footing Settlements

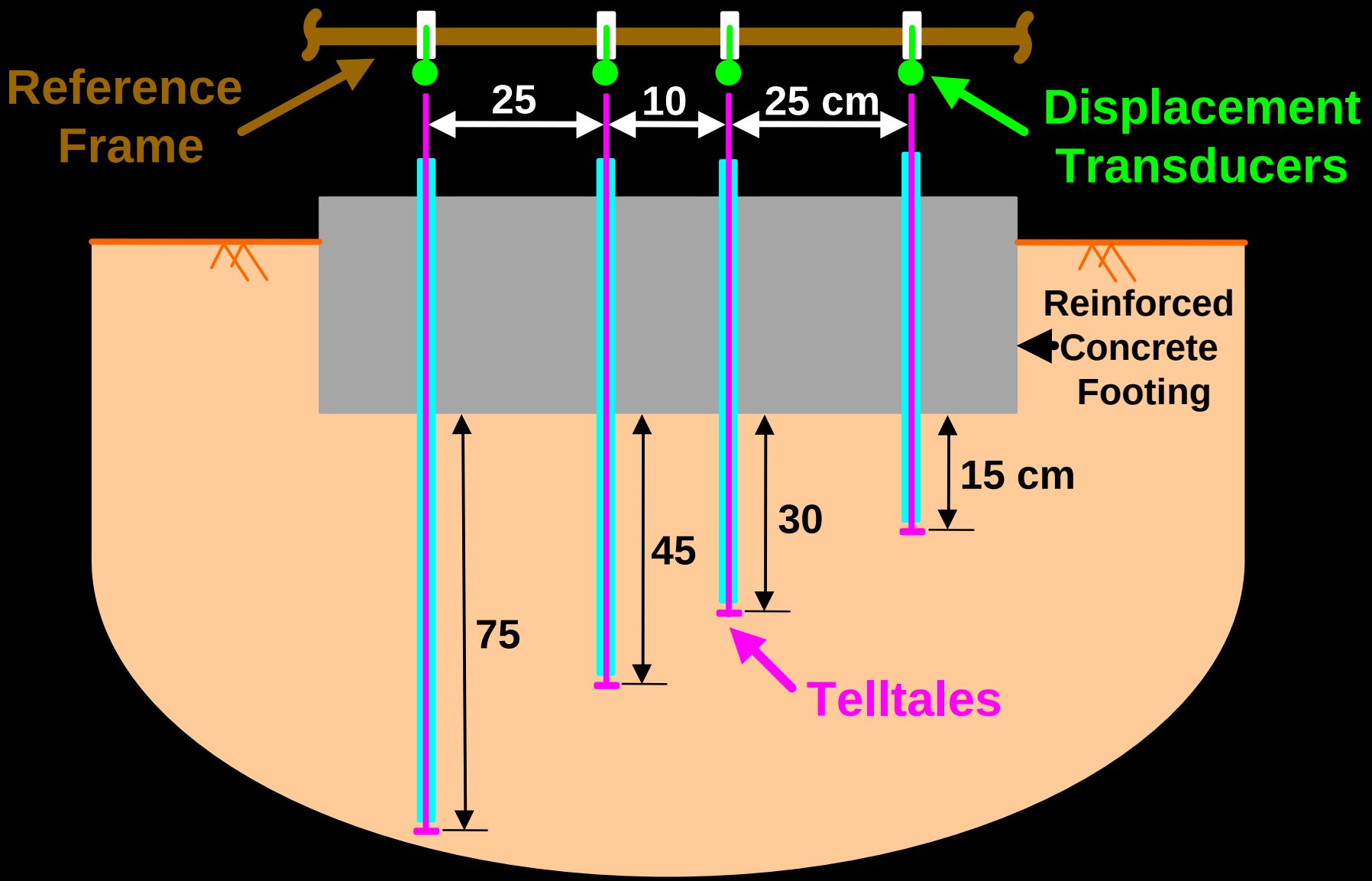




Soil, Footing and Loading Arrangement

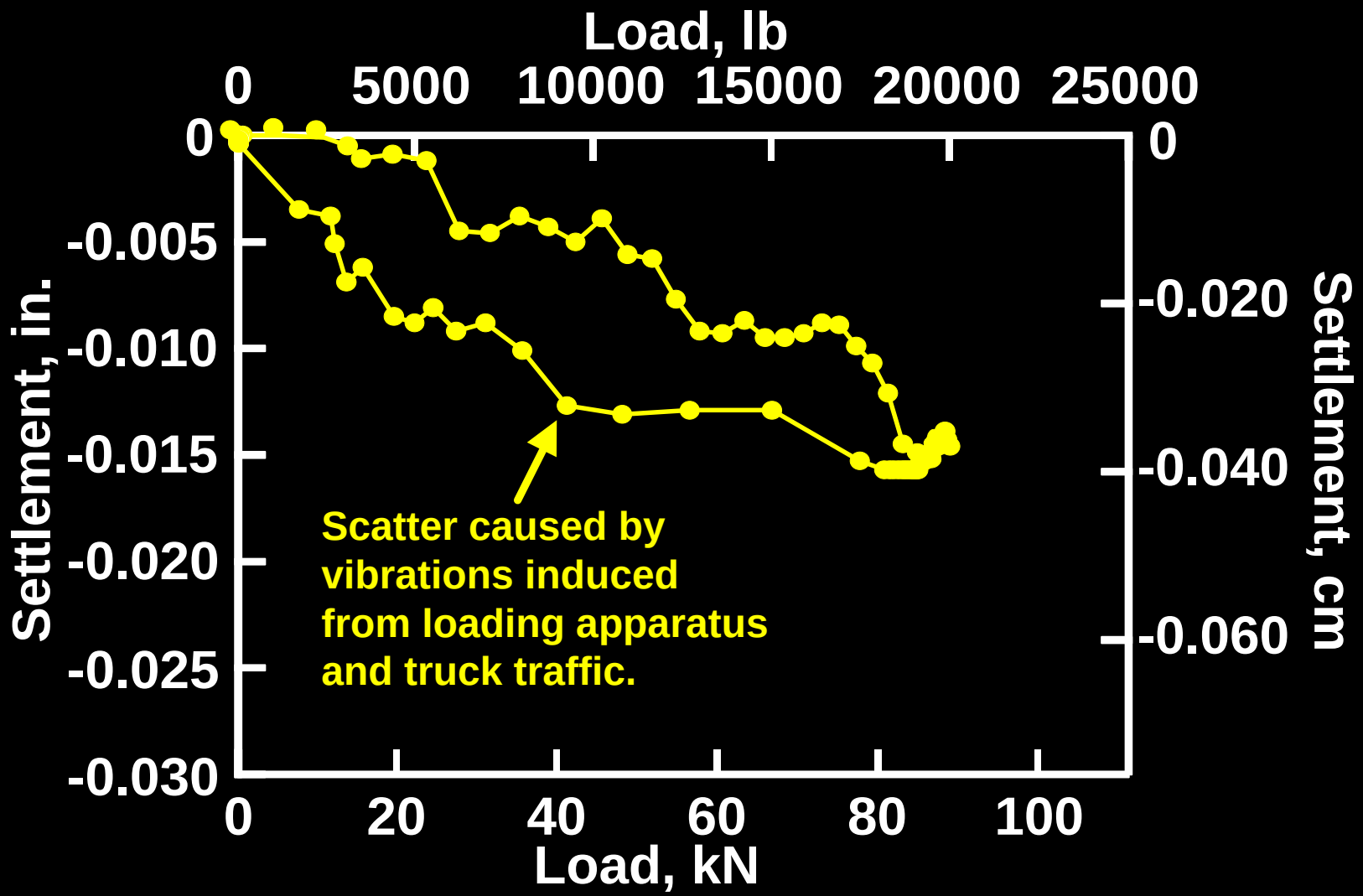


Telltales Beneath the Footing

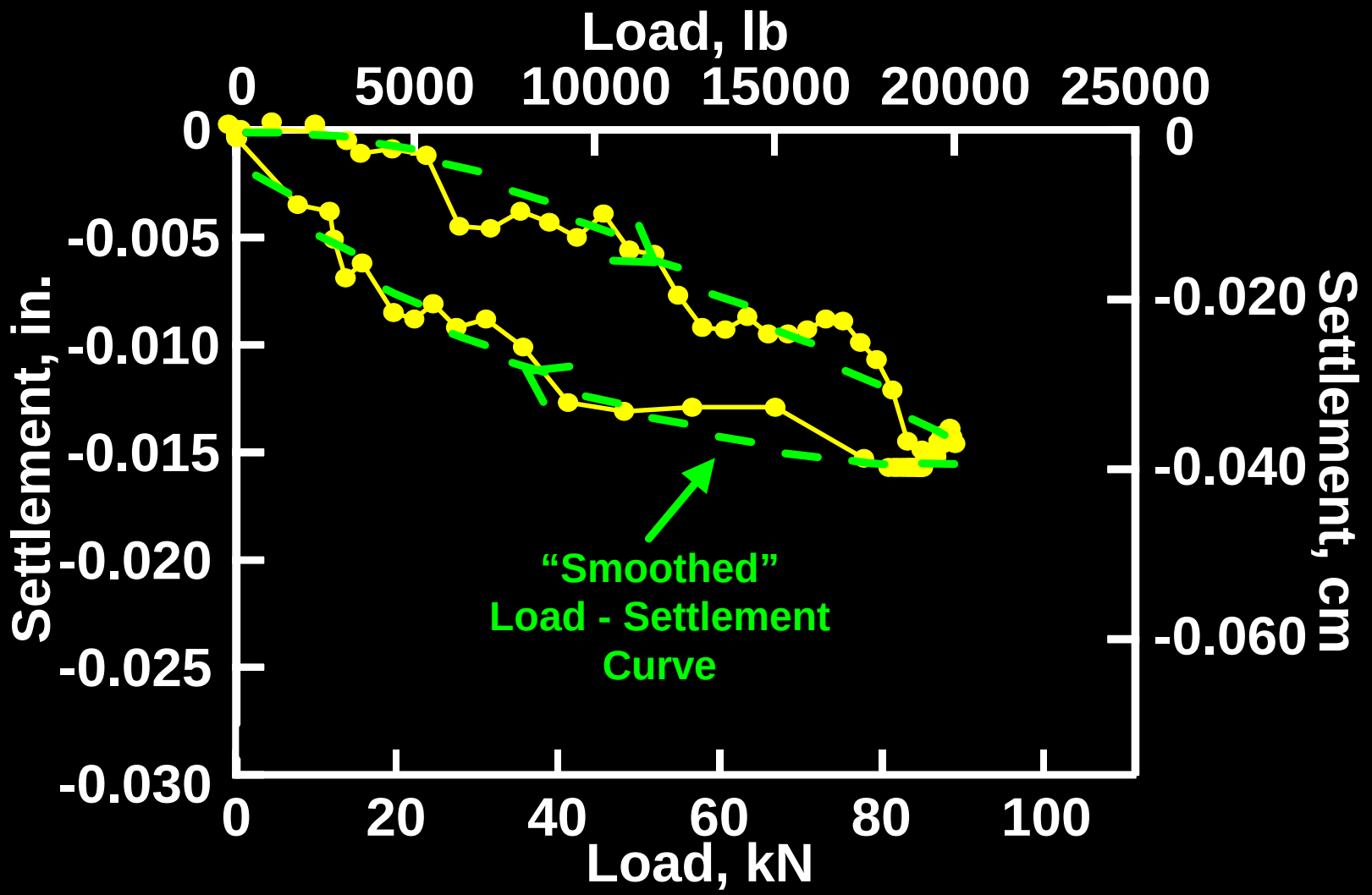


Loading Footing with T-Rex

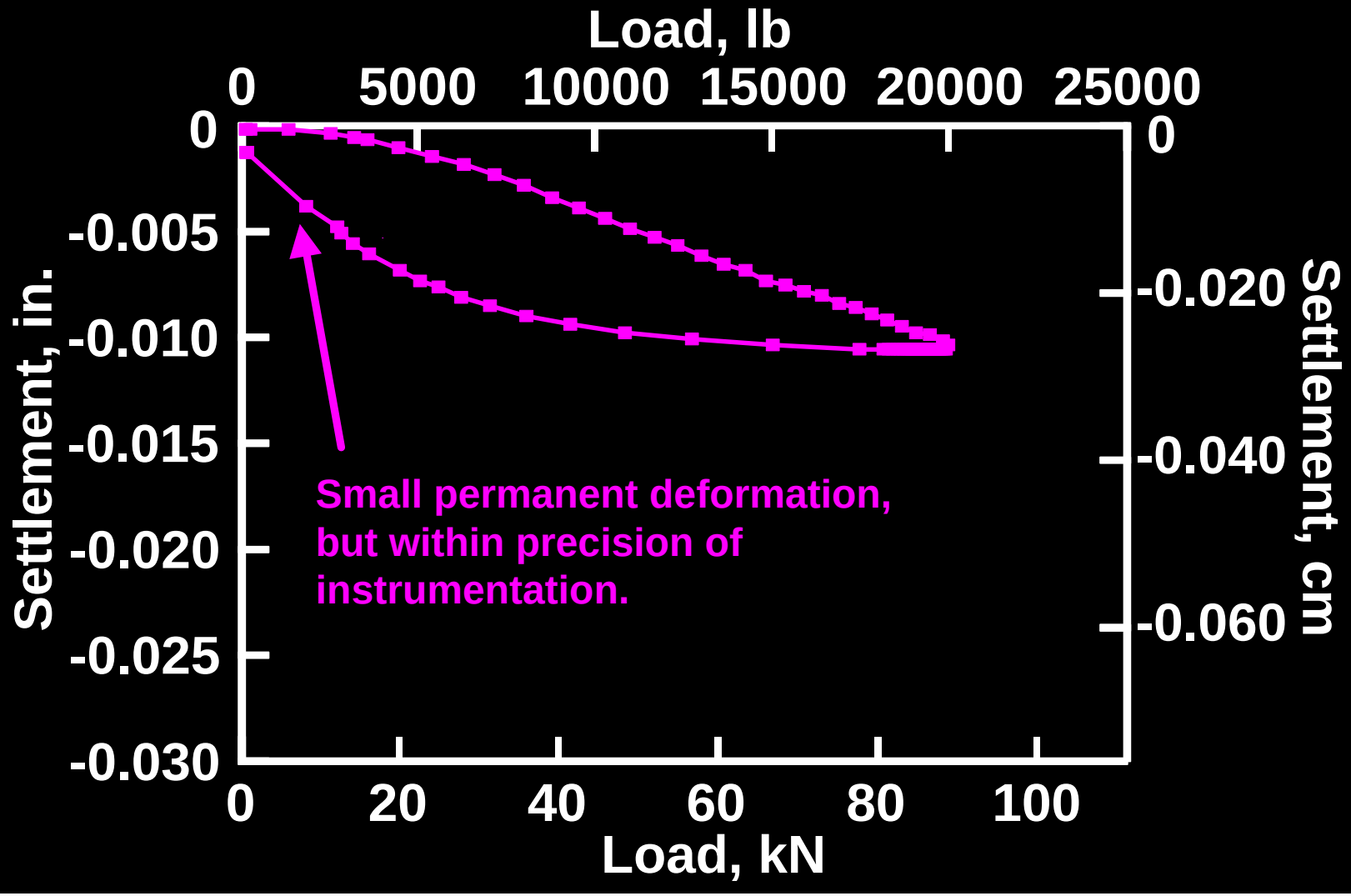
Typical Settlement Measurements: Top of Footing Near the Center



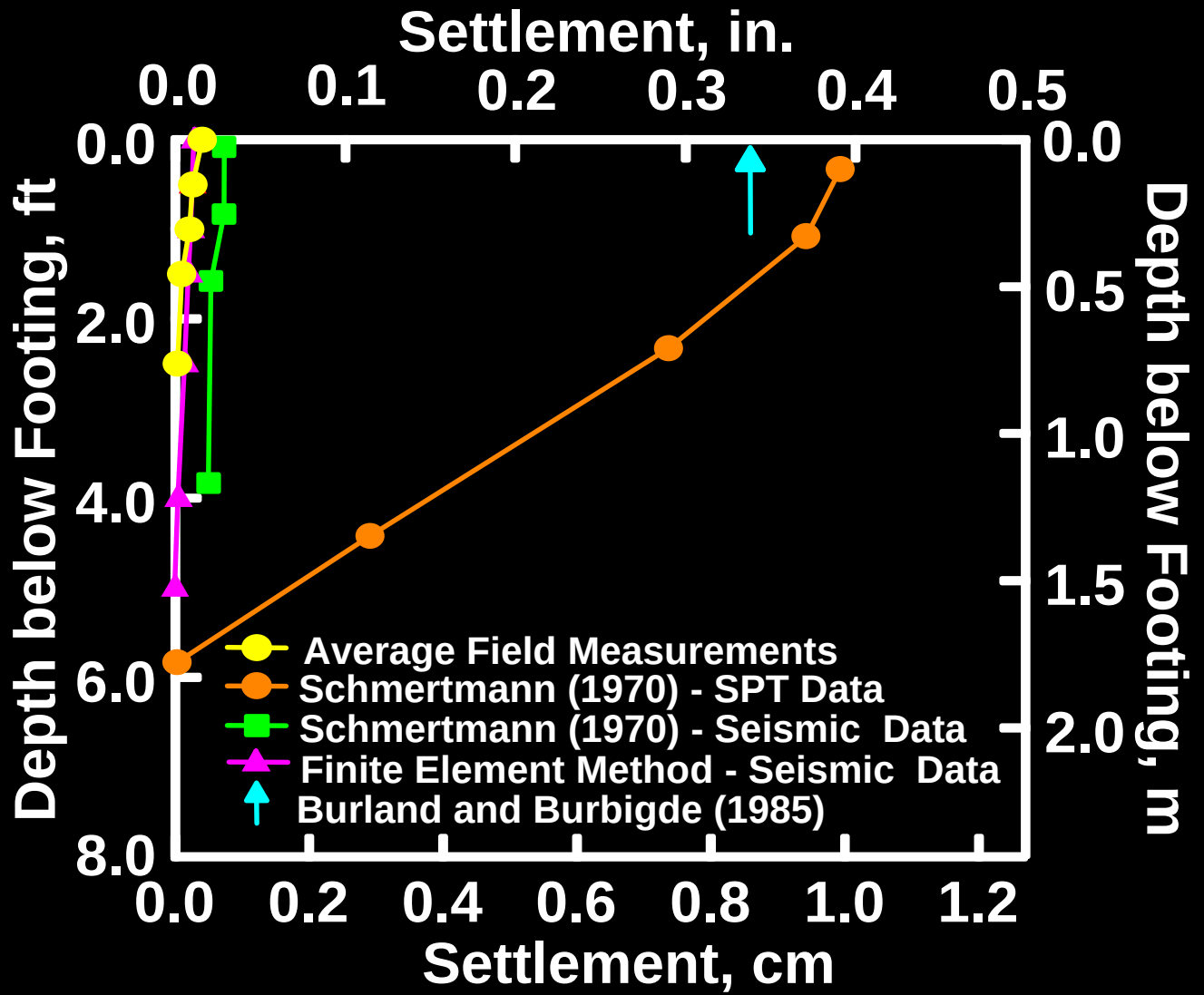
Typical Settlement Measurements: Top of Footing Near the Center



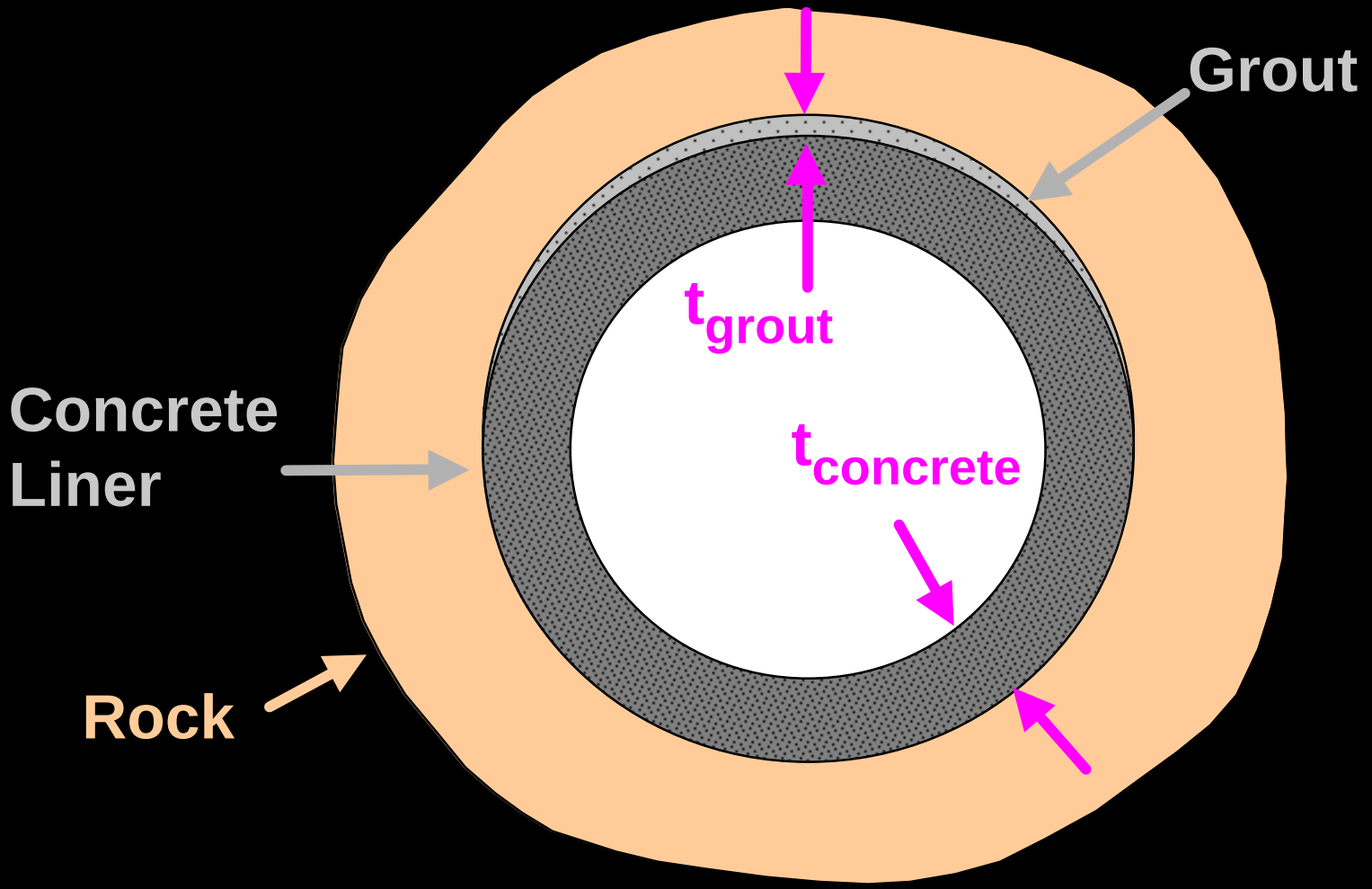
Typical Settlement Measurements with Telltales: 15 cm Beneath Center of Footing



Comparison of Measured and Predicted Settlements



Static Application #2: Tunnel Investigation

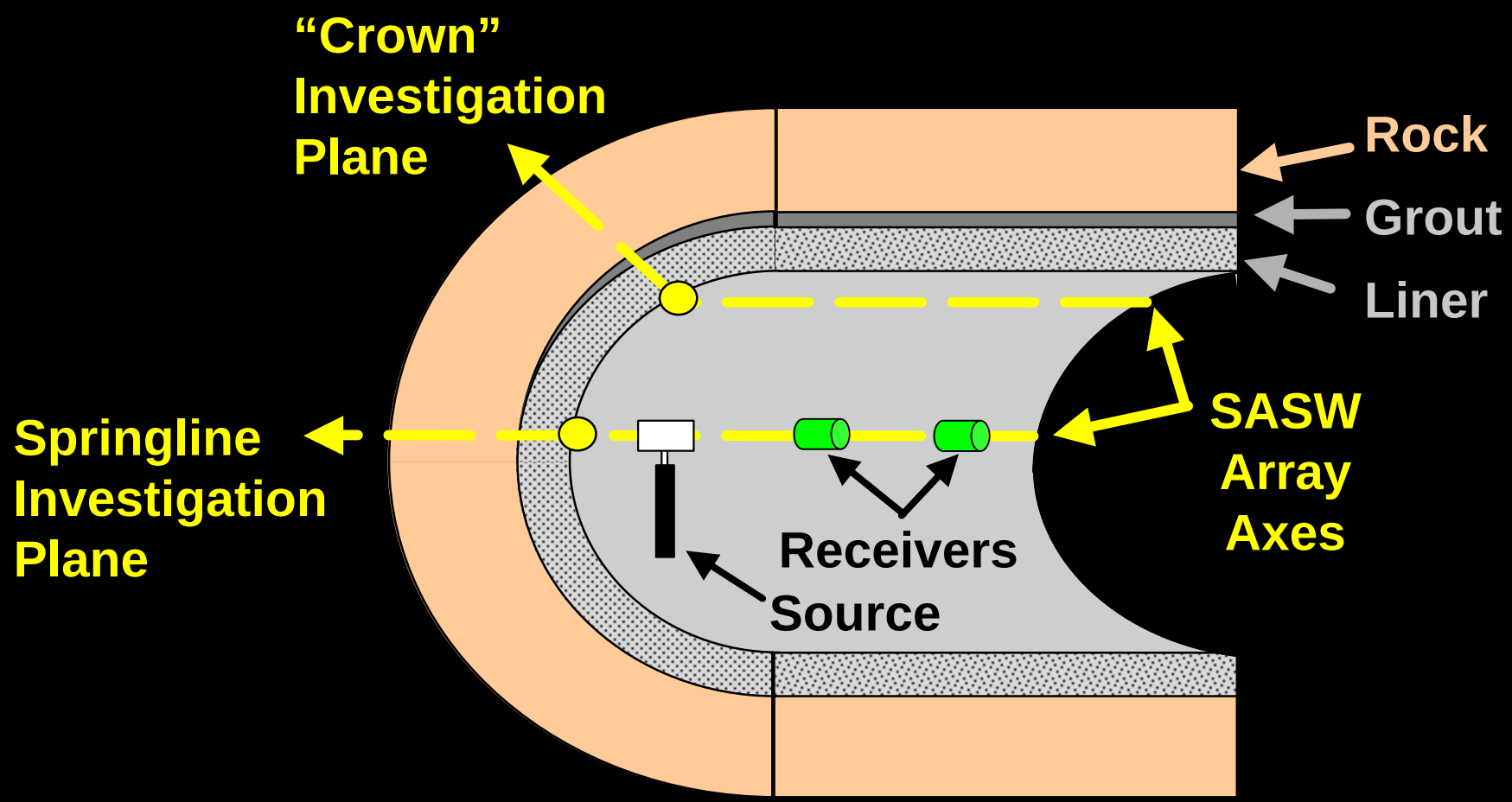


Some Questions

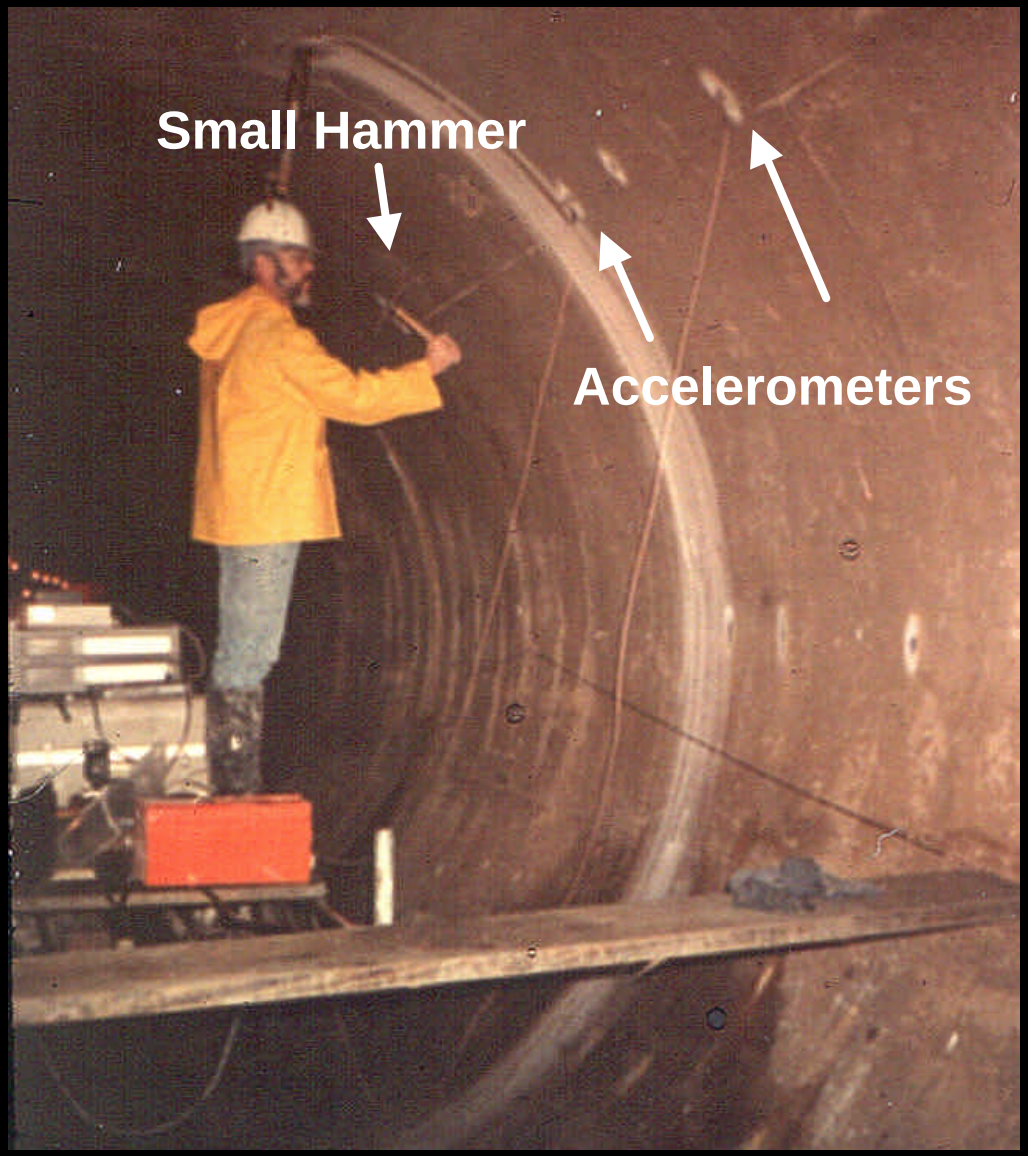
1. Quality of concrete liner?
2. Thickness of concrete liner?
3. Quality of grout in crown?
4. Thickness of grout in crown?
5. Any voids behind liner?
6. Stiffness of rock behind liner?

(Answered all Questions)

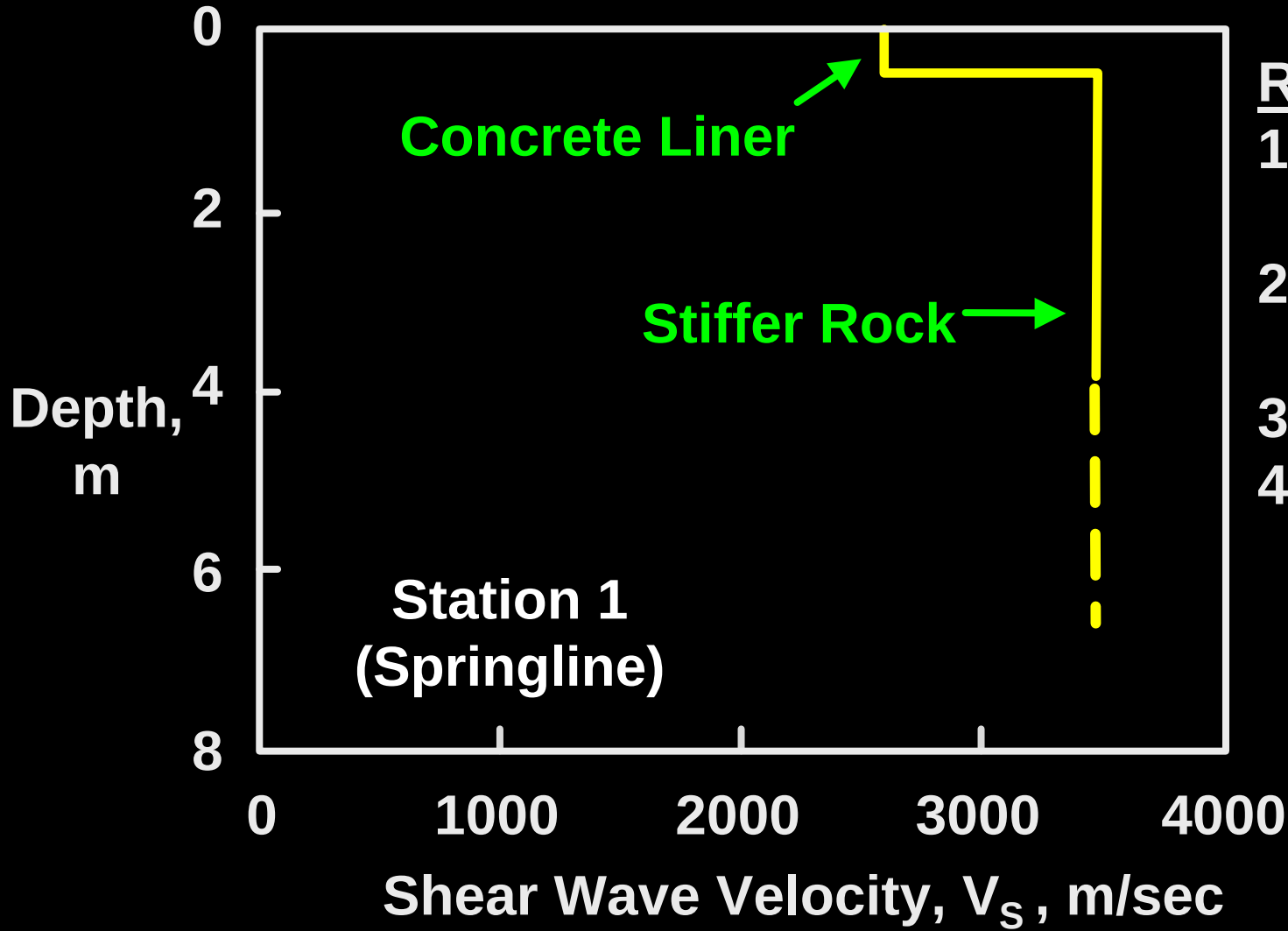
SASW Testing Arrangement and Planes of Investigation



Conducting SASW Tests



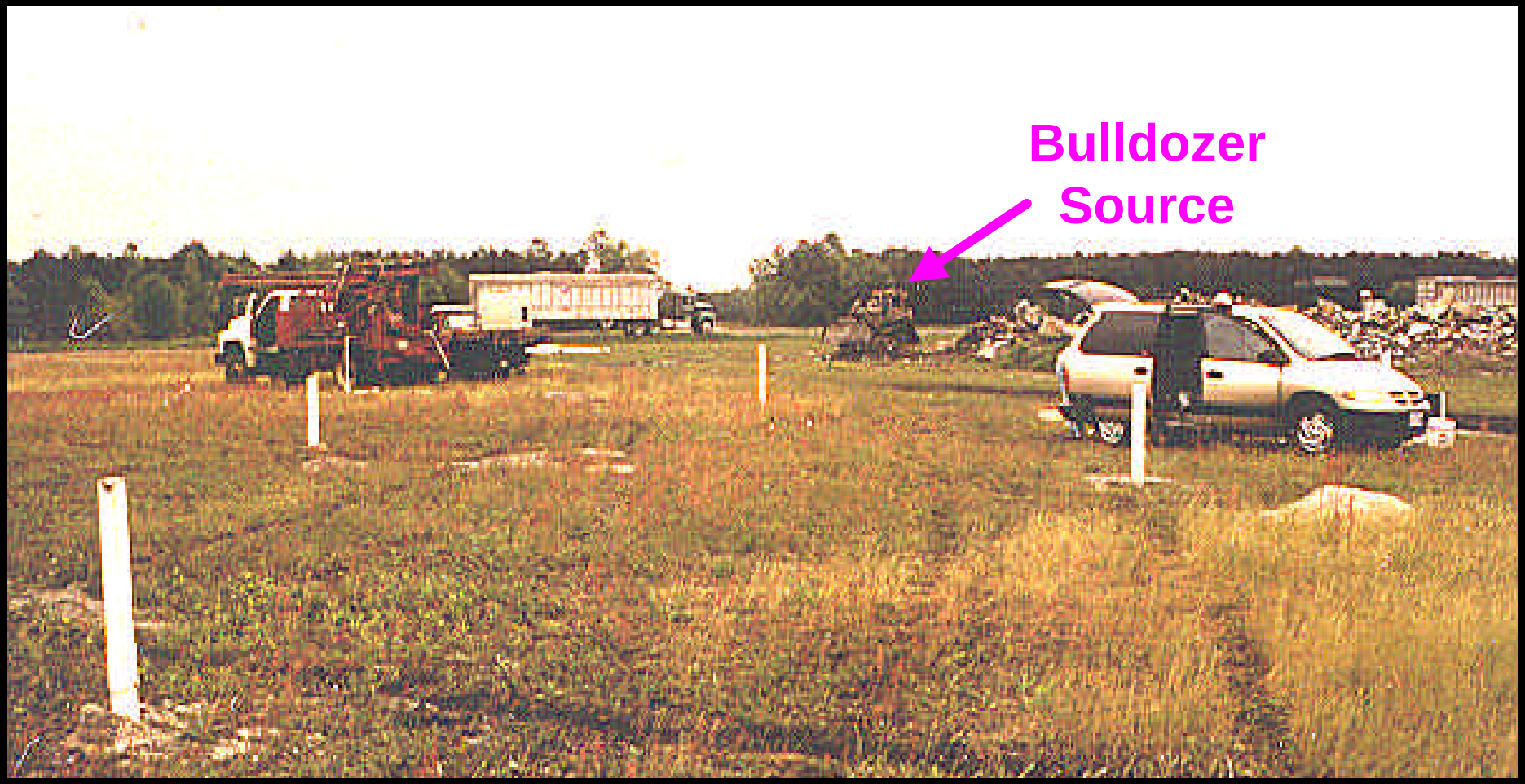
Interpreted V_S Profile Behind Tunnel Wall at Springline



Results:

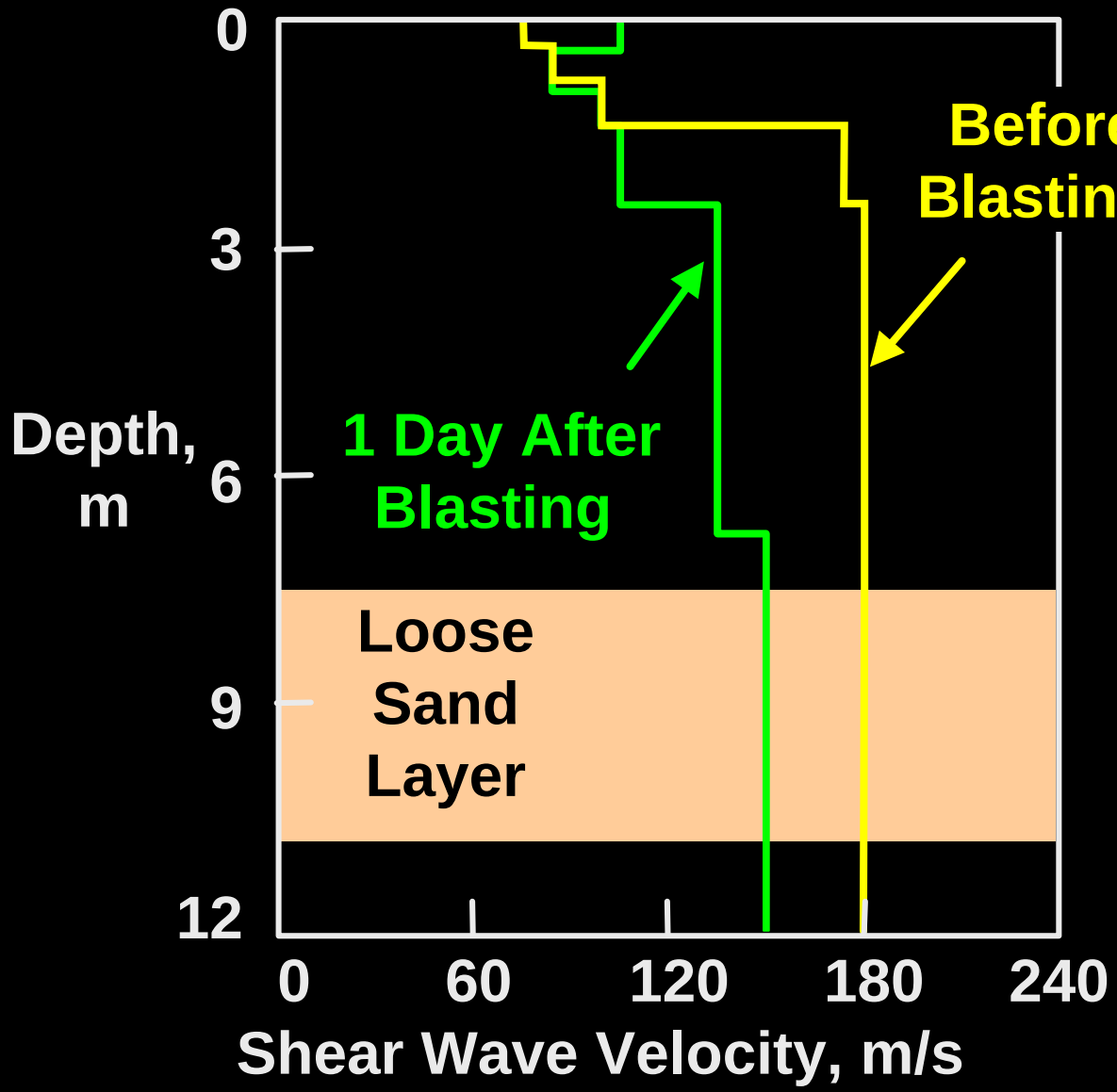
1. high-quality concrete
2. thickness: ~ 0.3 m
3. no voids
4. rock stiffer than liner

Static Application #3: Evaluating Soil Improvement at a Blast-Densification Field Trial



Blasting at Loose Sand Site

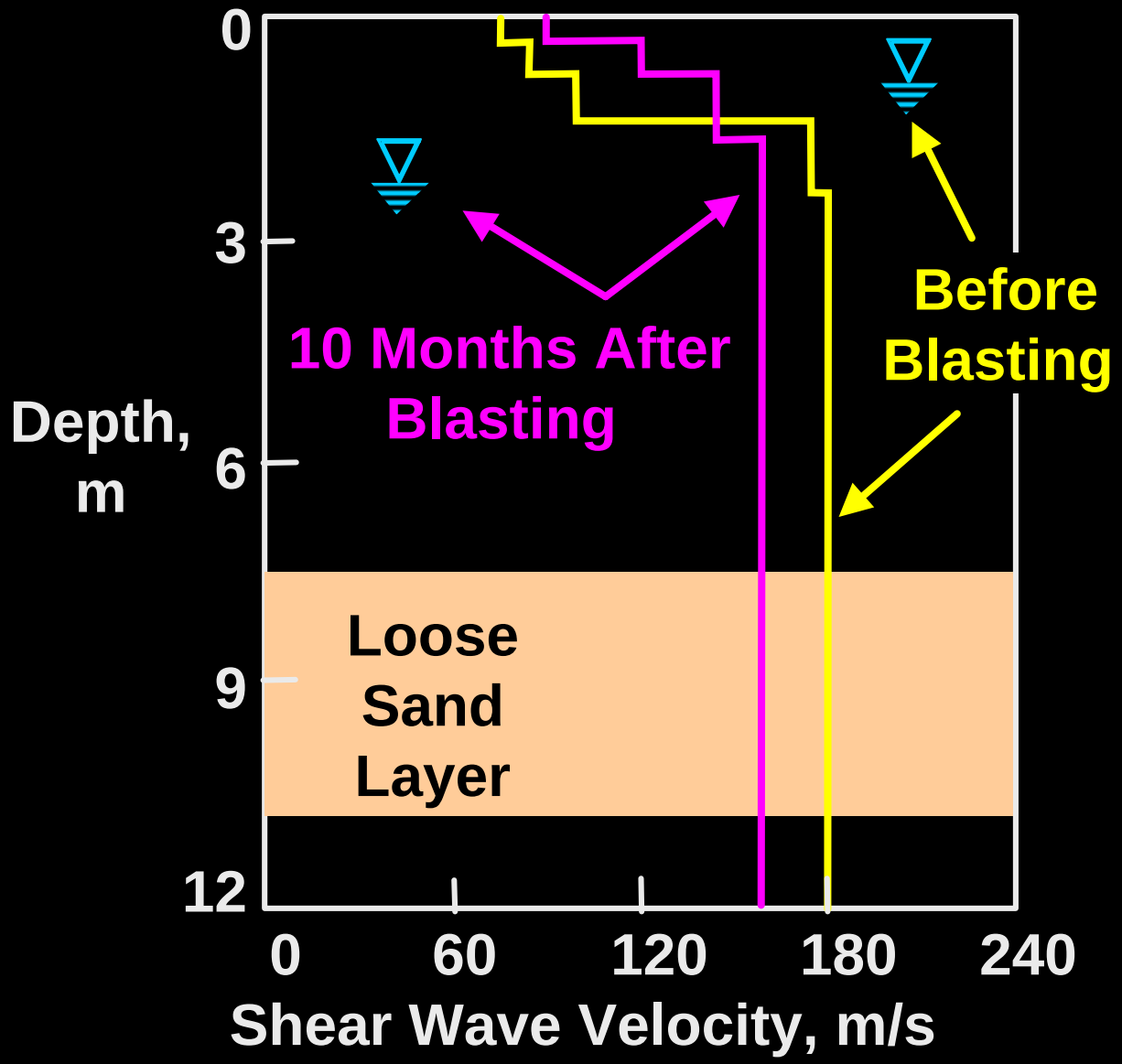
1 Day After Blasting



Question:
Did test plan work?

Answer:
No. Need to modify.

Comparison of Before and After States



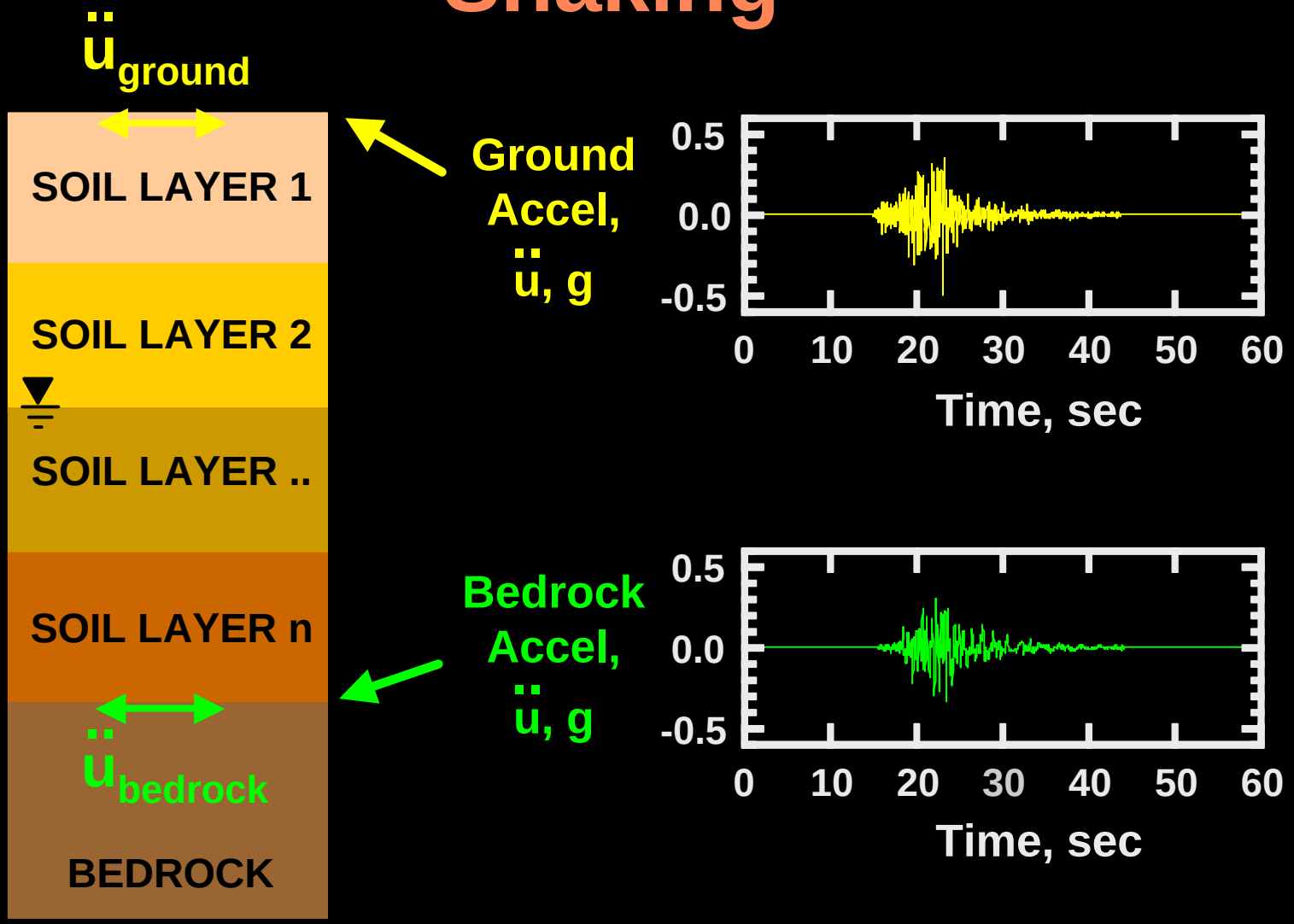
Question:
Did site improve with time?

Answer:
Slightly, but still less than “before blasting”.

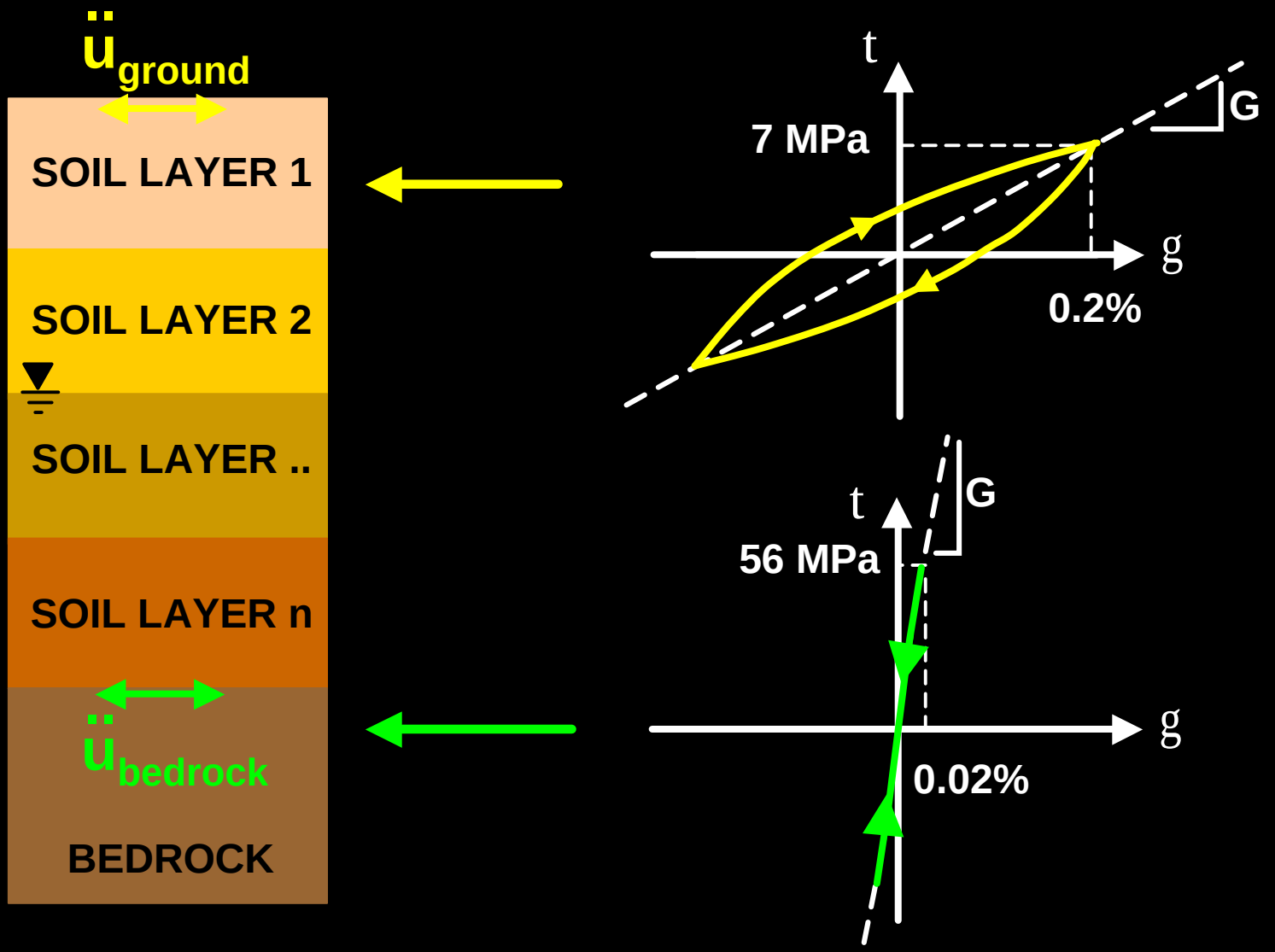
Solutions - Dynamic Conditions

1. Machine-Foundation Design
2. Vibration-Isolation Barriers
3. Earthquake Engineering
   - site response, soil-structure interaction, liquefaction, etc.
4. Link Between Field and Lab

Dynamic Application #1: Predict Ground Motions During Earthquake Shaking



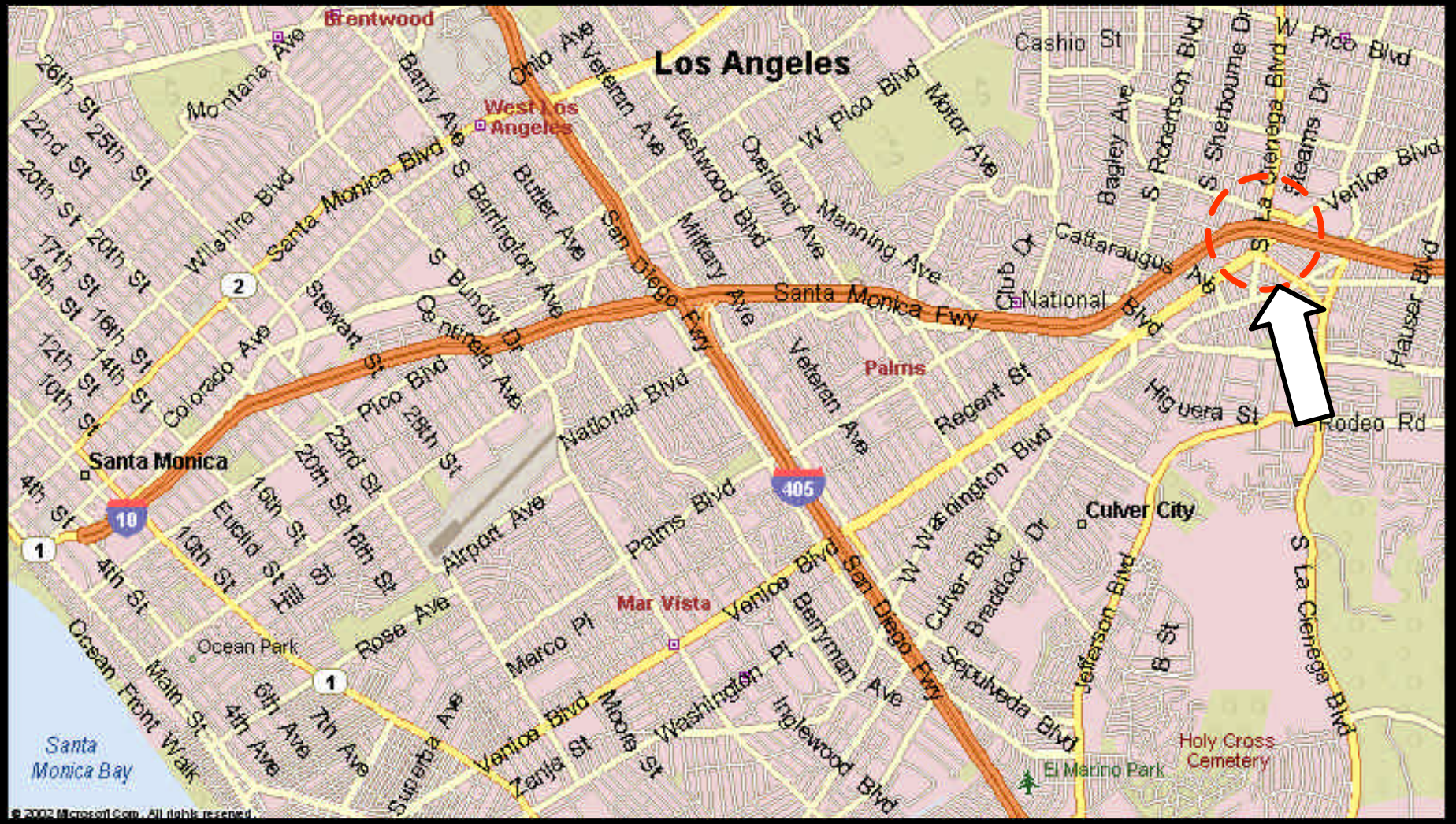
Required: Dynamic Stress-Strain Curves in Shear in the Field



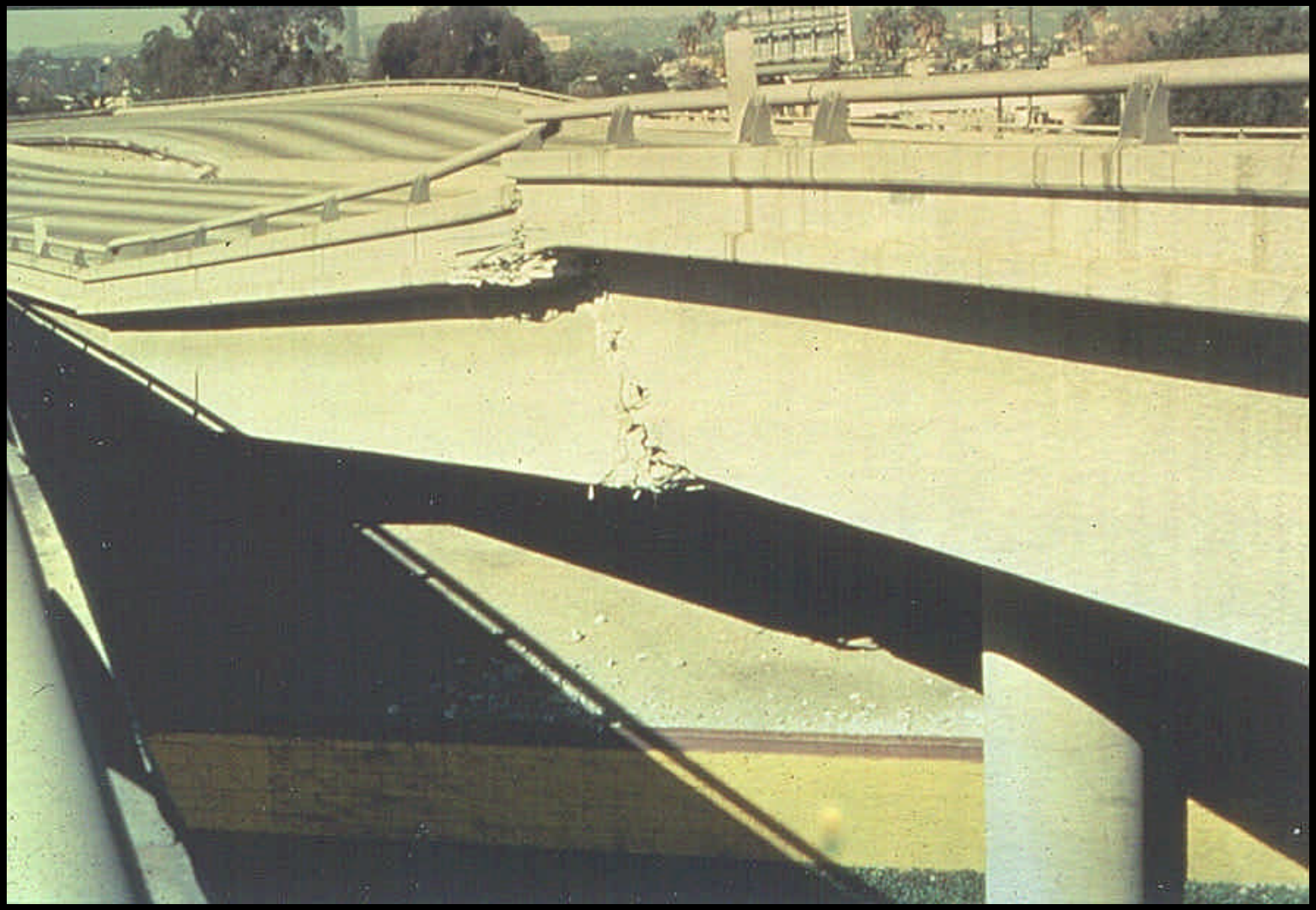
Example Site

- La Cienega Overpass Bridge
- 1994 Northridge Earthquake (M_w = 6.7)
- Epicentral Distance about 28 km
- Deep Soil Deposit (~ 300 m)
- Peak Shearing Strain, γ , less than 0.20%
- **R**esolution **O**f **S**ite **R**esponse **I**ssues in the **N**orthridge **E**arthquake (**ROSRINE**)

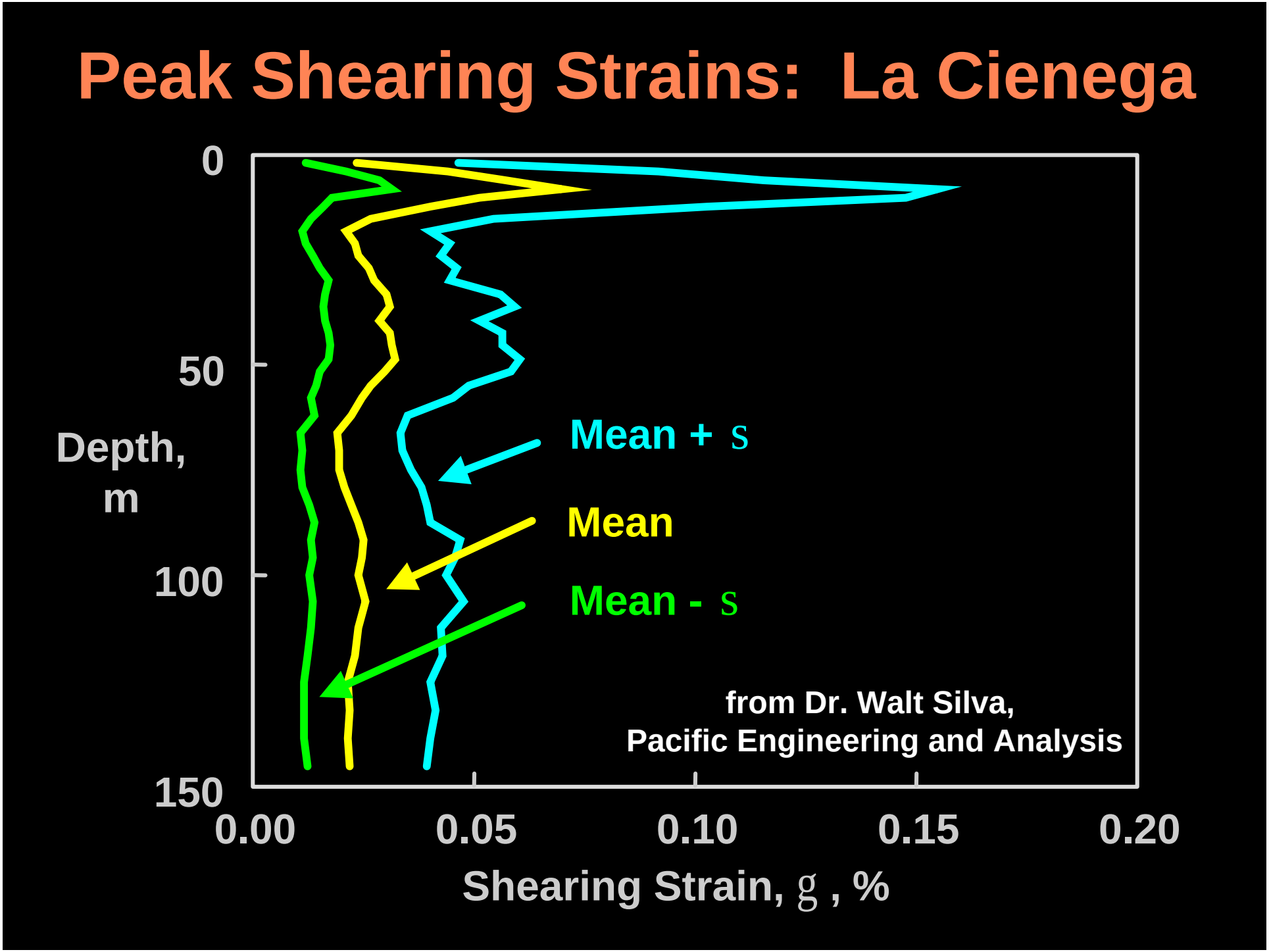
1994 Northridge Earthquake:
Site of La Cienega Overpass Bridge



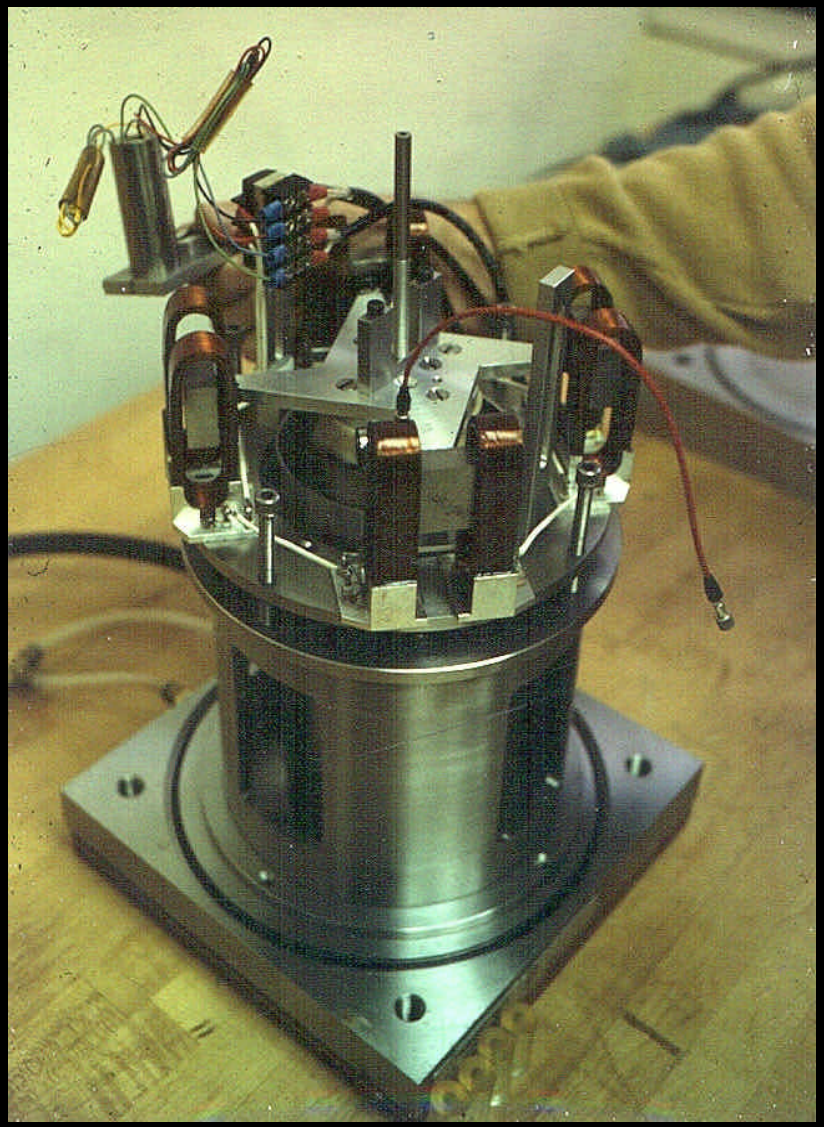
1994 Northridge Earthquake: La Cienega Overpass Bridge

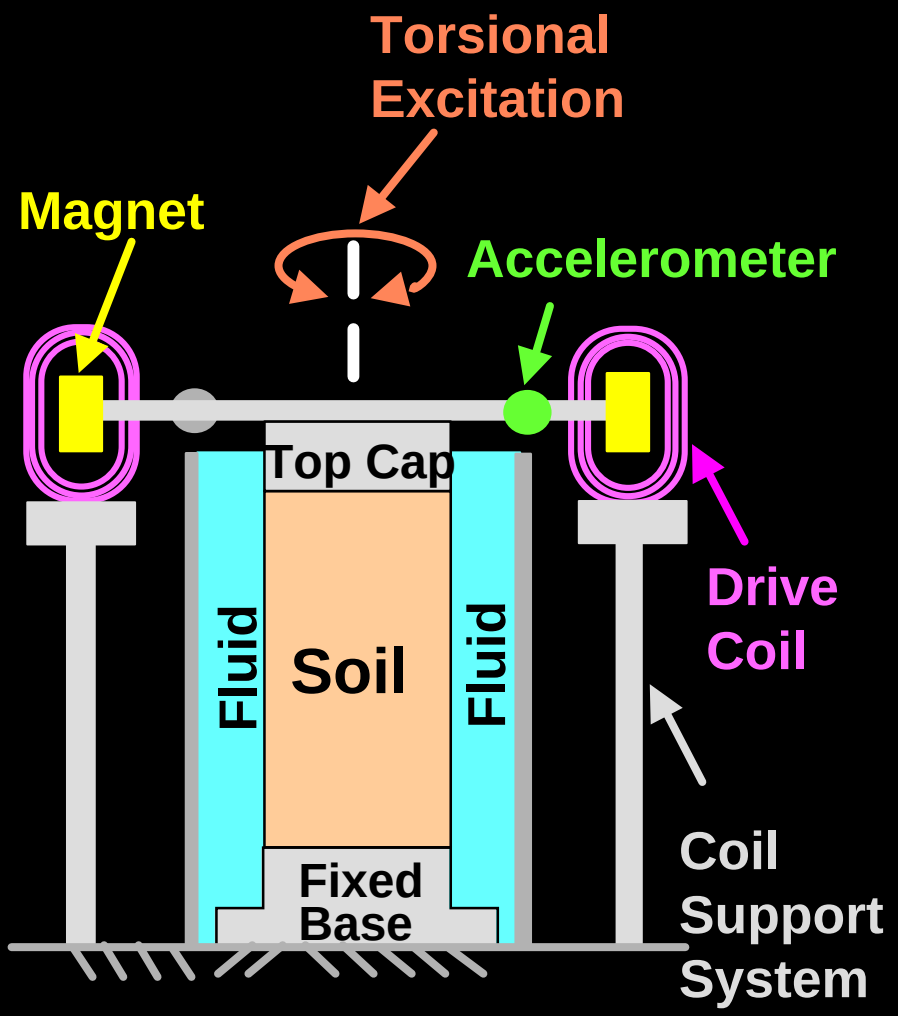


Peak Shearing Strains: La Cienega

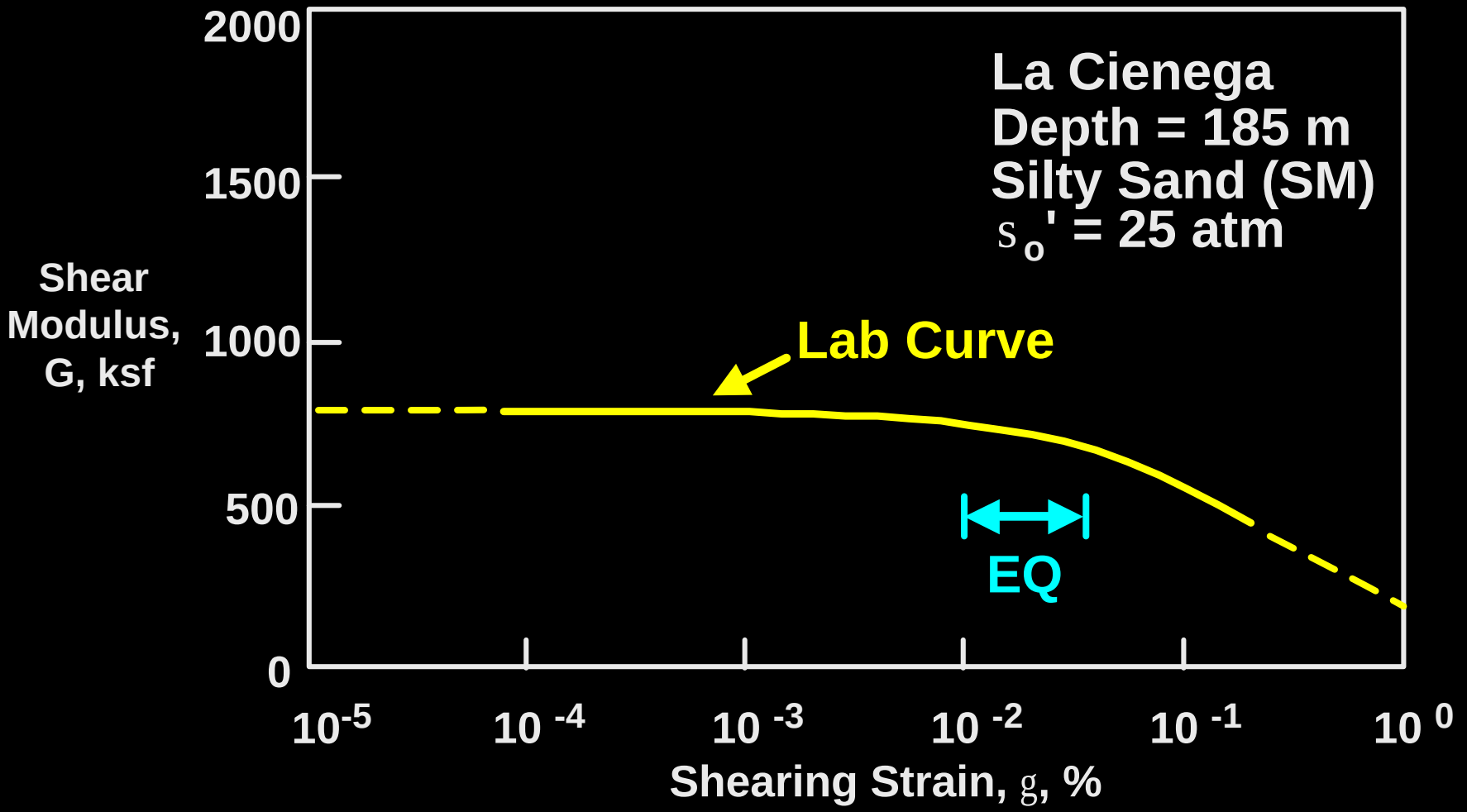


Torsional Resonant Column

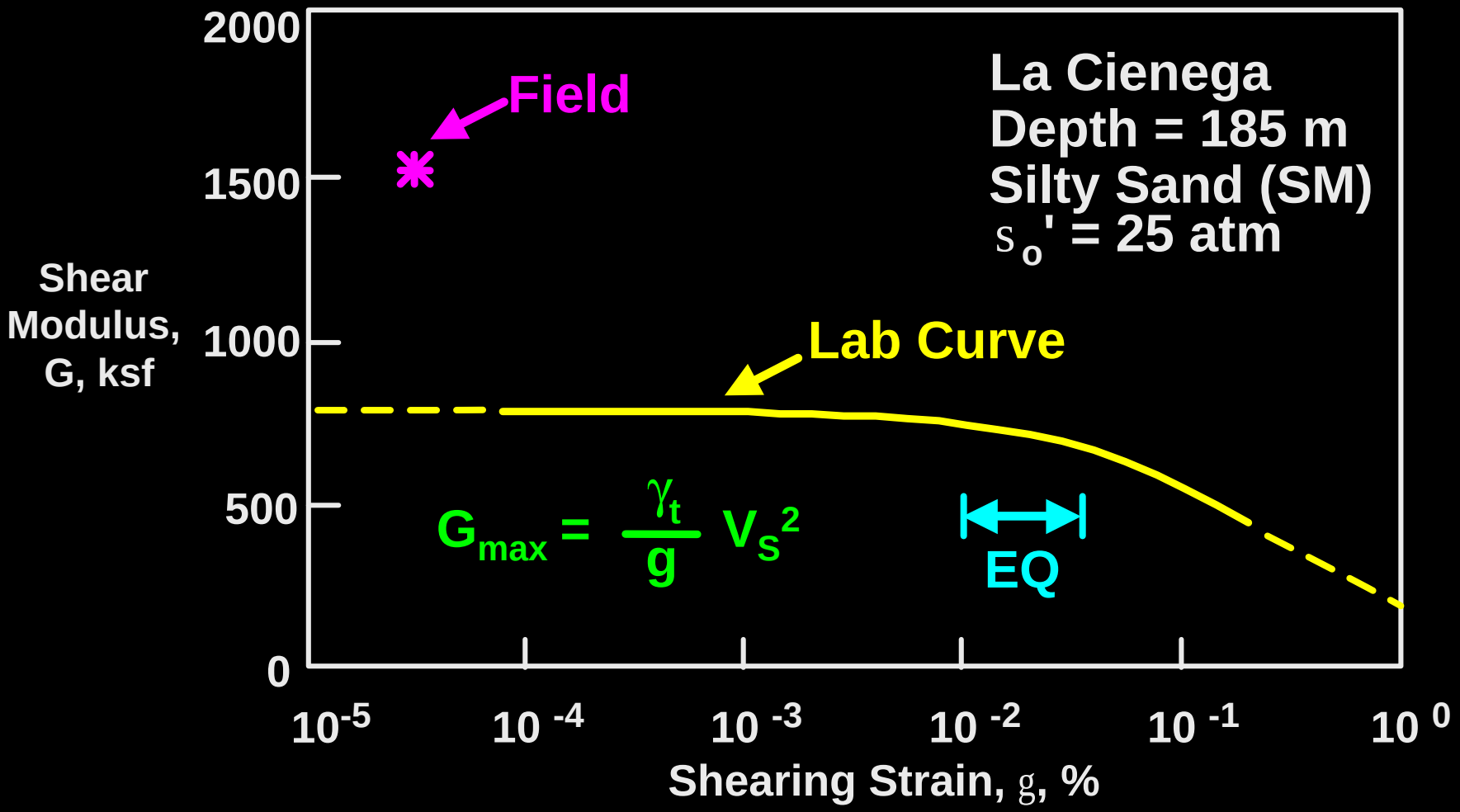




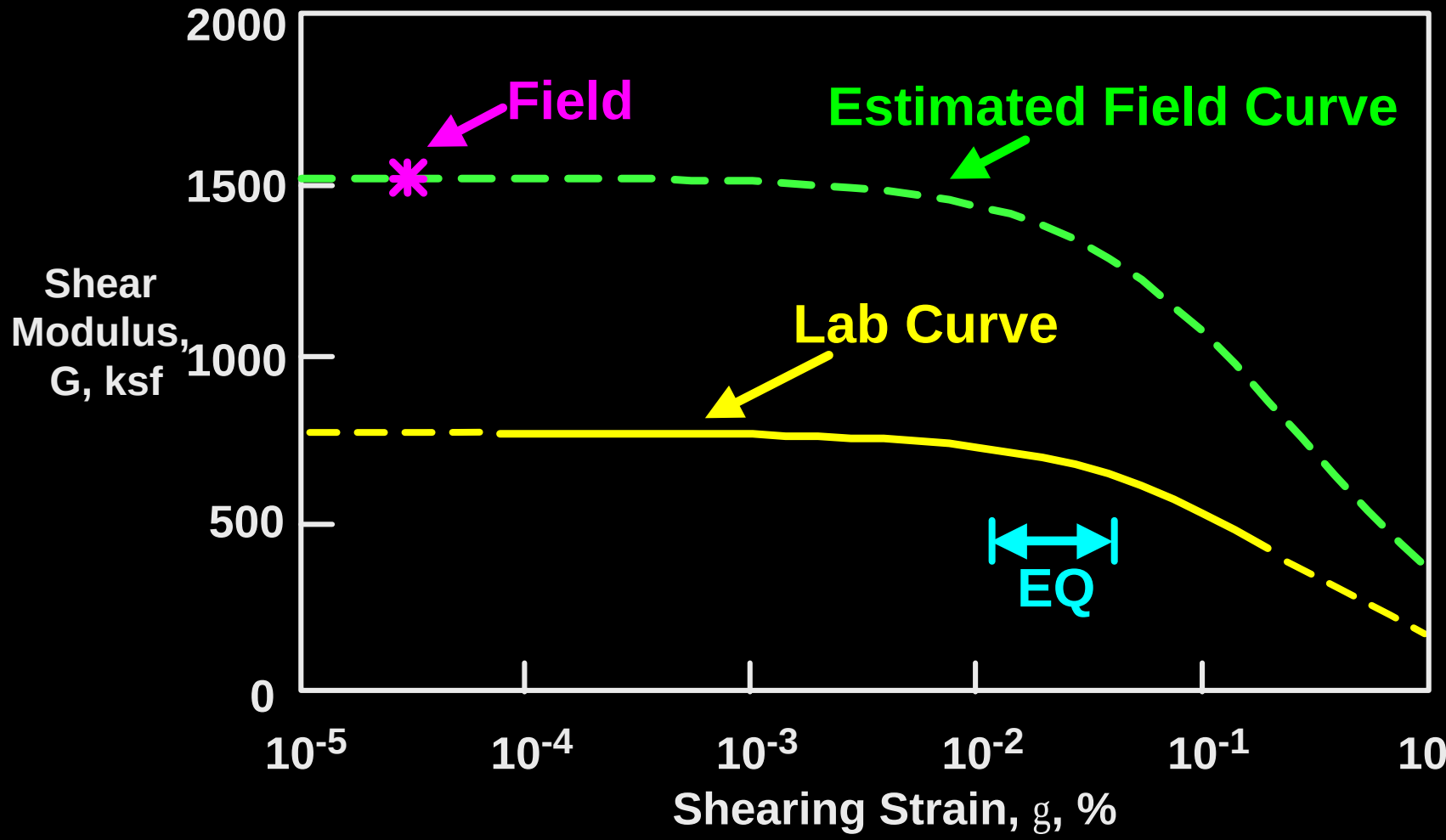
Resonant Column Test of Intact Soil Specimen



Comparison of Field and Laboratory G_{max} Values



Estimating the Field
G – log γ Relationship (Soil)

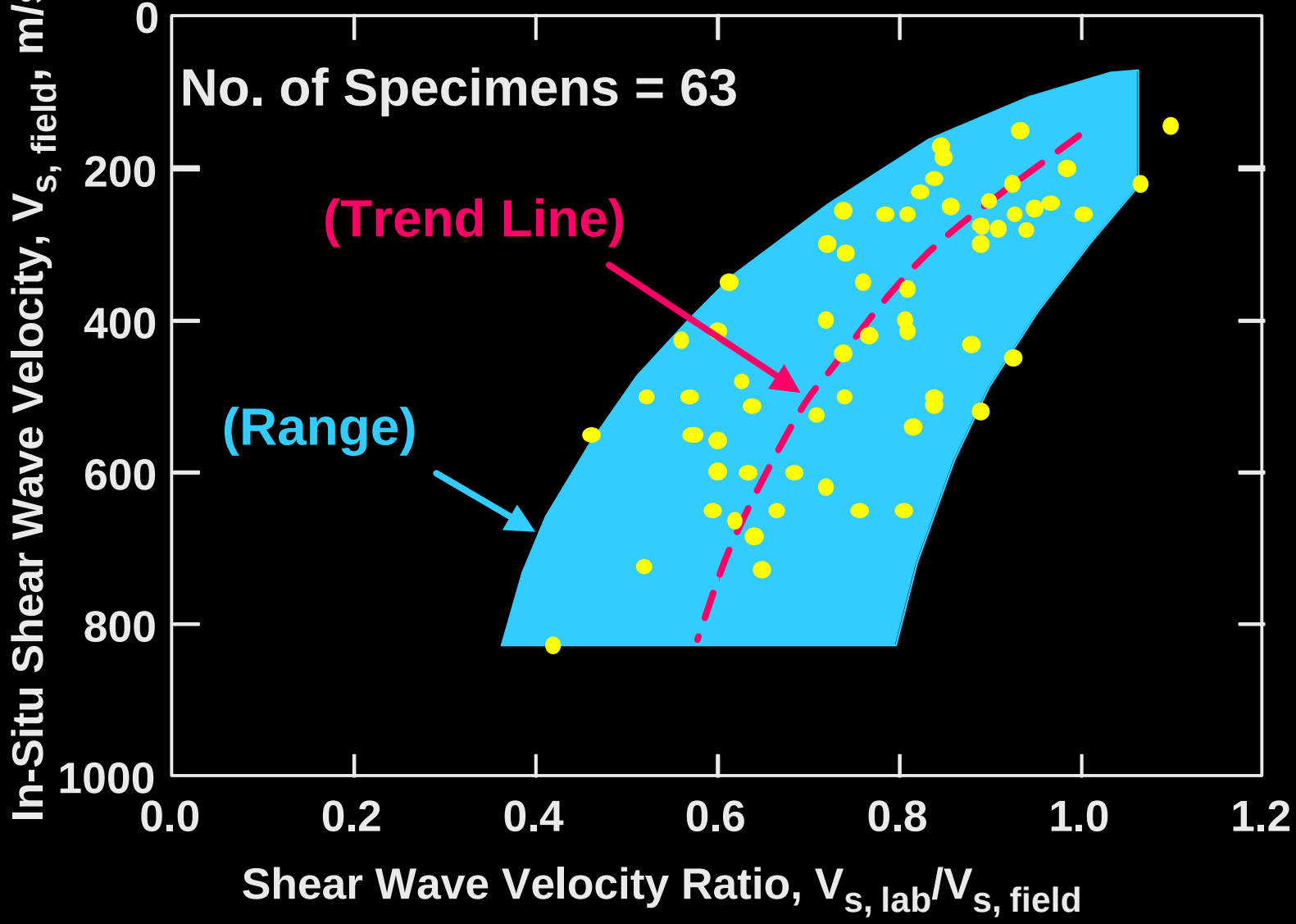


General Applications (Static and Dynamic): Impact of "Sample Disturbance" on G - log γ and τ - γ Curves

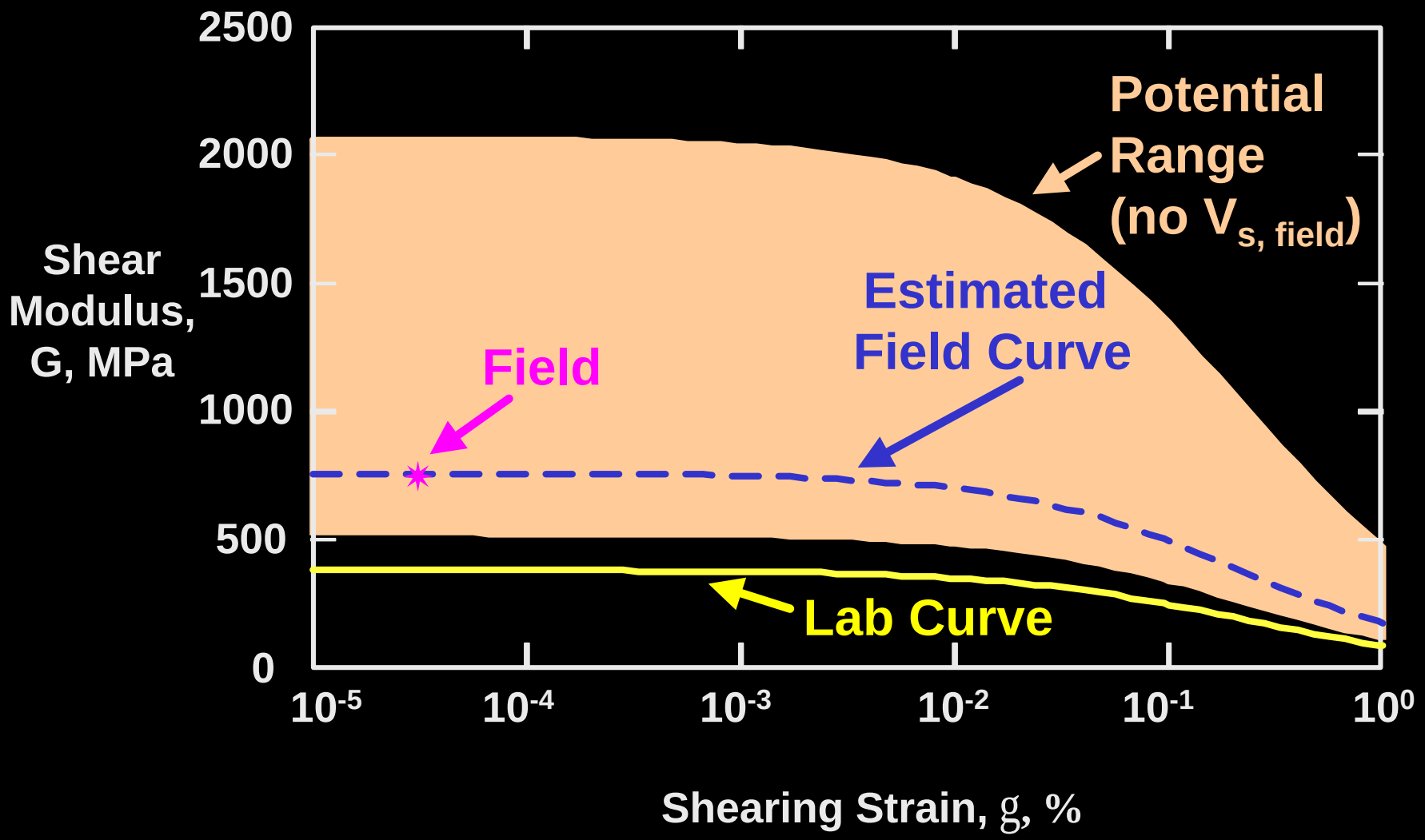
Subtitle: The overwhelming need for in-situ seismic measurements in nonlinear static and dynamic analyses.

Key: Seismic measurements link field and laboratory tests.

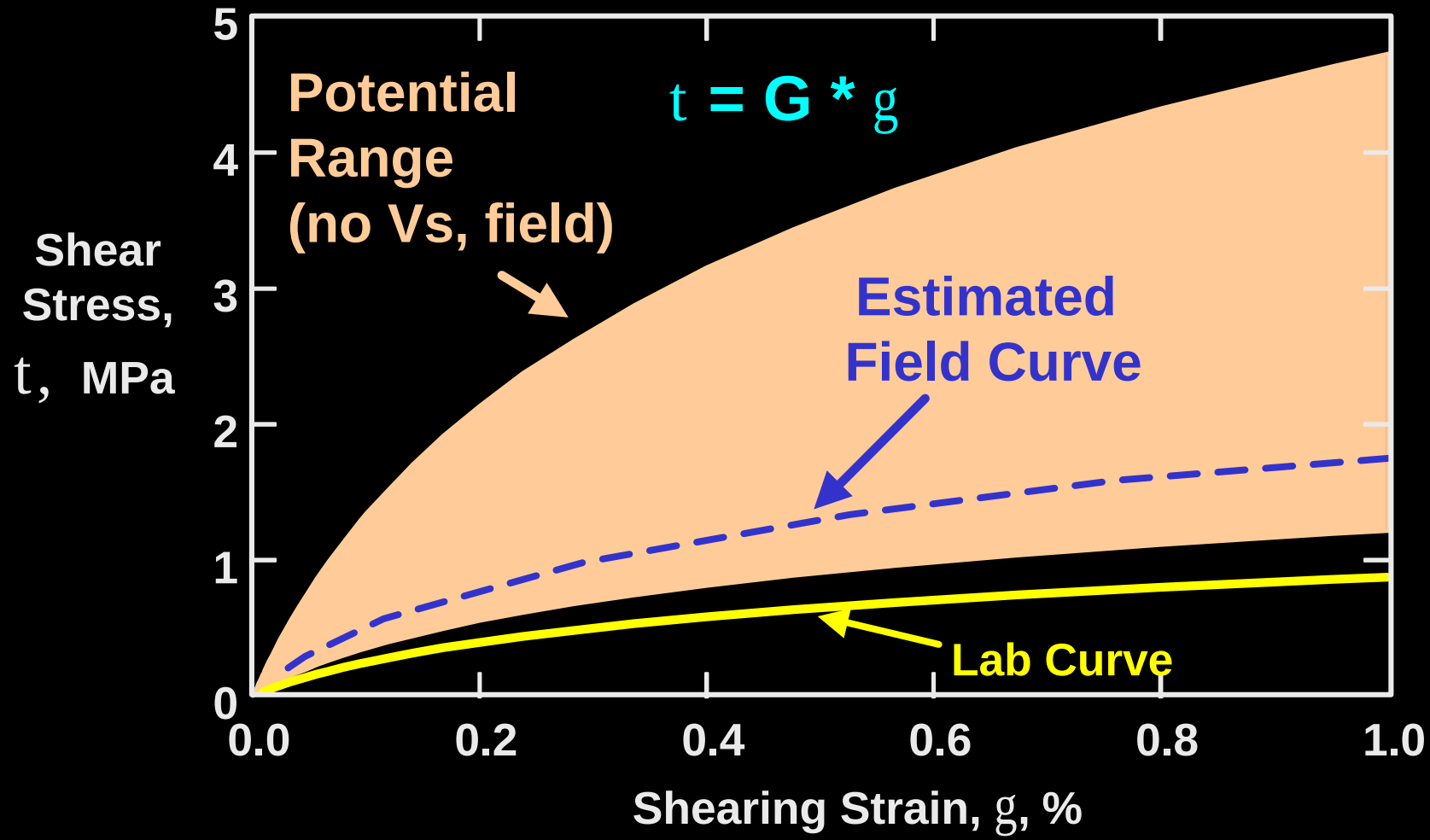
Relationship Between Field and Laboratory V_s Values



"Actual" Field G-log γ Relationship Compared to Potential Range



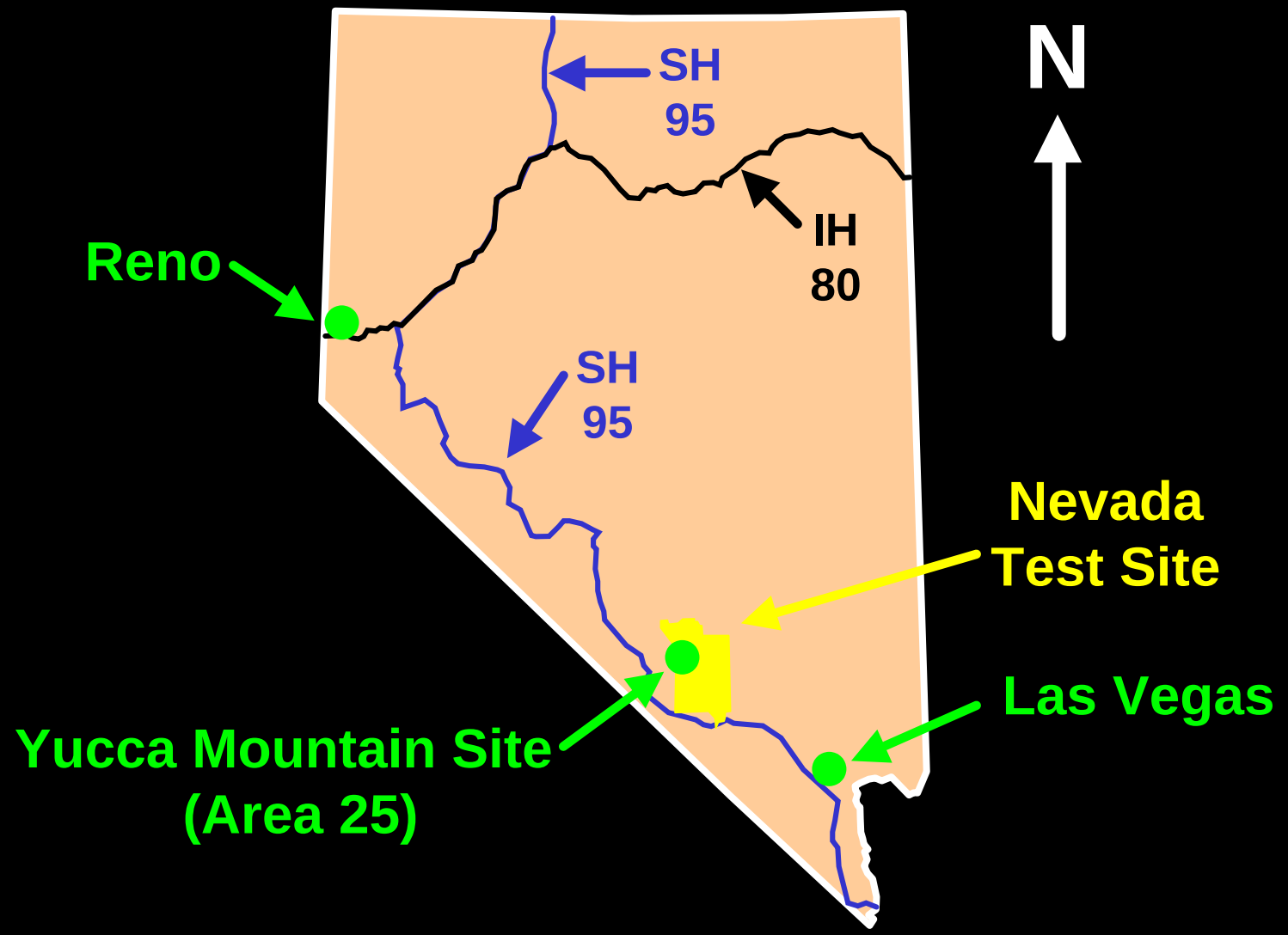
"Actual" Field t - g Curve Compared to Potential Range



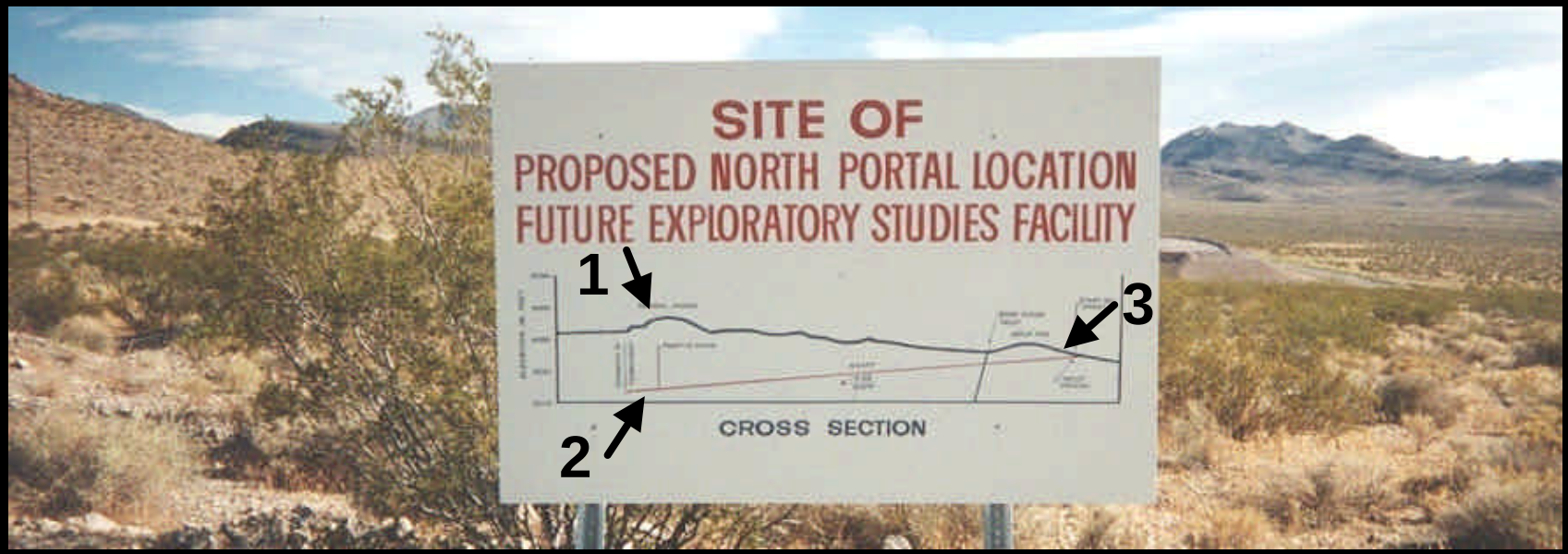
Dynamic Application #2:
Yucca Mountain Site, Nevada

- Designated as first permanent geologic repository for high-level radioactive waste in U.S.
- DOE has been studying the site for more than 25 years
- UTexas is involved with field seismic tests:
  1. on top of the mountain,
  2. in the exploratory tunnels, and
  3. at the proposed site of the Waste Handling Building (WHB).

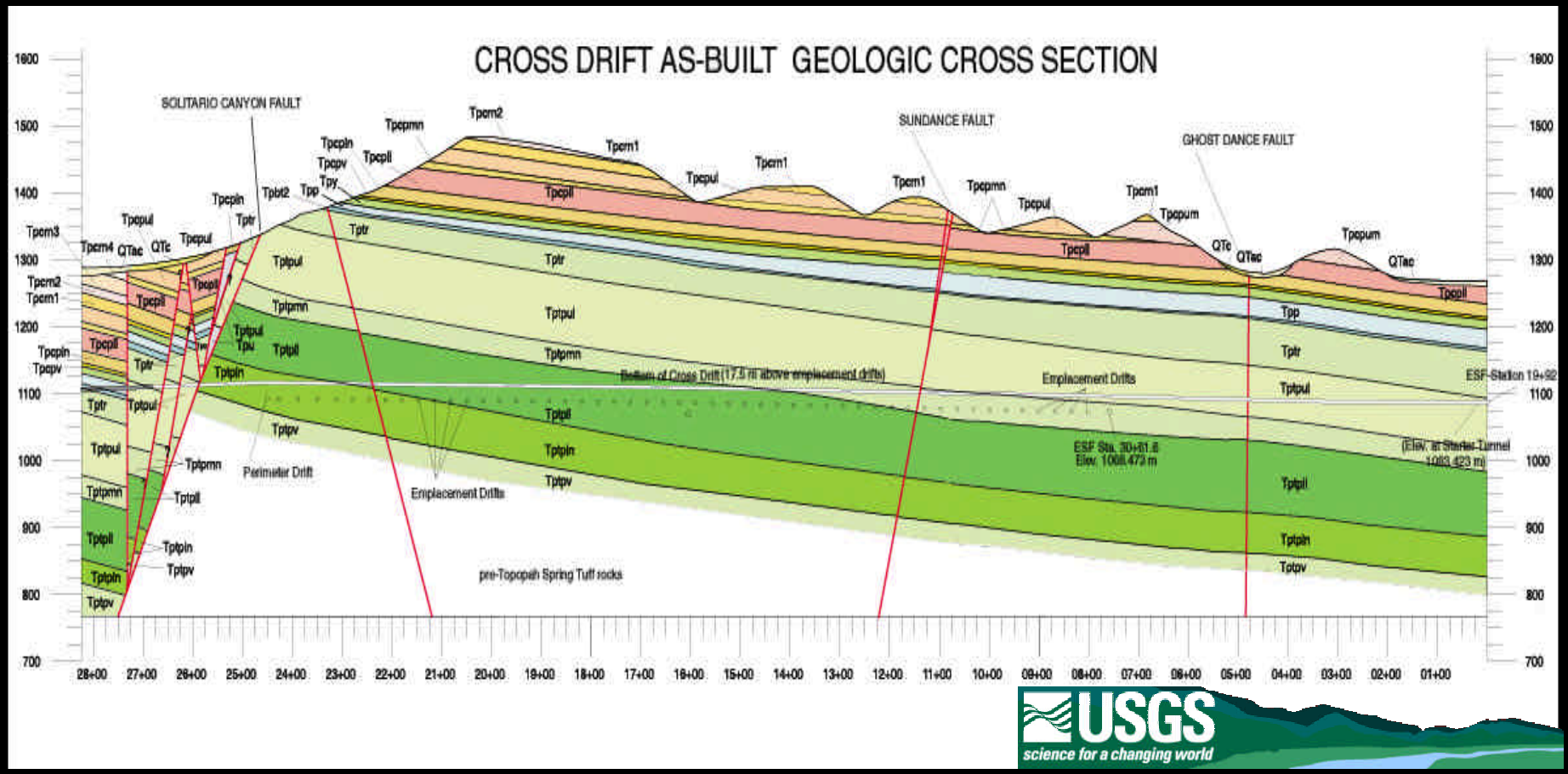
General Location of Yucca Mountain Site, Nevada

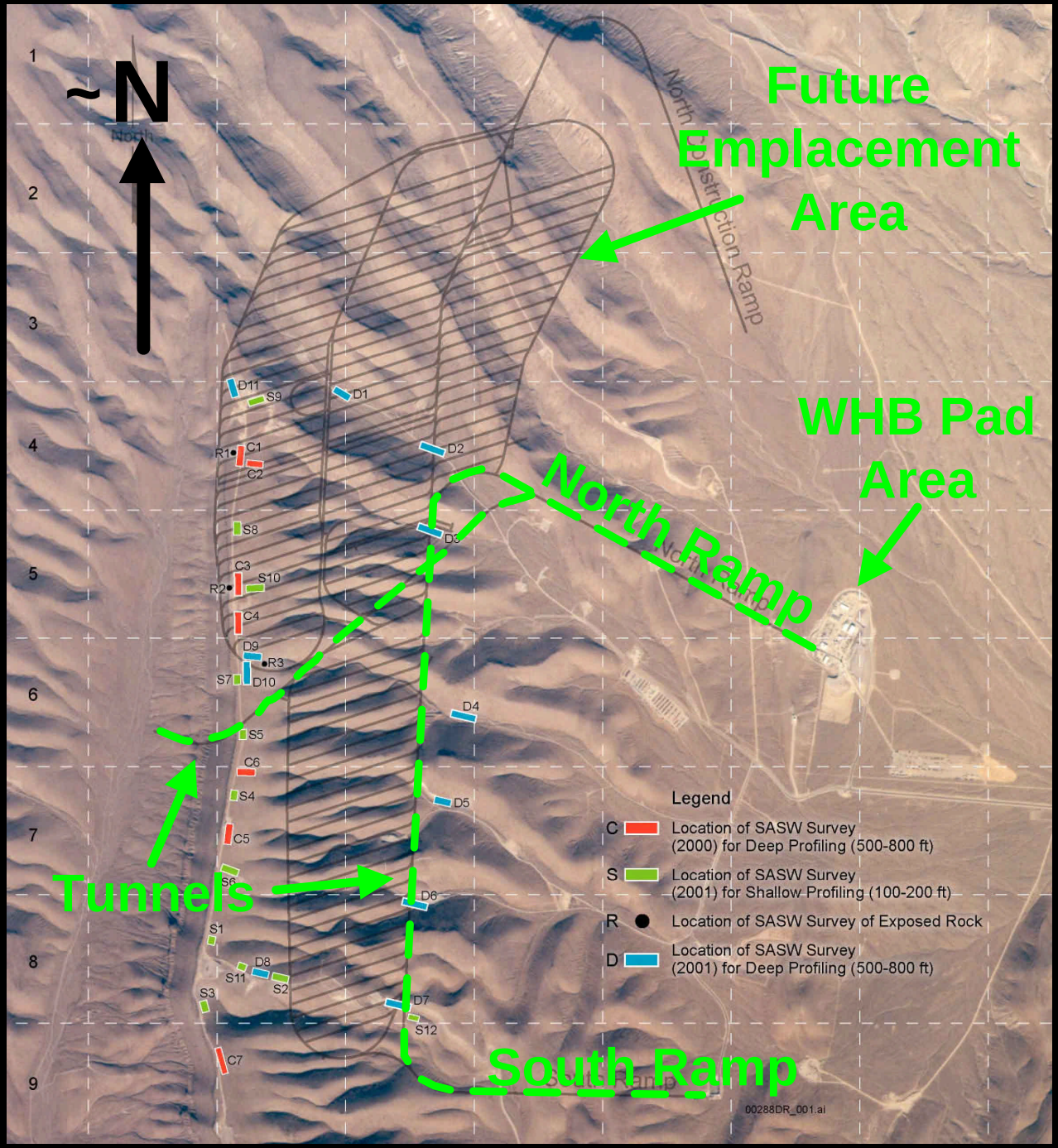


Recent Testing: Yucca Mountain Site



Generalized Geologic Framework Model of Yucca Mountain Site

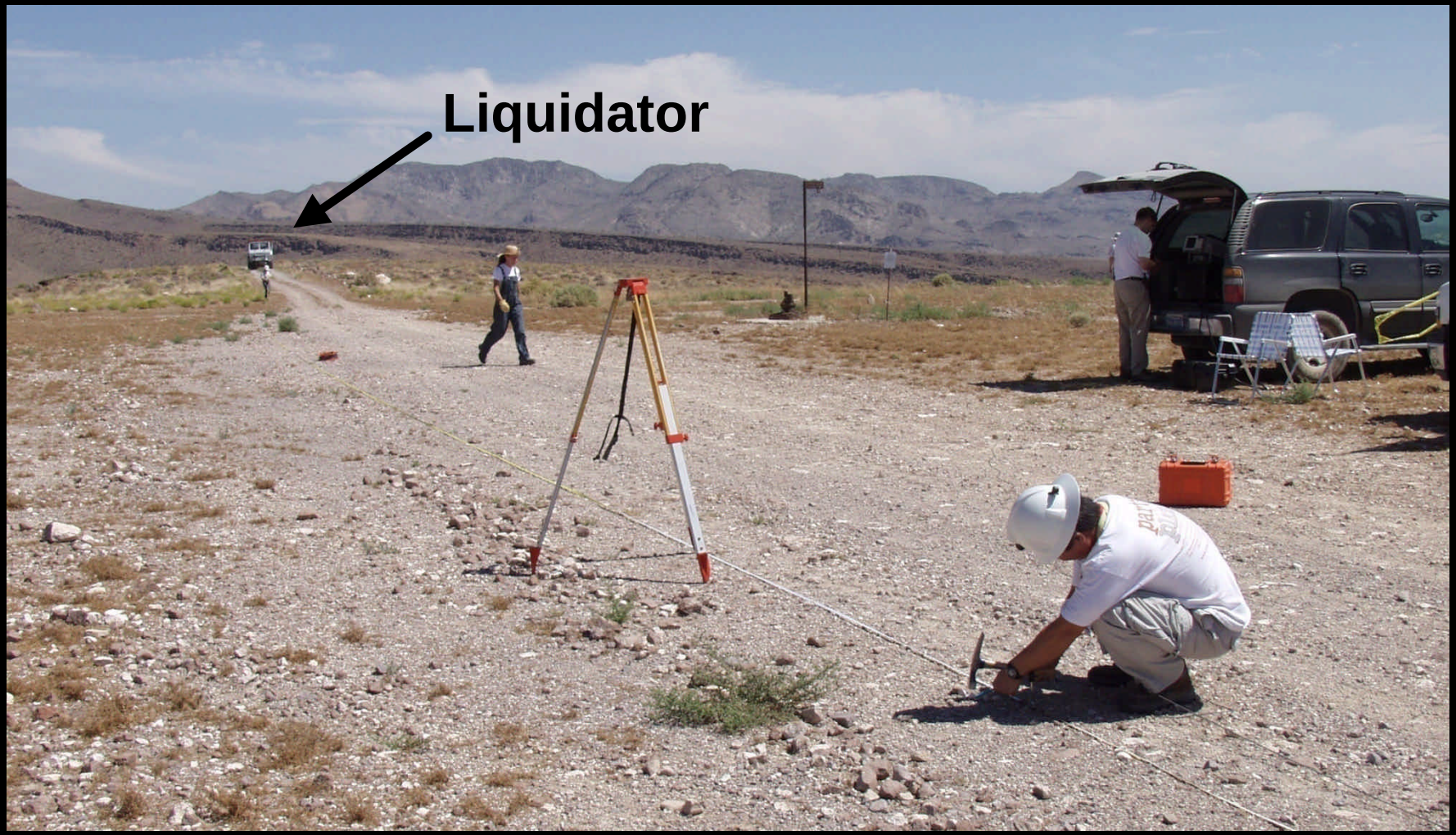




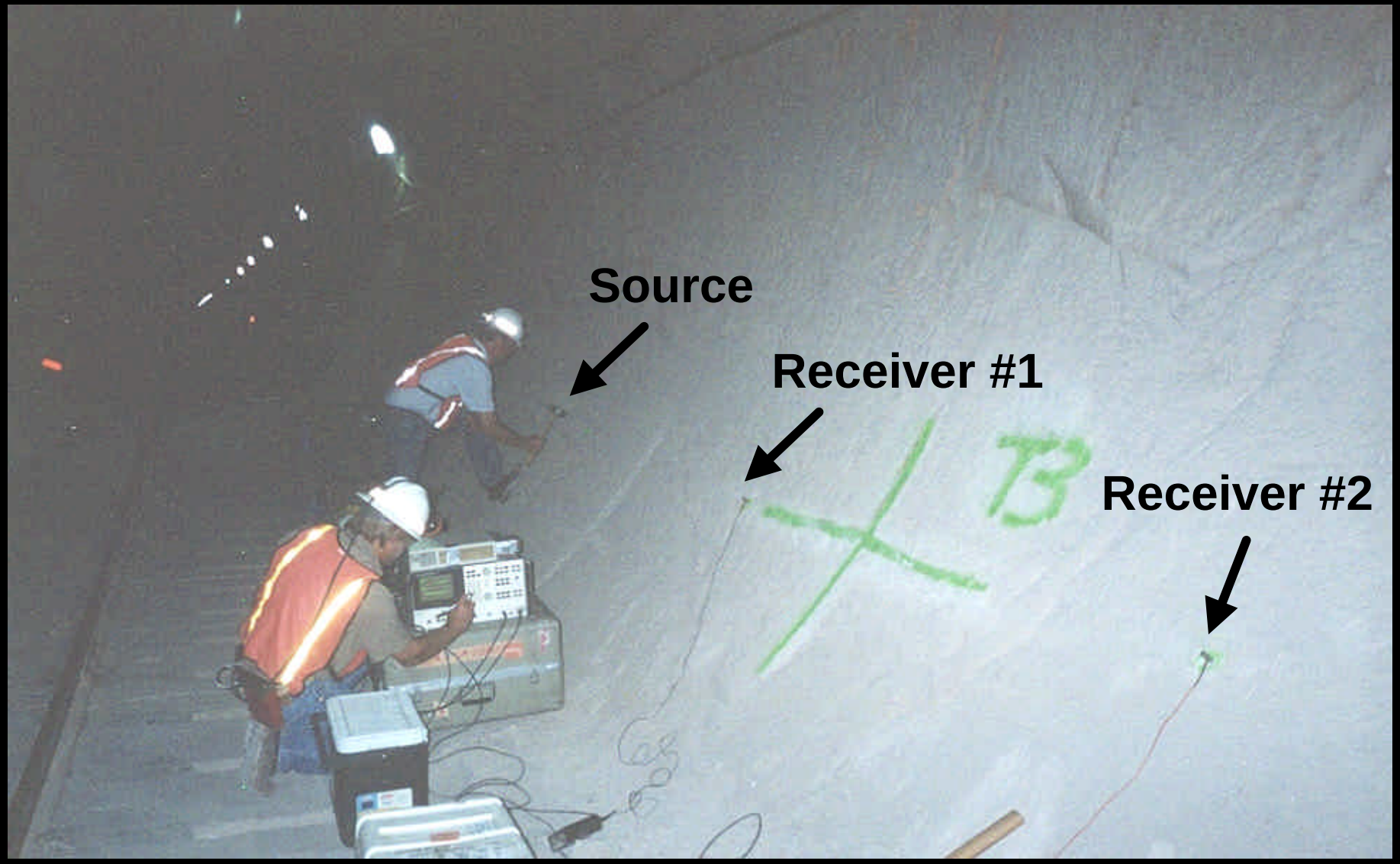
SASW Testing at Yucca Mountain Site

Liquidator Working on Top of Yucca Mountain

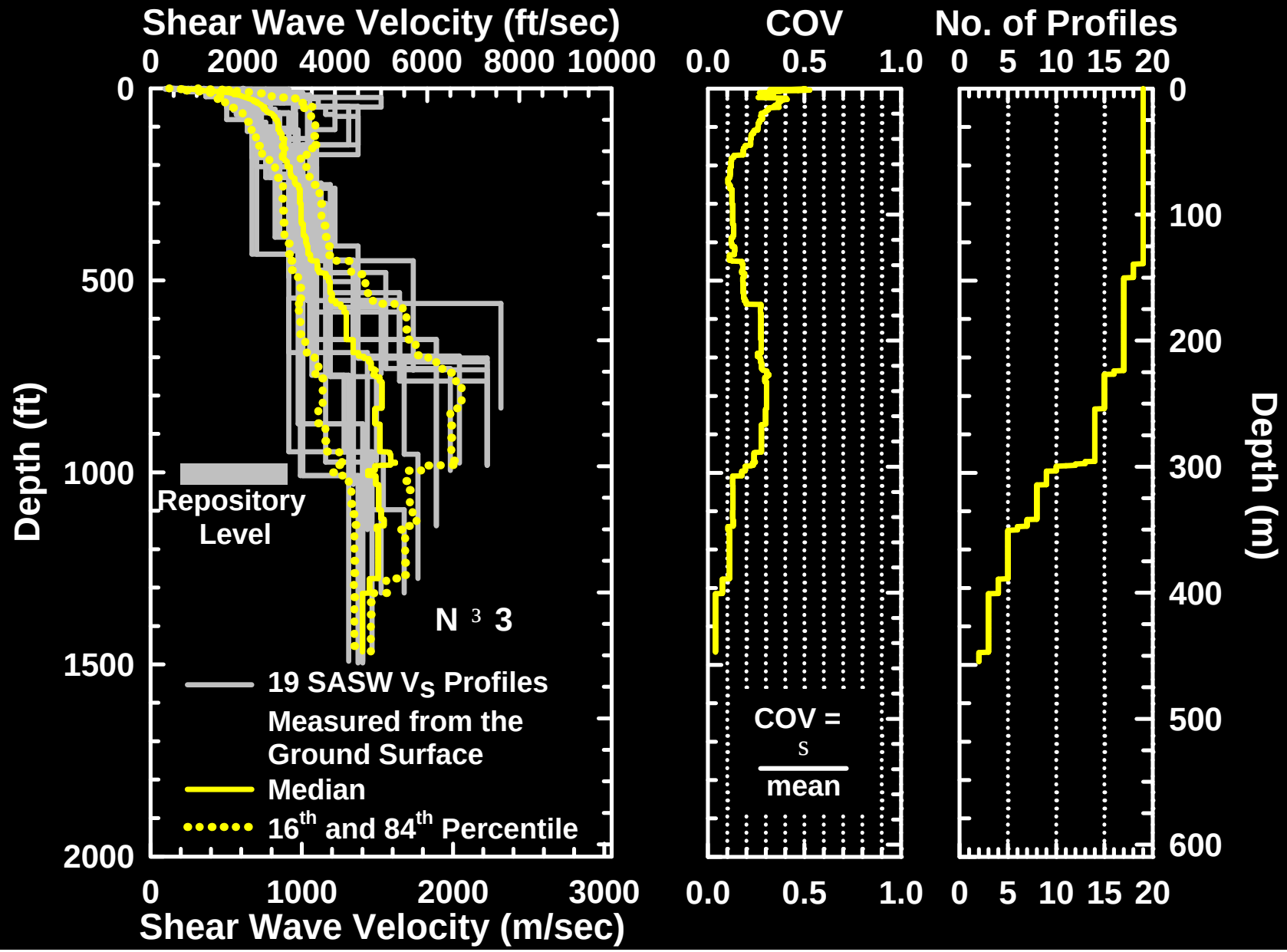
Recording Surface Waves up to 1000 m Long



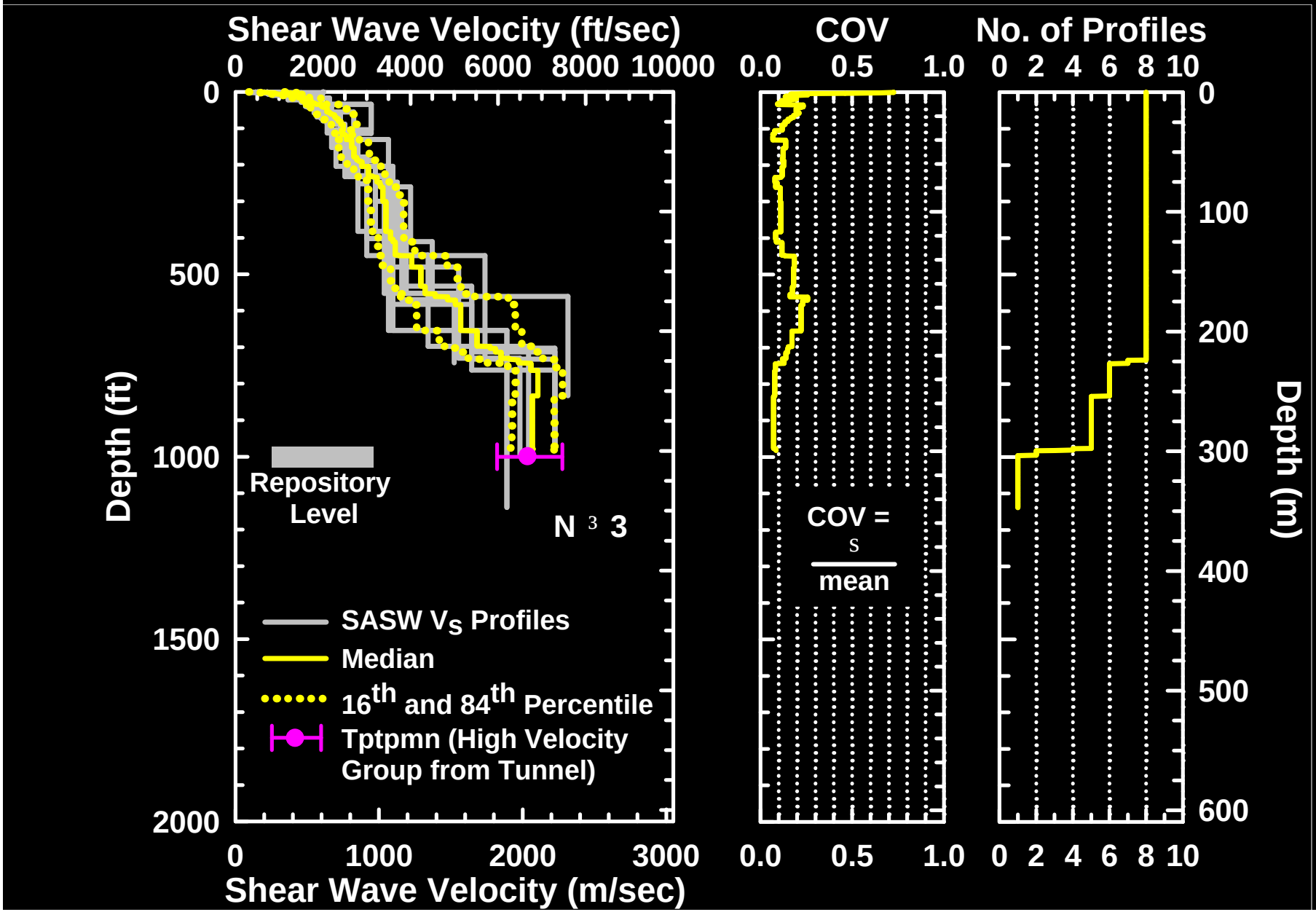
Testing in Tunnel Beneath Mountain



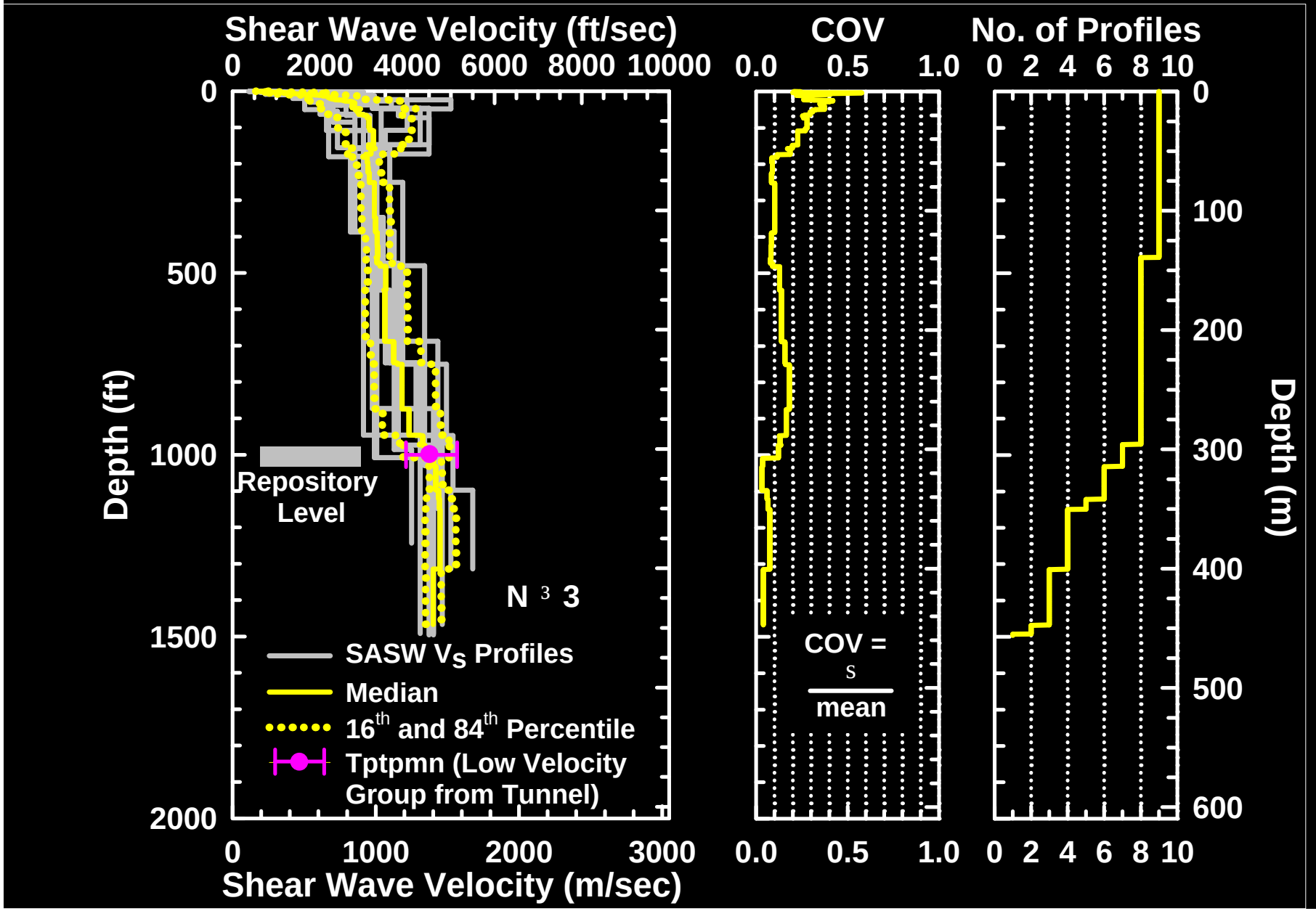
Statistical Analysis of 19 SASW V_S Profiles around the Proposed Repository Area



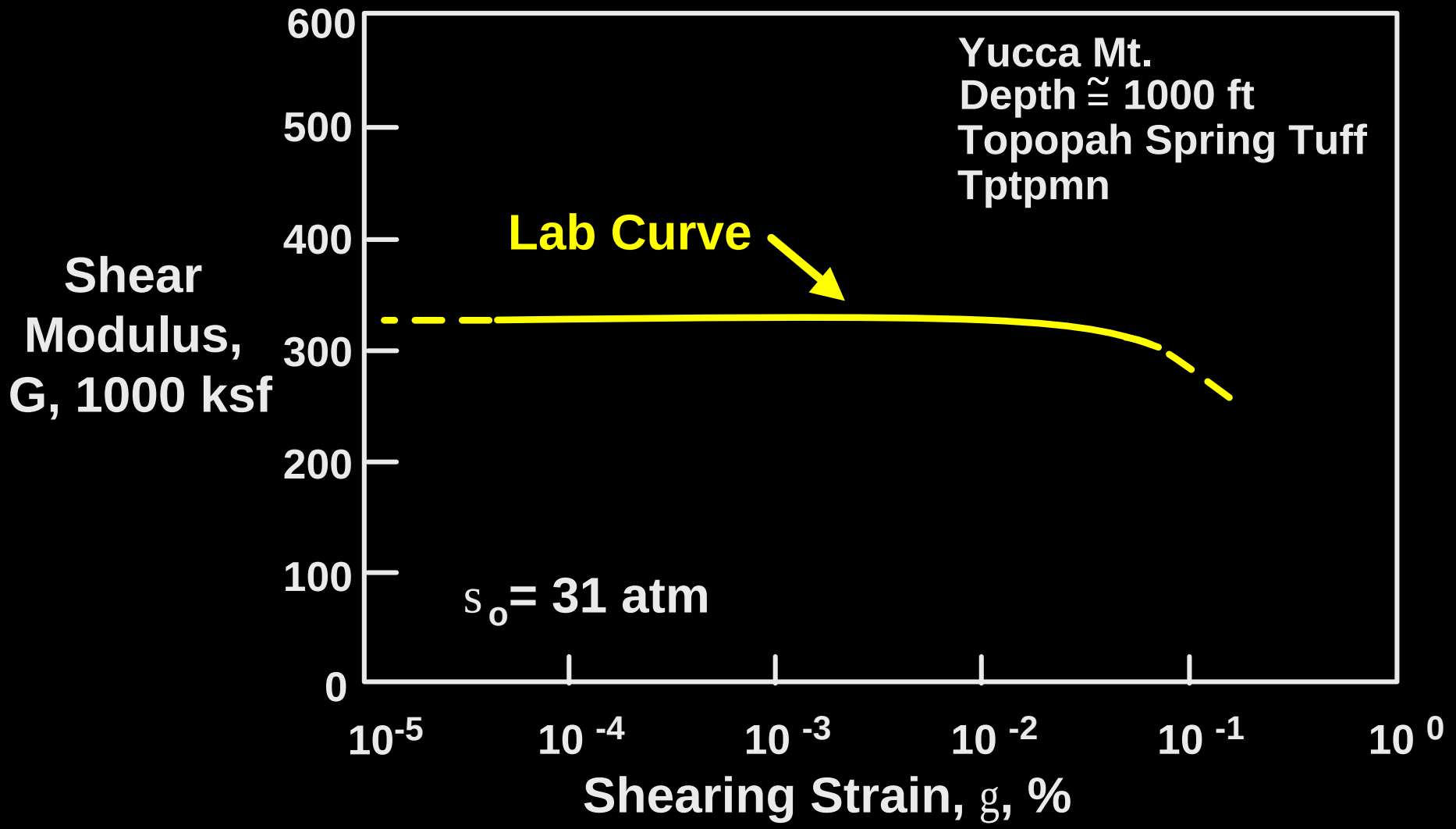
Comparison of Stiffer V_S Profiles Measured on the Surface and in the Tunnel



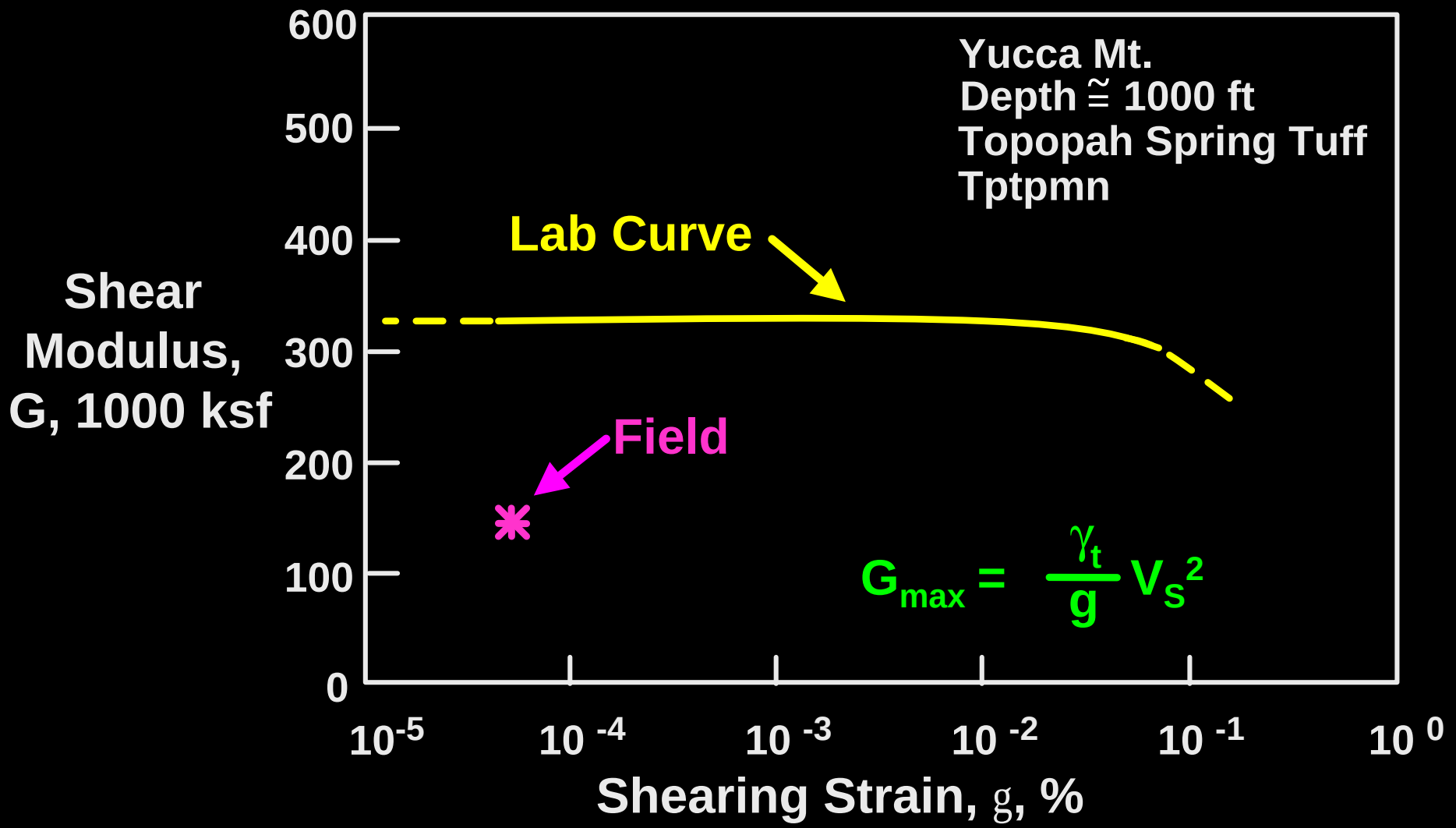
Comparison of Softer V_S Profiles Measured on the Surface and in the Tunnel



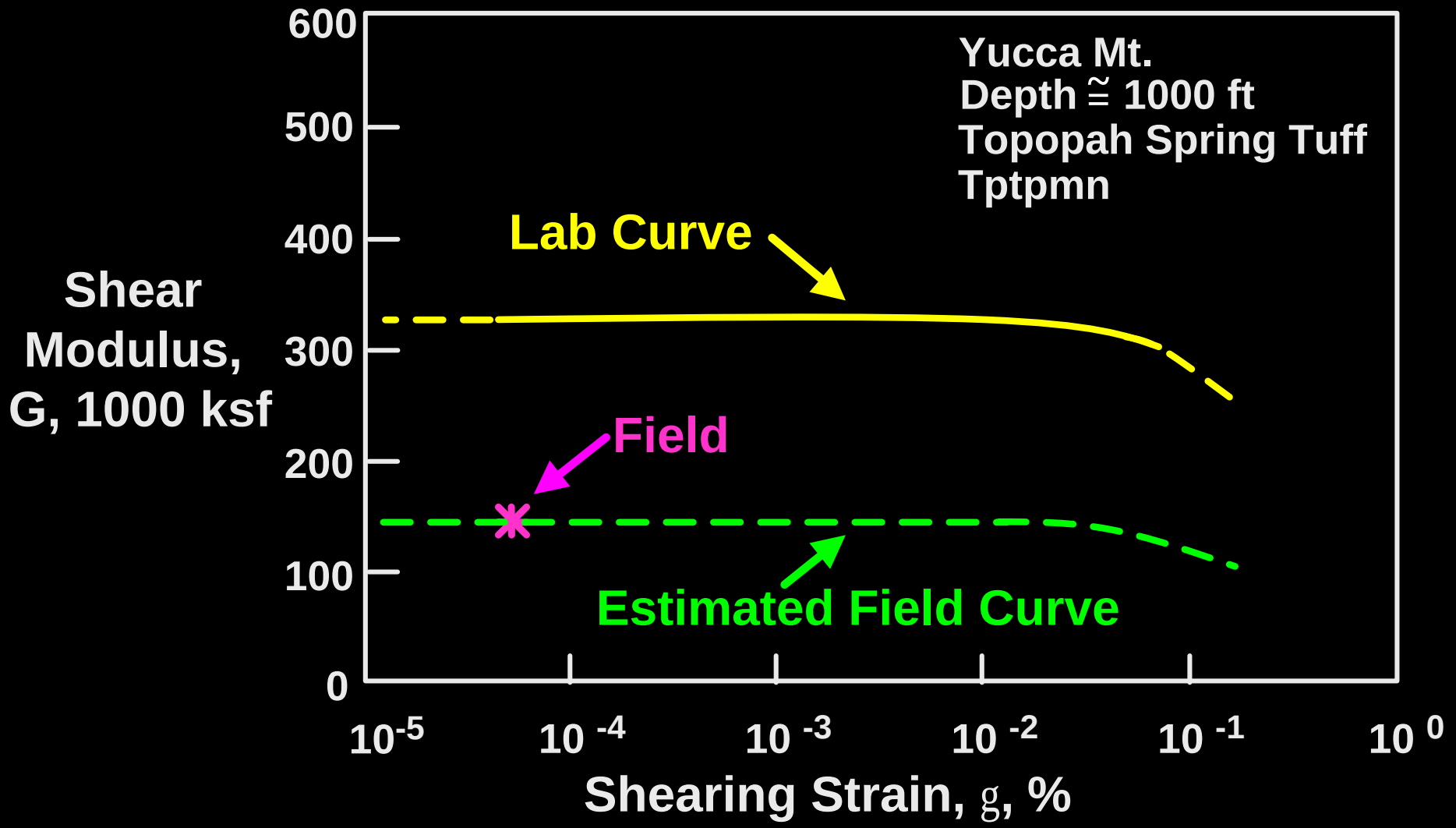
Resonant Column Test of Tuff Core



Comparison of Field and Laboratory G_{max} Values



Estimating the Field G – log γ Relationship (Rock)



Concluding Remarks

- **Stress wave (seismic) measurements play an important role in geotechnical engineering.**
- **This role will continue to grow in solving static and dynamic problems.**
- **The growth will involve four areas: 1. education, 2. integration, 3. automation, and 4. innovation.**

THANK YOU

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