PS Relating P-Wave Velocity to Rock Strength in High-Porosity, Shallowly Buried Sediments: Implications for in Situ Stress Estimates*

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Abstract

The magnitude of in situ stresses is important toward understanding fault and earthquake mechanics, as well as for hydrocarbon exploration. Wellbore failures, including compressional borehole breakouts (BO) can provide information about stress orientation and can be used to constrain in situ stress magnitude if the rock or sediment unconfined compressive strength (UCS) is known. Values of UCS used to estimate stresses from BO are typically determined from laboratory-derived empirical relations between P-wave velocity (Vp) and UCS. For many applications in sedimentary basins and tectonically active settings, UCS is estimated from relations developed for lithified shales. We seek to advance our understanding of Vp as a proxy for UCS, particularly in high-porosity (~30-60%), shallowly buried (<2 km) sediments where estimates of UCS based on relationships defined for fully lithified shales may lead to overestimates of strength. We focus on the Nankai accretionary prism offshore SW Japan, formed by subduction of the Philippine Sea Plate beneath the Pacific Plate. Breakouts have been identified from azimuthal resistivity logs at IODP Site 808, which penetrated the accretionary prism and plate boundary décollement ~3 km landward of the trench. We determine UCS from triaxial tests on core samples recovered during Ocean Drilling Program Leg 190 from ODP Site 1174, located ~1 km away from Site 808. We then compare UCS measurements to Vp data from wireline logging.

Our results indicate that directly measured values of UCS are considerably lower (>1 MPa) than those estimated from Vp using the existing relationships for shales. When applied to estimate in situ stresses from the observed wellbore failures, values of UCS determined from these relationships likely lead to significant overestimates of stress magnitude. Our results should apply to the general case of shallow, relatively high-porosity sediments, and therefore carry implications for borehole stability and assessment of shallow geohazards globally.

Relating P-Wave velocity to rock strength in high-porosity, shallowly buried sediments: Implications for in situ stress estimates

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1. Abstract

The magnitude of in situ stresses is important toward understanding fault and earthquake mechanics, as well as for hydrocarbon exploration. Wellbore failures, including compressional borehole breakouts (BO) can provide information about stress orientation, and can be used to constrain in situ stress magnitude if the rock or sediment unconfined compressive strength (UCS) is known. Values of UCS used to estimate stresses from BO are typically derived from laboratory-derived empirical relations between P-wave velocity (Vp) and UCS. For many applications in sedimentary basins and tectonically active settings, UCS is estimated from relations developed for lithified shales.

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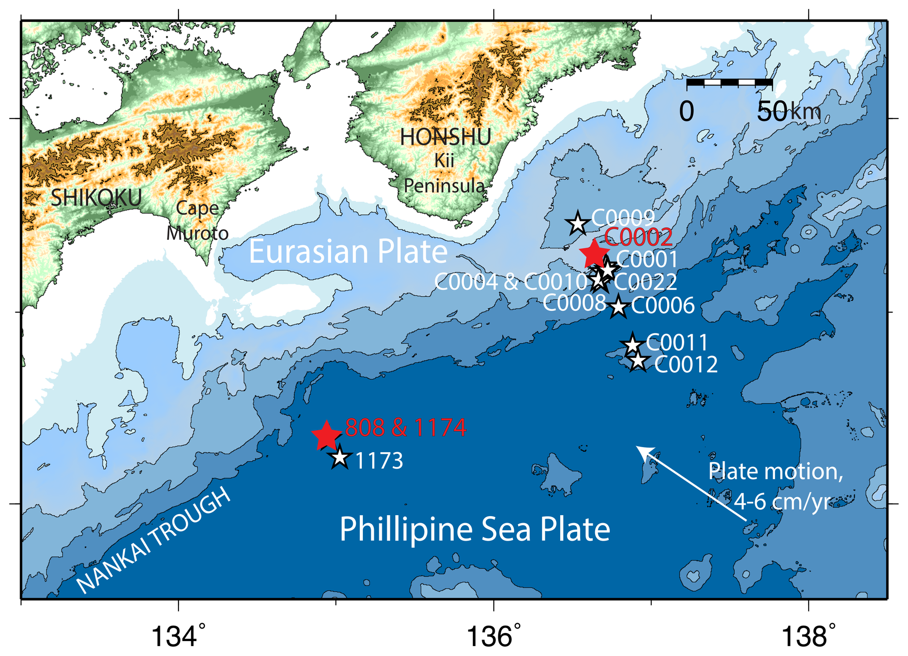
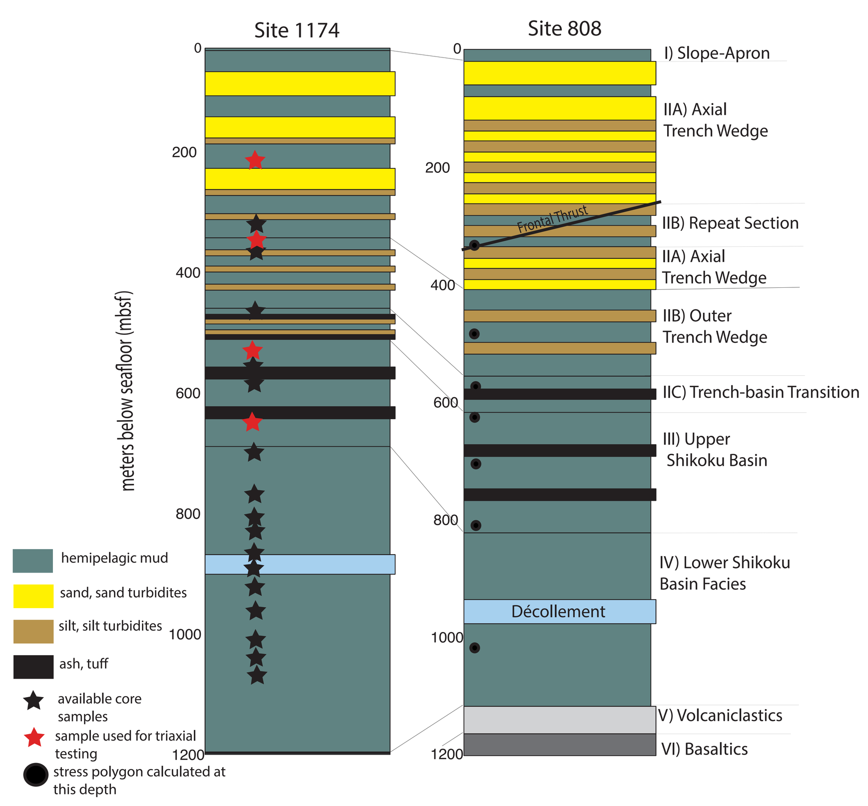
2.Geologic Setting

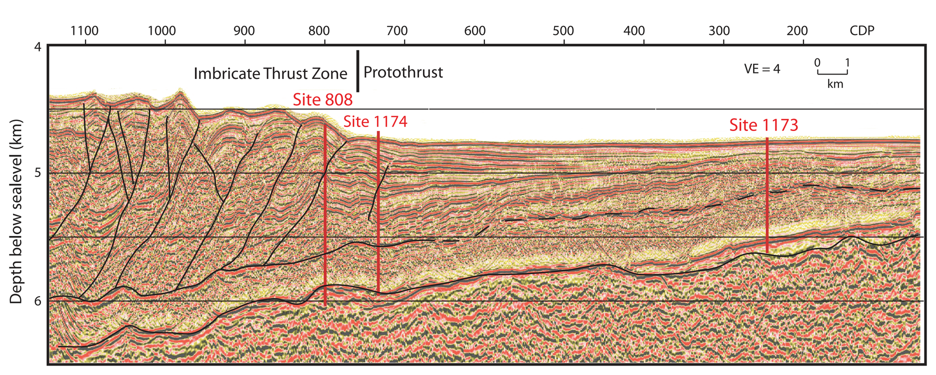
Map of Plate Boundary Locations and Muroto Transect, Offshore SW Japan



Stratigraphic Column of Site 808 and Site 1174 with Borehole Breakout Example from RAB Image



Seismic Line of Southeast Portion of Muroto Transect Covering Site 808, 1174, and 1173

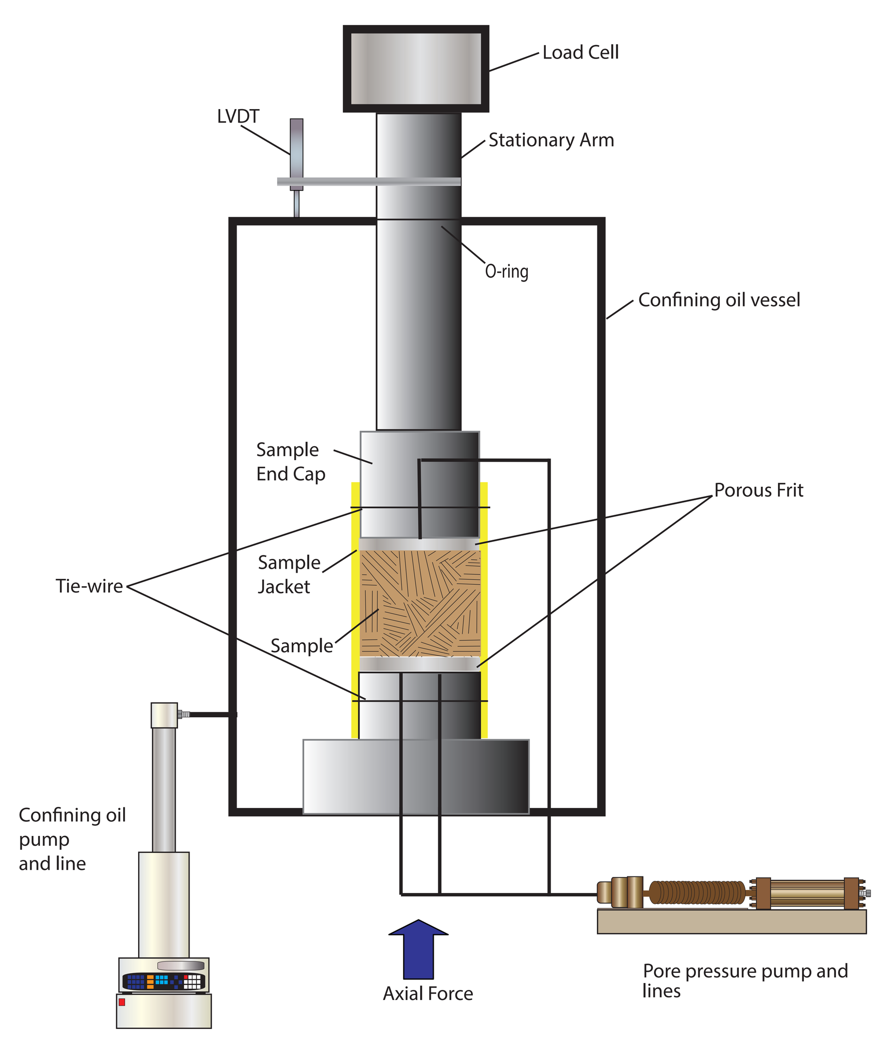


Site 1174 and Site 808 are located along the Muroto Transect in the Nankai Trough, offshore SW Japan. Site 1174 and Site 808 are within 2 km of each other and are thus very similar stratigraphically. Structurally, Site 808 is in the frontal thrust, whereas 1174 is in the protothrust. Site 808 has a repeat section where it crosses the frontal thrust.

3. Methods

A) Lab: Measurements of UCS and μ in Triaxial Apparatus

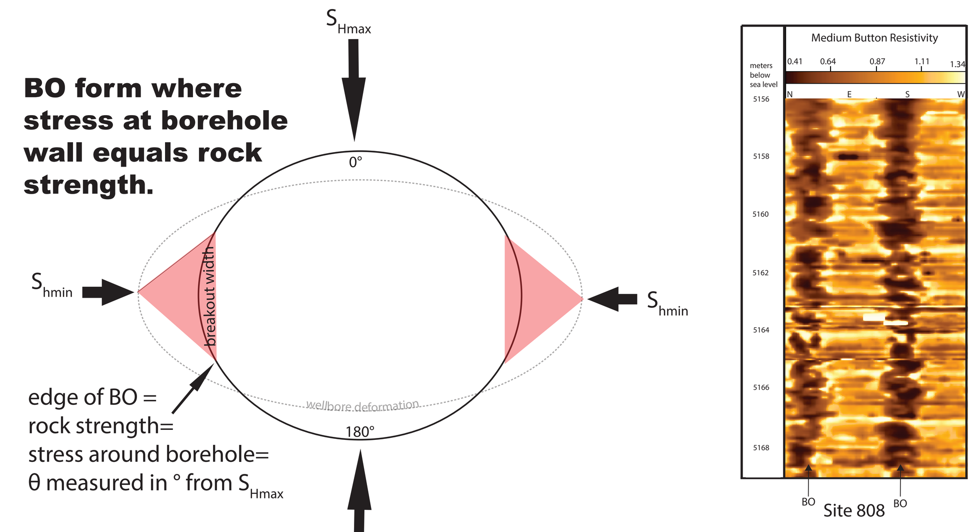
Schematic of Triaxial Apparatus



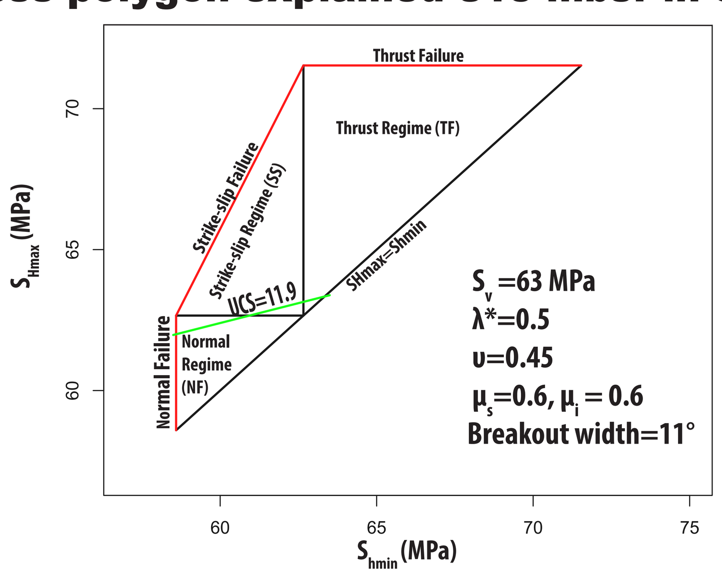
- Trim ODP sediment core from depth of interest to three cylindrical samples of 25 mm diameter by 50 mm length.
- Perform a consolidated-drained triaxial test on each of the three samples at three different effective confining stresses of 1.5, 2.5, and 3.5 MPa.
- Use failure criterion from triaxial tests to define UCS and μ.

B)Theory: Stress from BO width

Borehole Stress Relative to Breakouts



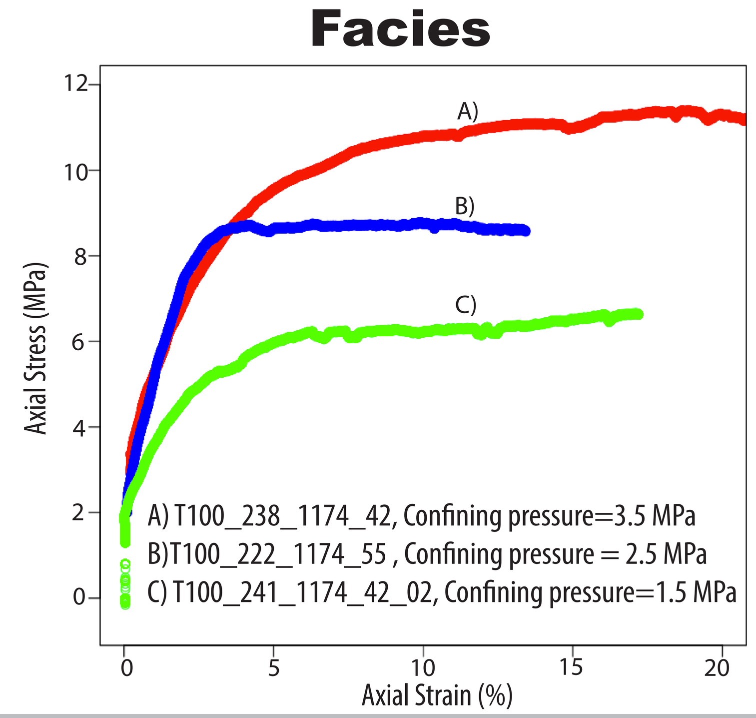
Stress polygon explained 815 mbsf in Site 808



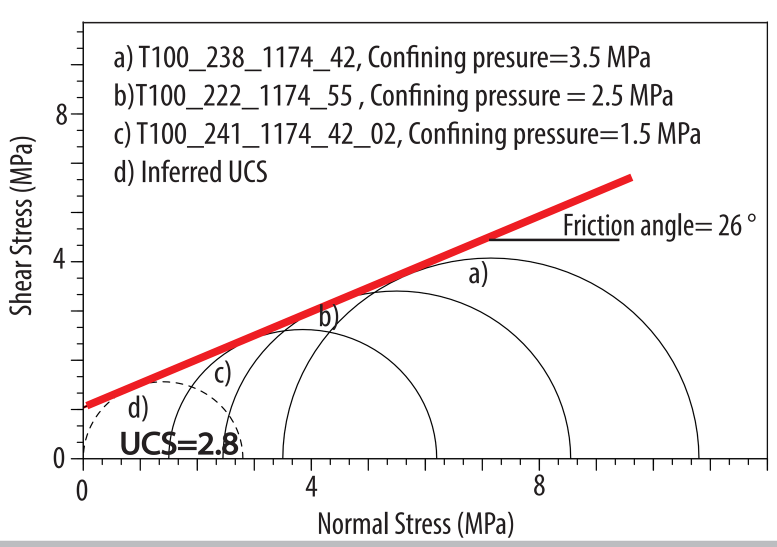
- Create stress polygon based on Coulomb theory of frictional sliding on critically oriented faults.
- Measure BO from LWD-RAB data.
- Assume rock strength is equal to stress at edge of breakout.
- Solve for far field stresses consistent with observed breakout width, using modified Wiebols-Cook failure criterion with stress at the borehole wall.

4. Results and Conclusions

Experimental Data from Three Triaxial Tests in the Upper Shikoku Facies

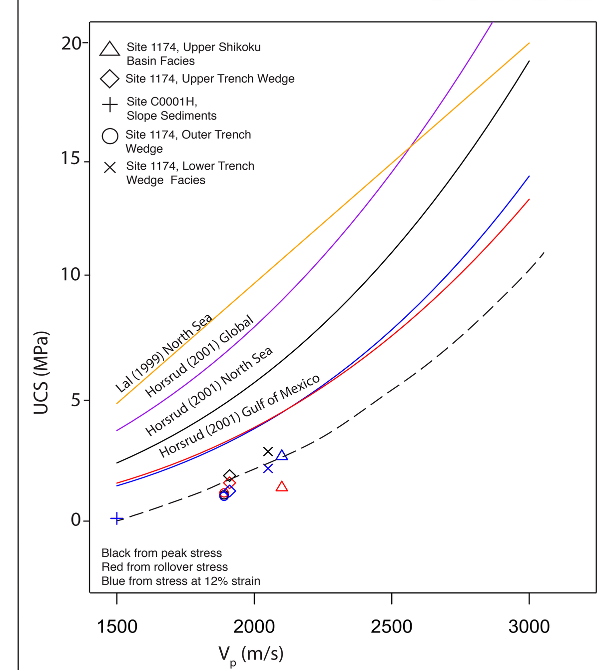


Failure reached for each experiment when axial stress no longer increases with axial strain.

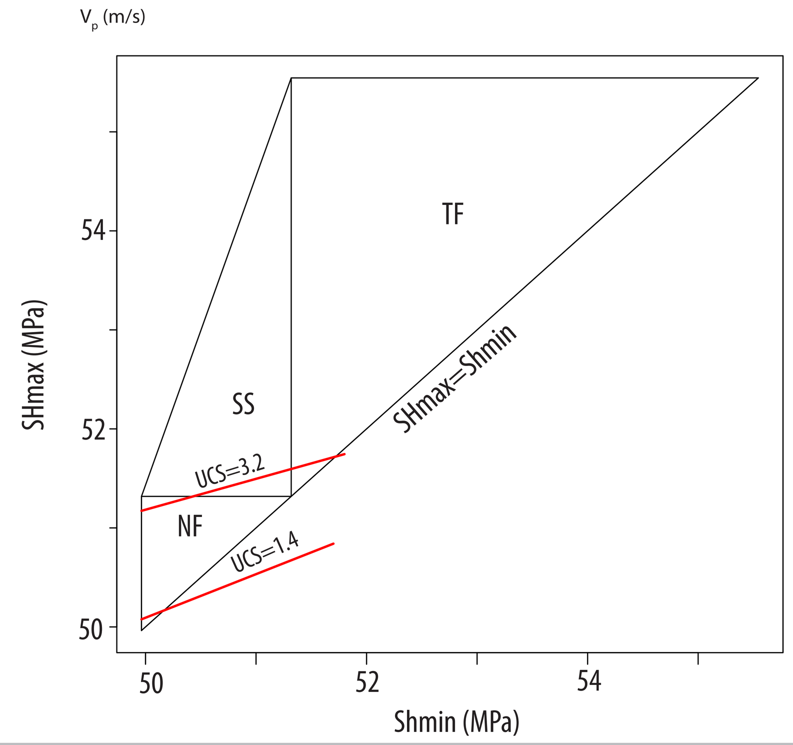


Axial stress at failure used to define failure threshold. UCS determined form fourth circle at 0 confining pressure.

Relation of V_p and UCS and Stress Constraints



- Results from all experiments plot below shale-derived equations.
- This lowers stress estimate magnitudes as illustrated in a specific case below at 235 mbsf at Site 808, in the vicinity of the upper trench wedge sample used in UCS tests.



Samples from the inner wedge with higher V_p will be focus of future experiments.

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