12.06: Claystone Porosity and Mechanical Behavior vs. Geologic Burial Stress

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ABSTRACT

A dataset was assembled from studies on 35 preserved claystone cores from different locations around the world and burial depths from <200 m to ~3700 m. Combining all data together, within a small amount of scatter there appears to be a single common trend for porosity (or bulk density) vs. depth (and vs. effective stress), irrespective of location, geologic age, clay type or the exact clay content, as long as the formation is clay-supported (Fig. 1). High-pressure mercury injection porosimetry shows that the modal size of the inter-clay-grain pores reduces in a systematic way with increasing burial stress. This loss of porosity and closer packing of the clay grains, likely combined with grain-to-grain bonding, causes mechanical properties to also change in a systematic way. Whether or not a claystone behaves in a brittle vs. a ductile manner generally depends on the value of confining stress relative to a 'preconsolidation' stress, with young high-porosity claystones behaving quite similar to soil mechanics critical-state theory and deeper, low-porosity claystones deviating from several aspects of this theory and having an apparent preconsolidation stress much higher than actual (Fig. 2). Various diagenetic mechanisms are likely responsible for 1) an apparent shift to higher bulk density (lower porosity) at a certain depth/stress/temperature (Fig. 3) and 2) the development of bonding strength and the transition from soil-like to rock-like behavior with increasing burial depth.

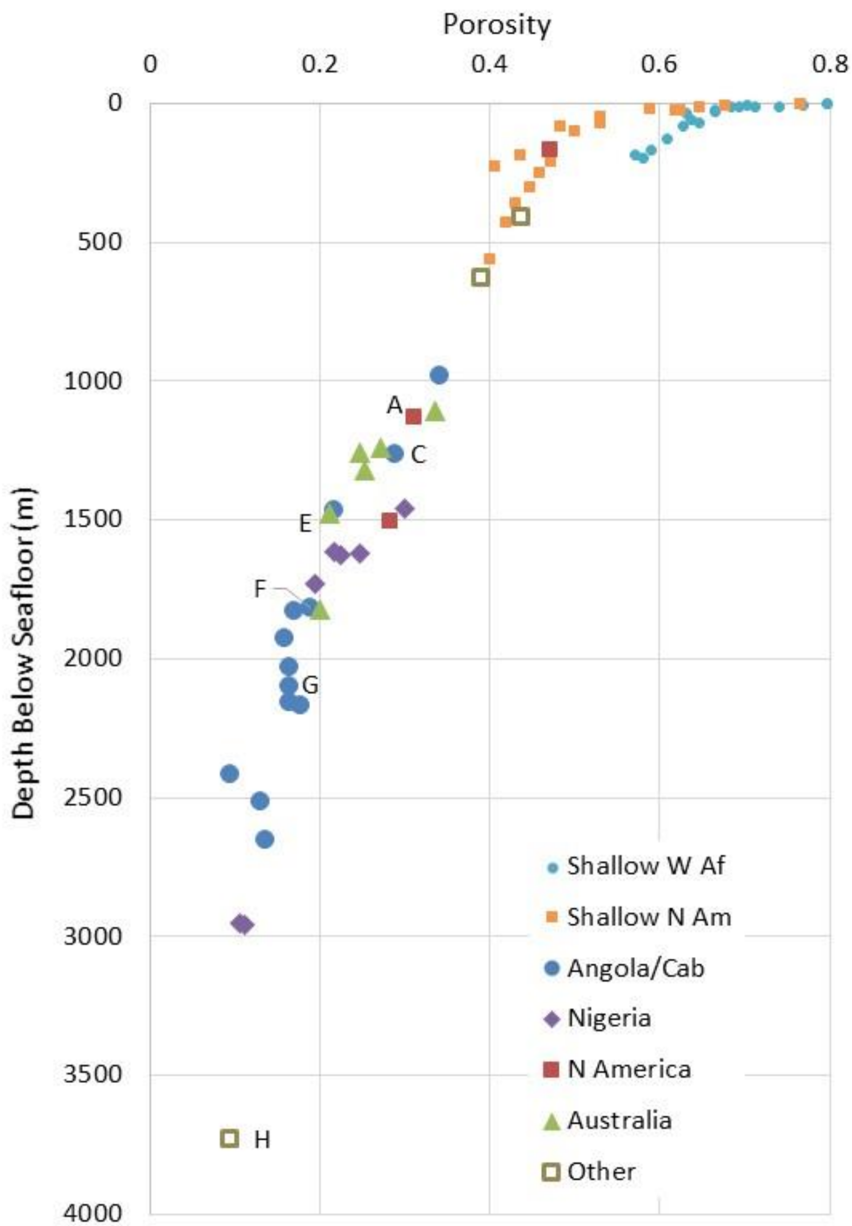

Fig. 1: Porosity vs. depth below seafloor, for oilfield cores combined with shallow geotechnical cores. All data points are at or close to normal pore pressure.

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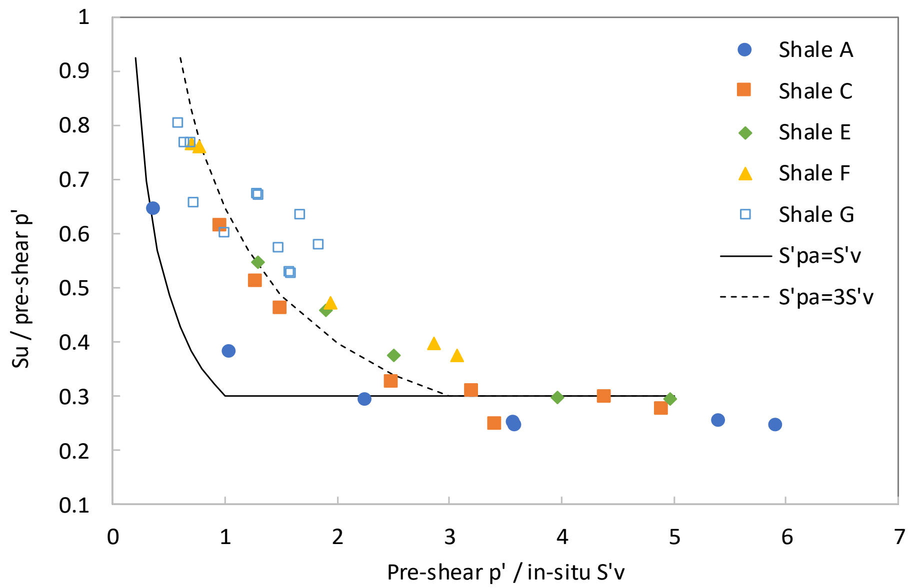

Fig. 2: Undrained shear strength (normalized by the hydrostatic effective stress prior to deviatoric loading, p') plotted against the normalized starting points of the stress paths (p'/S'v). The solid and dashed lines show the SHANSEP prediction (with s=0.3 and m=0.7) setting σ'_{pa} apparent preconsolidation stress) equal to S'v and 3S'v, respectively. S'v equals present-day (same as maximum past) vertical effective stress.

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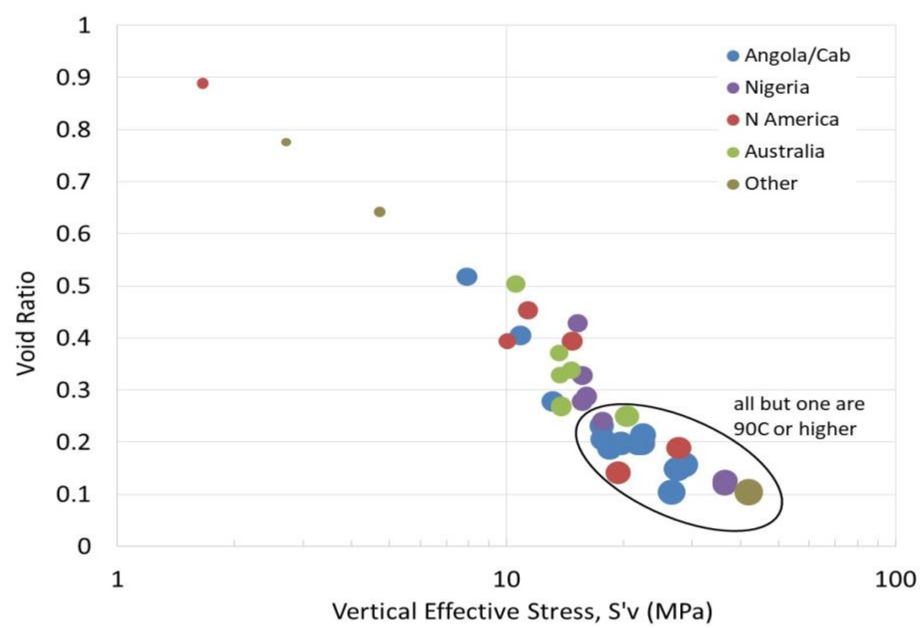

Fig. 3: Void ratio vs. in-situ vertical effective stress with data points sized by temperature (range 16°C to 138°C). The cores at 90°C and higher appear to be shifted to slightly lower void ratio (higher bulk density) than the trend from the shallower cores, with a possible transition occurring at the temperatures that coincide with 12 to 17 MPa vertical effective stress.

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