Experimental Study of Porosity, Pore-Size Distribution, and Permeability Change in Clay-Rich Sediments under Compaction

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Clay minerals constitute about 30-70% of shales. Clays are sheet silicate with grain size of < 2μm. Their presence makes shales predominantly meso-porous (pore-size below 50 nm). Unlike macro-porous rocks such as sandstones and limestones, the porosity measurement in meso-porous rocks depends on the molecular size of the fluid used in the experiment. This is because small pore throats that have diameters comparable to the molecular size of the transport fluid, act as molecular sieves. The other complicating factor is the high pore surface area to pore volume ratio. Clays have large, often negatively charged, surface areas that attract and hold significant amounts of gas molecules. Microstructural alignments of clay particles also govern the low permeability measured in shales. To understand how gas transport occurs in shale reservoirs, it is essential to understand the effect of clays on physical parameters of shales. This study focuses on understanding the effects of clays on the stress-dependent physical properties such as porosity, pore-size distribution and permeability.

For this research, we prepared clay pellets by cold pressing Na-montmorillonite powders at different pressures (upto 13000 psi). We measured the surface area, porosity and pore-size distribution of these pellets using gas adsorption isotherm technique. We will present comparisons between gas-adsorption porosity values and porosity obtained with saturation method using decane, Beckman's pycnometer, and mercury injection porosimetry, along with measurement of permeability using constant head techniques.

We find (i) strong hysteresis effects in the adsorption and the desorption curves (ii) the porosity values obtained from adsorption are smaller than those obtained from desorption; (ii) surface area is a function of sorting and compaction; (iii) with increasing compaction the surface area decreases; (iv) clays shows bimodal pore-size distribution; with peaks at 30 Å and 500 Å; (v) with compaction there is a reduction in the pore volume around 500 Å but 30 Å peak remains constant. We will present our research on pure end members of clay and sand mixtures as well as organic-rich shale samples.

Applications:

- Estimating the physical properties of shale reservoirs based on the clay mineralogy, clay content and compaction history
- Understanding the role of hysteresis in the gas adsorption-desorption behavior in clay-minerals to help estimate reserves in shale reservoirs.