Outcrop/Behind Outcrop (Quarry), Multiscale Characterization of the Woodford Gas Shale, Oklahoma

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An outcrop-behind outcrop study was conducted in and adjacent to a 250x175x40m quarry of the gas-producing Woodford Shale to structurally/stratigraphically characterize it from the pore- to subregional scales using a variety of techniques.

Strata around quarry walls were described and correlated to a 70m long continuous core drilled 150m back from the quarry wall and down to the Woodford-Hunton unconformity. Well logs obtained include Element Capture Spectroscopy (ECS), Neutron Porosity (NPHI), Density Porosity (DPHI), Combination Magnetic Resonance (CMR), Formation Micro Imager (FMI), and Sonic Scanner (MSIP), all trademarks of Schlumberger.

Strata around the quarry are horizontally bedded. ECS, FMI and porosity logs provided a basic two-fold subdivision into an upper, relatively porous, quartzose lithofacies and a lower, more-clay rich, and less porous lithofacies, but detailed core description, coupled with FMI and quarry wall correlations revealed several types of finely-laminated lithofacies. Organic geochemistry and biomarkers are closely tied to lithofacies, and reveal cyclic variations in oxic-anoxic depositional environments.

FMI and core analysis indicated fracture density is much greater in the upper quartzose lithofacies, than in the lower, more clay-rich lithofacies. A LiDAR survey around the quarry walls identified two near-vertical fracture trends in the quartzose lithofacies: one striking N85E with spacings of 1.2m, and the other striking N45E corresponding to the present stress field. FMI analysis only displayed the latter fracture set.

Based upon log- derived geomechanical properties, Young’s Modulus and Poisson’s Ratio are lower for the quartzose interval, probably due to its higher porosity. However, at a finer scale, some clay rich zones exhibit a relatively low Young’s Modulus and high Poisson’s Ratio while other zones of similar composition exhibit the opposite trend, indicating factors beside porosity play a role in geomechanical properties. SEM analysis of core samples indicated that, in addition to porosity, mineral composition and crystal structure, lithofacies type, and micro-fractures/-porosity all affect geomechanical properties to varying degrees.

This integrated study has provided improved insight into the causal relations among properties at a variety of scales, which can be valuable for improved targeted drilling and production in the Woodford, and perhaps other gas shales.