ANALYSIS OF ROCK MECHANICAL PROPERTIES BY MINERALOGY AND THEIR POTENTIAL EFFECTS ON HYDRAULIC FRACTURING IN THE WOODFORD SHALE, WEST TEXAS

by

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ABSTRACT

Shale reservoirs are commonly considered to be fine grained, low permeability rocks with high clay content and little inherent heterogeneity. However, as more shale plays are developed, it is evident that shale reservoirs vary considerably in their mineralogical and geochemical properties and that this variability has consequences for physical properties. Given the fact that shale reservoirs are almost always subjected to hydraulic fracturing treatments, investigating the relationship between the mineralogy and the physical and mechanical properties of these reservoirs is crucial.

The outcome of a small hydraulic pump-in treatment on a well (RTC #1) drilled in the Woodford shale, Permian Basin, west Texas, suggested systematic differences in mechanical properties between the middle and lower Woodford. While the middle, more quartz-rich, section responded positively to fracturing, the lower, more clay rich, zone did not show any improvement. This raised the need for a thorough investigation of why the formations responded in the way that they did and how the mineralogy of the Woodford shale relates to the mechanical properties.

This study was performed using a well log data set from the subject well including gamma ray, photoelectric, resistivity, density, sonic and neutron. Additionally, mineral, geochemical, acoustic and petrophysical data from a 260 ft core from the subject well were used. The core acoustic velocities, V_p and V_s, were recorded under surface conditions using a hand-held velocity probe. This resulted in a slight difference between the core V_p and log V_p, and an acute difference between the core V_s and log V_s. The differences in core and log acoustic velocities translated into differences between core and log mechanical properties. Log data were found to be more representative of the mineralogy of the Woodford and were the ones used in the statistical analysis. Three statistical methods, factor analysis, cluster analysis and stepwise linear regression, were used to evaluate potential relationships between the mechanical properties,

Young's modulus and Poisson's ratio, and the mineral/geochemical elements of the formation. A hydraulic fracturing simulator, GOHFER^{TM}, was used in order to evaluate certain hydraulic fracturing treatment designs in the Woodford shale of west Texas.

The results of the study suggest that Young's modulus is influenced by carbonates, clays, feldspars and total organic carbon (TOC). High carbonate content, dolomite and calcite in this case, are more likely to result in high values of Young's modulus, therefore a more brittle rock. High clay and feldspar contents, illite and albite respectively, and TOC, on the other hand, are more likely to cause the formation to be less brittle by causing the Young's modulus values to be slightly lower. However, because of the low correlation coefficients of these elements with Young's modulus, no single element can be considered as the main driver of this mechanical property. Poisson's ratio is controlled by quartz, clay, feldspars and TOC. High quartz content and abundant TOC are more likely to result in low Poisson's ratio values, therefore a more brittle rock, while high clay and feldspar contents are more likely to result in a ductile formation with high Poisson's ratio values. The high correlation coefficients that associate quartz and clays with Poisson's ratio indicate that these minerals are strong controllers of this mechanical property.

Based on the mineralogy of the different zones of the Woodford and the relationships established between the mechanical properties and different mineral components, it is inferred that the upper Woodford, very rich in quartz and very poor in clay, will probably be the region most prone to hydraulic fracturing. The middle Woodford will more likely show little higher resistance to fracture initiation due to its slightly lower quartz content and little higher clay content. The lower Woodford will be the most resistant to hydraulic fracturing because of its high clay content, low quartz and low TOC.

Based on initial hydraulic fracture modeling, hybrid (slickwater/gel) treatments with ceramic proppant appear to be the most appropriate hydraulic fracturing treatments for this formation. Fractures initiated in the middle Woodford showed a tendency to grow upwards. This suggests the existence of a path of least resistance right above this zone and is an indication of a possible anisotropy in the mechanical properties. This also agrees with the mechanical properties results that show that the upper Woodford is the most prone to hydraulic fracturing.