

Considering the Vertical Variation in Rock Mechanical Properties of a Lithologic Zone Using Laboratory Derived Data – Is it Time for Geomechanical Stratigraphy?*

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Abstract

In both vertical and horizontal hydraulic stimulation schemes, the geomechanical properties of the rock volume to be stimulated are of primary consideration when designing the fracturing process and understanding reservoir geomechanical behavior (see Zoback, 2007). Typical rock mechanical properties such as Young's Modulus and Poisson's Ratio, various pressure gradients, density, pore pressure, porosity, permeability, general lithology and fluid content are generally derived from a variety of borehole logs. These borehole log values are usually derived from the vertical section of the well and applied across any subsequent horizontal section for both geo-steering and determination of completion intervals. For hydraulic stimulation planning, an average of wireline geomechanical values across the zone of interest is typically used. If core is taken, then geomechanical values from lab results may also be utilized. As more and more rock mechanical property data are collected both in the lab and from the field, then observations on the variation of geomechanical properties over reservoir height, and in adjacent intervals in the borehole may be made. It also becomes possible to compare lab derived versus log derived values, even seismic derived values, and look for potential patterns that may have meaning, leading to the development of a possible geomechanical stratigraphy.

Introduction

Following Murphy and Salvador (2012) a "stratum is a layer of rock characterized by particular lithologic properties and attributes that distinguish it from adjacent layers" and a "stratigraphic unit is a body of rock established as a distinct entity in the classification of the Earth's rocks, based on any of the properties or attributes or combinations thereof that rocks possess. Stratigraphic units based on one property will not necessarily coincide with those based on another." This is easily understood when considering lithostratigraphy, hydrostratigraphy, chronostratigraphy, biostratigraphy, climatostratigraphy, isotope stratigraphy, magnetostratigraphy, etc. We look at a regional body of geomechanical properties for one formation in one basin to search for distinguishing geomechanical characteristics. We also look at a single highly sampled well core to see if distinguishing characteristics might exist on a well scale.

Methods

The laboratory data evaluated for the well core includes both destructive and non-destructive test results. Young's Modulus, Compressive Strength, Average Tensile Strength and Poisson's Ratio are determined under various confining pressures. Brinell Hardness is also determined. In some cases, permeability is measured under pressure or in some cases is a calculated measurement from Micro-CT Scan and from gas injection. Porosity and pore geometries are also determined by Micro-CT and Nano-CT analyses. Mineralogy is determined from analytical XRD, elemental analyses, if any, are from FIB-SEM, and organic carbon analyses are from Rock-Eval. Ultrasonic compressional and shear velocities, electrical resistivity, and gas permeability are determined from NER Core Autos Scan measurements. For this study, we will concentrate on Young's Modulus and Poisson's Ratio although the results from other lab derived rock property data suggest that similar conclusions might be reached.

Discussion

[Figure 1](#) is a subset of laboratory derived Young's Modulus and Poisson's Ratio for a set of wells in the Cotton Valley trend of the Texas-Louisiana Basin following the descriptions of Dyman and Condon (2006). There is a wide range of depth and area implied by these data and a casual glance suggests that there is no easily observable trend or unique pattern in property data that could be mapped as stratigraphically significant. The sparse sampling and range of the data may be insufficient to spot trends that highlight unique values but may be sufficient to highlight trends of similar values. On a basin scale, it may be possible to map strata of approximately equal values of rock properties only looking to the values outside of the first standard deviation as statistically significant and unique and potentially mappable as distinct strata.

[Figure 2](#) is a series of log-derived values for Young's Modulus and Poisson's Ratio as well as a Gamma Ray curve. This well represents at least three distinct lithologies; one with a gradational boundary and one with a sharp to discontinuous boundary, or possibly two formations with three members within a sand-shale depositional system with some interspersed lime. Also shown on this figure are lab derived Young's and Poisson's data.

Unlike [Figure 1](#), there are patterns available that may have significance. Initially there are obvious stacked trends of progressively decreasing Poisson's Ratios with depth followed by an increasing with depth trend shown by the black lines. The Young's Moduli are only moderately tracking in these intervals. There are zones where the Young's and Poisson's data are tracking such as those in the box and there is an interval where the Young's and Poisson's data are tracking well as indicated by the arrows. It is interesting to note that both the Young's and Poisson's data, where it is outside of the first standard deviation may be indicating key breaks in the rock property stratigraphy or at least acting as a pointer for where the adjacent data should be evaluated for relevant rock property similarity. It is possible that these trends, suggesting rock property relationships, progressively and over a distinct depth range, may be mappable and define a geomechanics stratigraphy. The lab data general matches the log data (except for the shallowest sample) suggesting that, given more data, basin wide trends such as in [Figure 1](#) might be more interpretable.

In both of these examples the first standard deviation is taken as an initial suggested standard for distinguishing potentially mappable zones of rock mechanical properties based on 1) patterns within the first standard deviation have a higher confidence interval for interpretation and

correlation and patterns may be more recognizable, and 2) values outside of the first standard deviation may act as markers. We believe that these second standard deviation values may help eliminate the Type 2 and 3 errors defined in Mann (1993) and further discussed in the work of Wellman et al., (2010).

Conclusions

In summary, while not defining key parameters that might be used to formalize a stratigraphy for geomechanical properties that could then be mapped and analyzed similar to other stratigraphic systems already in use, it is suggested that the rock property data collected via borehole logs and from core does exhibit patterns on a scale that is interpretable over a measurable distance and therefore defines the basic requirements of a mappable stratigraphic system. Two initial suggestions were made for determining patterns of mappable data, first within the standard deviation of the data and second by using values outside of the first standard deviation as markers, or pointers, to potential adjacent mappable units. Further work will help define specific elements of a potential rock property stratigraphic system.

References Cited

- Dyman, T.S., and S.M. Condon, 2006, Assessment of undiscovered conventional oil and gas resources—Upper Jurassic–Lower Cretaceous Cotton Valley Group, Jurassic Smackover Interior Salt Basins Total Petroleum System, in the East Texas Basin and Louisiana-Mississippi Salt Basins Provinces: U.S. Geological Survey Digital Data Series DDS–69–E, Chapter 2, 48 p.
- Mann, J.C., 1993, Uncertainty in geology. Computers in Geology—25 Years of Progress: Oxford University Press, pp. 241–254.
- Murphy, M.A., and A. Salvador, 2012, International Stratigraphic Guide – An abridged version: Episodes, v. 22/4, 18 p.
- Wellman, J.F., F.G. Horowitz, E. Schill, and K. Regenauer-Lieb, 2010, Towards incorporating uncertainty of structural data in 3D geological inversion: Tectonophysics, v. 491/3-4, p. 141-151, doi:10.1016/j.tecto.2010.04.022.
- Zoback, M.D., 2007, Reservoir Geomechanics: New York, Cambridge University Press, 449 p.

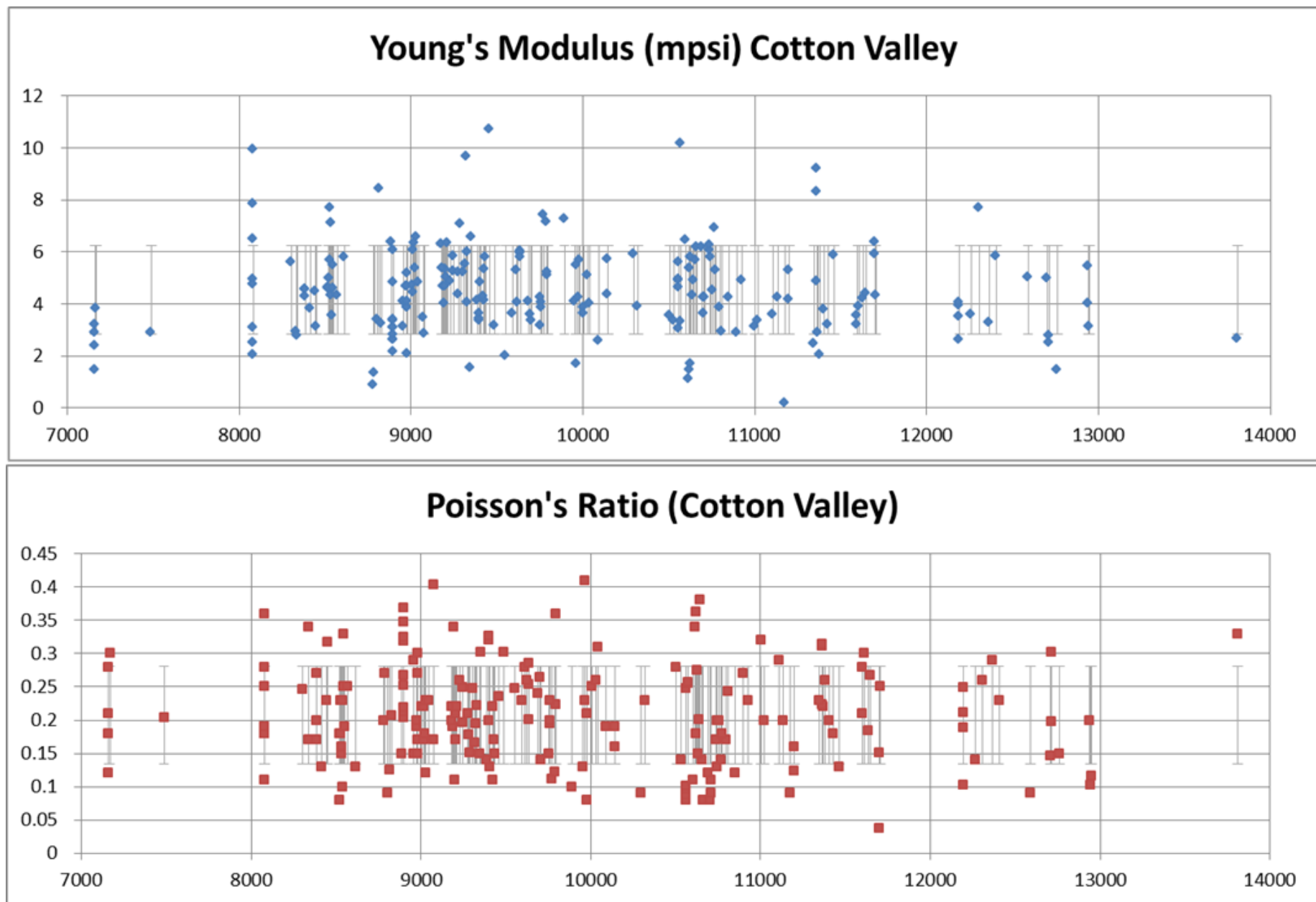


Figure 1. Young's Modulus and Poisson's Ratio for 60+ wells in the Cotton Valley Trend of the TexLa Basin plotted by depth. Two hundred fourteen results are shown from 7,000 to 14,000 feet (2,134 to 4,267m). Light gray vertical lines are the range of the first standard deviation.

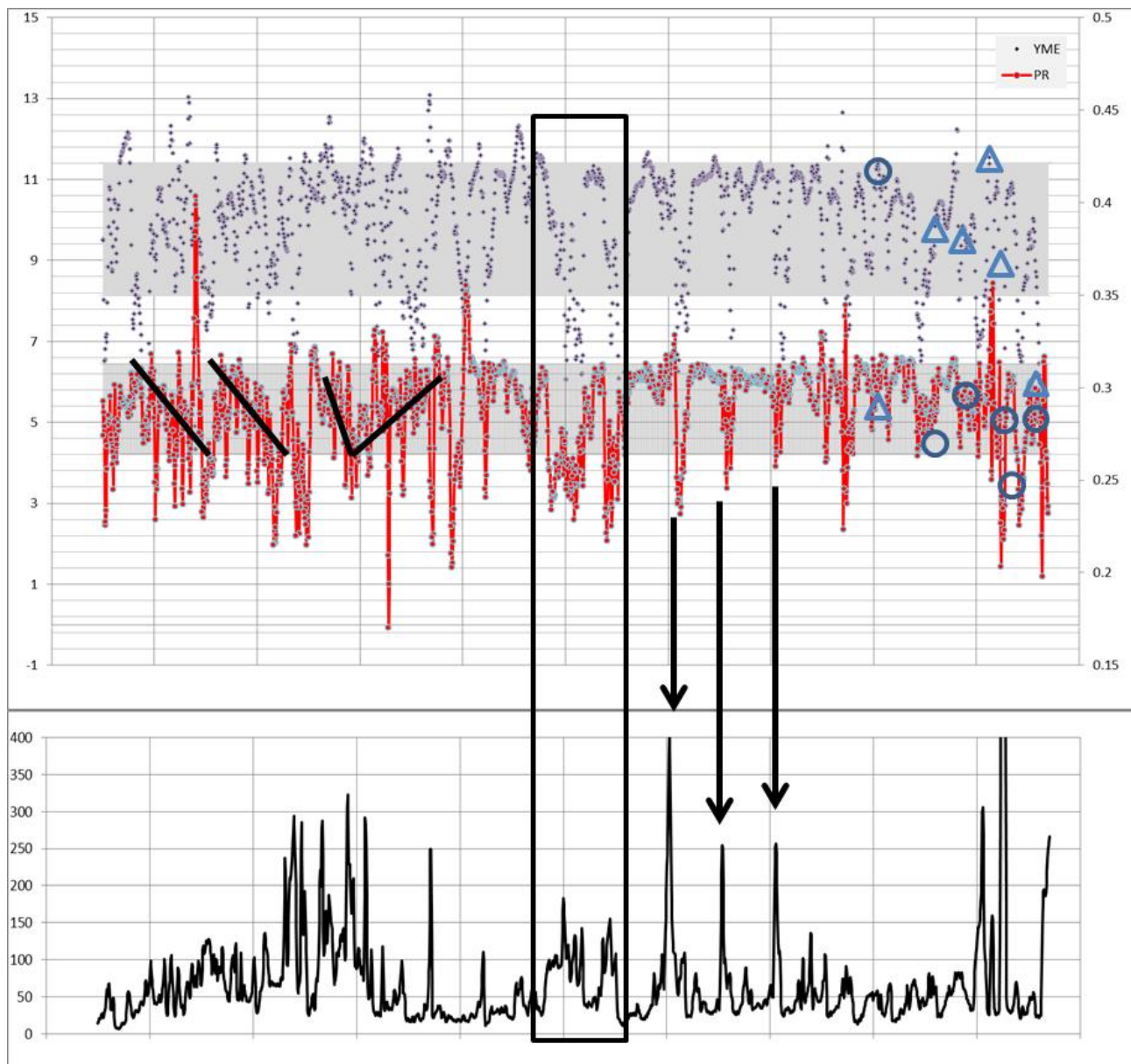


Figure 2. Log-derived Young's Modulus and Poisson's Ratio with lab derived data also shown (triangles are lab based Young's Modulus and circles are Poisson's Ratio). The round markers are Young's data and the diamonds are Poisson's data. The gray boxes are the first standard deviation for each set of values. The black curve is the gamma ray log. Vertical lines are depth in increments of 100 feet (32m).