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Geomechanical characterization methodology for quantifying fine scale heterogeneity

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Summary

The integration of plug and log scale characterization is key to generating representative engineering inputs for geomechanical models in oil and gas exploration and development. The importance of plug measurements is especially vital in finely laminated rocks where well-log scale measurements miss mechanical heterogeneities that are required for realistic mechanical models. The presence of mechanical heterogeneity and anisotropy under the well log resolution is commonplace in unconventional plays and can deeply impact geomechanical assessments ranging from wellbore integrity to horizontal stress estimates.

The first part of the presentation will focus on a few laboratory- based inputs that are increasingly being recognized as high impact. We will address the topics of continuous mechanical profiling, and anisotropy quantification for both poroelastic constants including the extraction of anisotropic stiffness tensor and Biot coefficients.

In a second part, we will address the optimization aspect. To that effect, we will suggest ways to greatly increase workflow relevance and efficiency by relying on the use of petrophysical core scanning for screening, rock typing and plug picking. New closed loop workflows allow for upscaling lab observations to the log scale at different stages of the process, thus providing an early option for decision making.

Continuous Mechanical Profiling

NER's Core AutoScan is a unique measurement platform developed for the detailed quantitative and efficient description of core properties. It is capable of scanning slabbed and whole core or plugs for gas permeability, resistivity, ultrasonic compressional-and shear-wave velocities, composition, mechanical strength, and elastic stiffness (Impulse Hammer) at the mm scale.
The Impulse Hammer was originally developed to provide a non-destructive method to measure the mechanical profile along a core. The Impulse Hammer captures the physics of the impact by measuring the force-time function as the indenter is free falling onto thesample surface, and thus two independent parameters can be extracted, reduced Young's modulus and an impulse hardness.

An example of fine scale heterogeneity observed in a Wolfcamp core can be seen in Figure 1.

Mechanical and Poroelastic Anisotropy

It is possible to measure 4 of the 5 independent static moduli for a single plug with the plug axis parallel to bedding. The static elastic moduli are measured by fitting the stress versus strain response to a sequence of loading cycles. Using this method we measure all the static moduli except C44=1/S44=G. The static test can be continued with a sequence of confining and pore pressure cycles -after the introduction of pore fluid to constrain a poroelastic model including the anisotropic Biot parameters αv and αh. The horizontal samples can then be conditioned and tested for anisotropic dynamic moduli using both axial and radial compression-and polarized shear-wave ultrasonic velocity transducers. A three-axis velocity test can be performed to measure the five in dependent stiffnesses (including C13), and thus compute all of the VTI elastic constants.

From a single horizontal plug, dynamic/static and poroelastic VTI properties are measured which greatly reduces the uncertainty in multiple measurements using plugs that could sample several bedding layers, if vertical or 45° can be obtained at all. This process of using horizontal plugs lends itself well to the use of rotary sidewalls as well.

Optimization and Upscaling

There arises two large core to log integration problems when fine scale heterogeneity data is not available or used, (1) plugs typically chosen based on well-log scale information in unconventionals are often consisting of several rock types (mechanical, compositional, petrophysical) which makes individual plug interpretation cumbersome at best and impossible at worst, and (2) if one is able to interpret plug data coming from a sample consisting of several rock types, how is this data then integrated back into the log scale? To this end, the mm scale measurements made with the AutoScan apparatus can provide enough information for rock typing using composition, mechanical, or petrophysical properties at several scales, and thus provide detailed estimations of where plugs are required, and where traditional plugging plans may provide redundant or no information on several rock types. The optimized plug sample scheme typically requires fewer total samples, and provides a more intuitive interaction between the plug and log scale. Upscaling workflows using these datasets can generally take three paths depending on what data is available (1) plug information applied directly to logs, (2) plugs plus AutoScan upscaling using core only, and (3) Core calibrated upscaled transforms, from (2), applied to logs.

The full presentation will discuss these aspects in more detail and compare/contrast the results of each using the Wolfcamp shale as an example. Figure 1 shows some of the Wolfcamp dataset consisting of fine scale heterogeneity information from the AutoScan, as well as the rock types determined at the log and sub-log resolution (far right column).

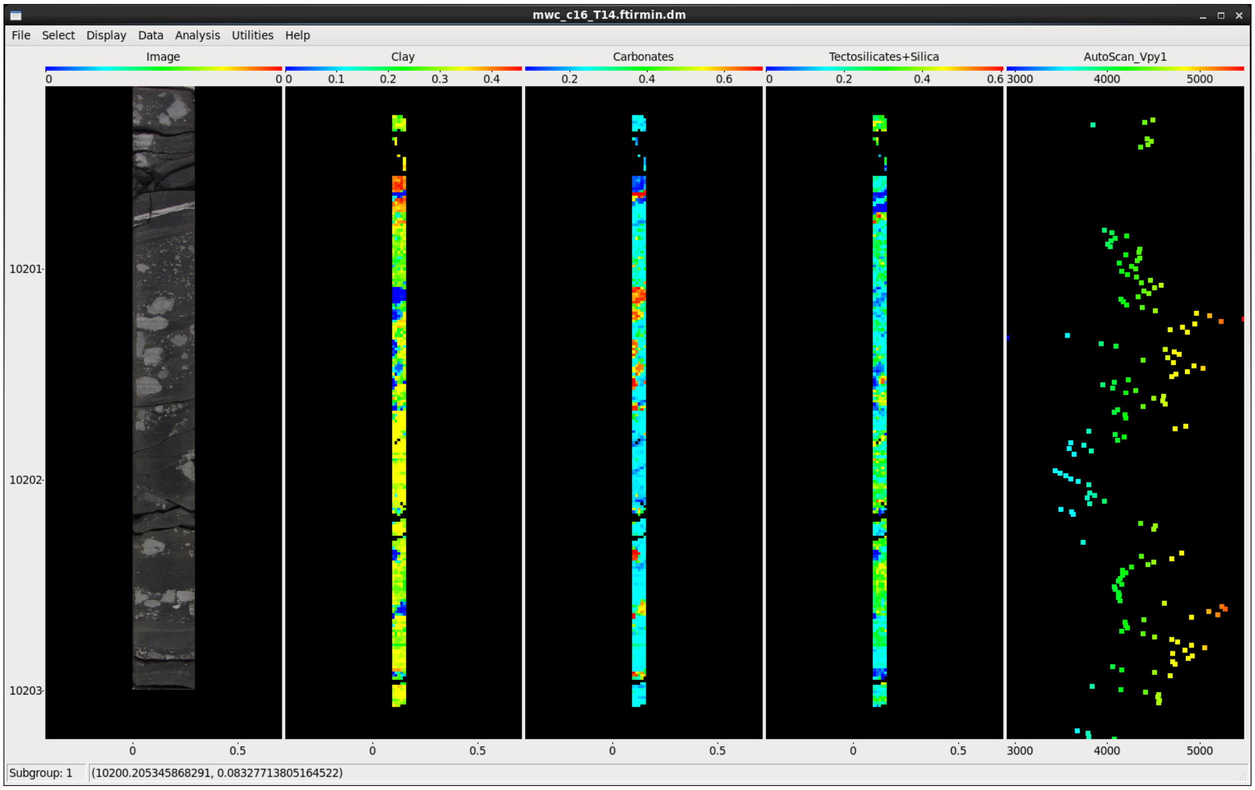

Figure 1. Small section (three feet) of the large Wolfcamp dataset showing fine scale heterogeneity information and comparison between mechanical properties and composition, separated by mudstone type