Quantifying and Linking Shale Properties at a Variable Scale

Elizabeth Diaz, Carl Sisk, Avrami Grader, and Jack Dvorkin
Ingrain, Inc., Houston, Texas

At least three characteristics of shale are key to asset evaluation and development: (a) the presence of organic matter and free gas; (b) the porosity and permeability of the shale matrix; and (c) the susceptibility of the matrix to fracturing. Only a favorable combination of these three factors allows for discriminating good from poor shale reservoir. How to quantify these factors at the early stage of field evaluation and then use them for long-term field production and development? One way of addressing this challenge is by using computational rock physics. Specifically, the volume of hydrocarbons in place is quantified from multiple high-resolution 3D nano-scale images of shale fragments, which could be regular core plugs; side-wall plugs; or even drill cuttings. The same images (Figure 1) can be used to compute porosity and the directional gas or oil permeability of shale.

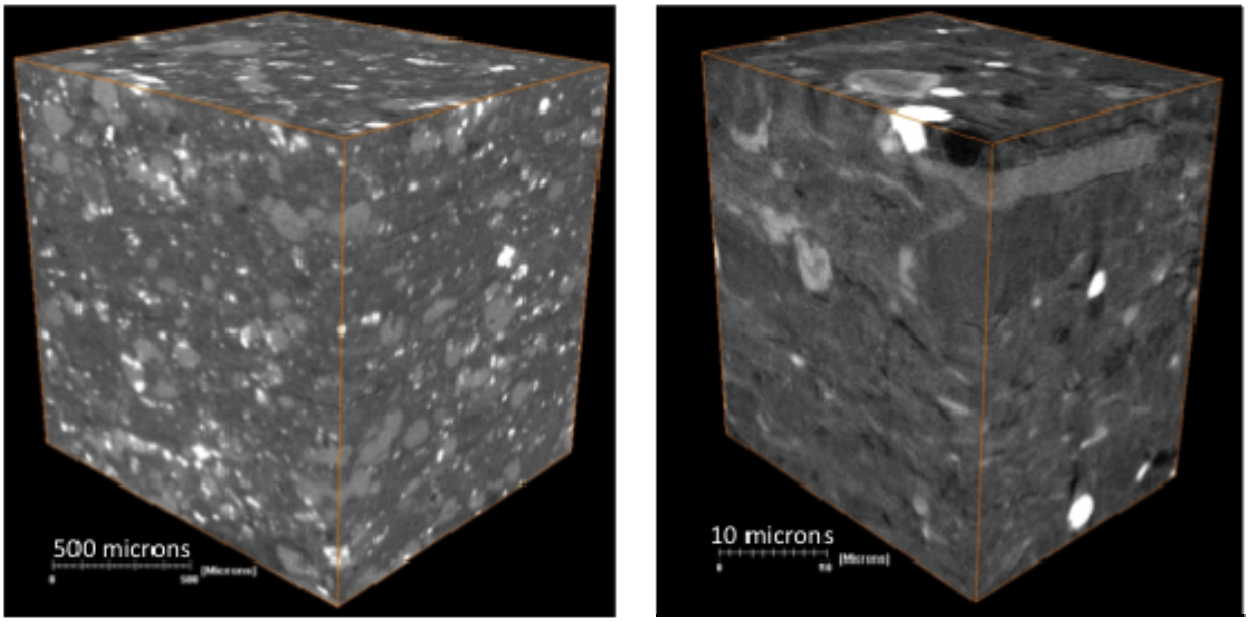

Figure 1: Micro-CT volume on the left and Nano-CT volume on the right

Finally, the brittleness of shale is likely to be related to its mineralogy, specifically the amounts of silica and carbonates. This mineralogy is quantified in a range of scales: (a) at a nano-scale by image-processing microscopic 3D images to highlight the principle constituents and (b) at the core scale by using dual-energy X-ray CT scanning that supplies the bulk density and the atomic number logs. The latter is directly related to the mineralogy. The dual-energy core-scale scanning combined with well logs and traditional visual inspection gives an overall picture of macroscopic heterogeneity of the rock under examination. This scanning points to the locations where micro- and nano-scale tests have to be selected for computing the bulk and transport properties. Finally, by integrating measurements of total organic content, porosity, and permeability at the nano-scale with the shale units segregated using the core-scale measurements, we cover, in a unique way, a range of heterogeneity scales present in any natural rock, especially in shale. The technology described here became available only recently by combining the-state-of-the-art imaging hardware and image-processing software as well as the most advanced computer hardware and algorithms.