

“As one drills deeper into the reasons behind the variability seen in the perforations that actually produce gas, it is important to understand the producing mechanisms of shale and other unconventional reservoirs from the pore scale where heterogeneities can be very apparent. This is where Ingrain’s technology comes into play.”

*Ingrain’s approach to shale plays,
Hart’s E&P, November 2010*

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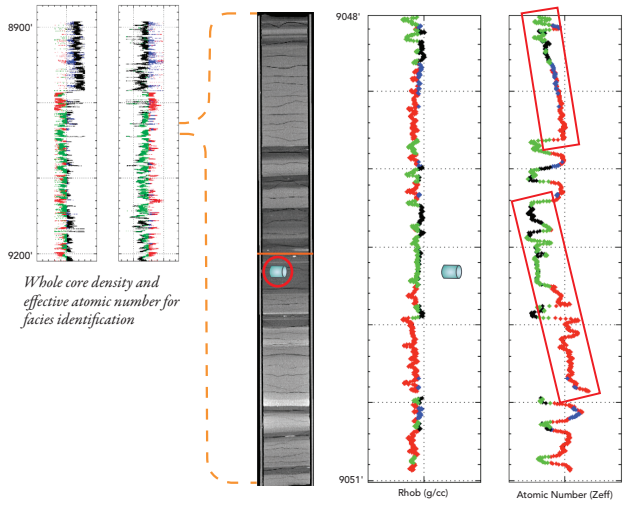
DIGITAL ROCK PHYSICS *for* **SHALE PLAYS**

INGRAIN

Shale Digital Rock Physics Workflow

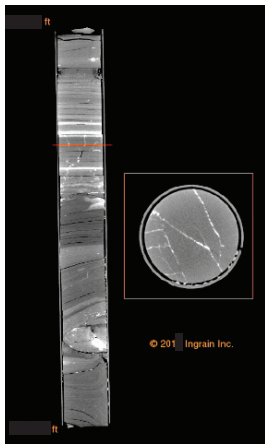
1 CoreHD® Whole Core Imaging & Logging

CoreHD® is Ingrain's breakthrough technology platform for high-definition CT imaging and logging of whole core. Ingrain's unique and proprietary methods allow computations of bulk density (RhoB) and effective atomic number (Zeff).



Whole core density and effective atomic number for facies identification

Parasequences with plug locations identified

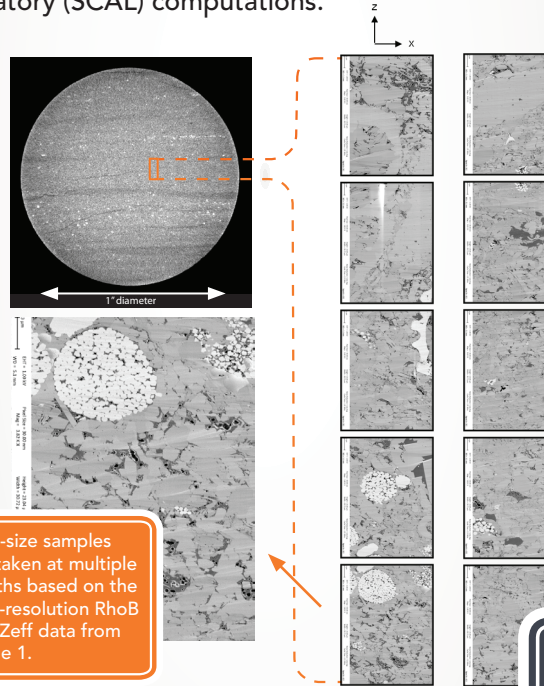


The Ingrain Continuous Core Viewer is a movie showing 500 digital cross sections per foot. The 2D vertical image provides definitive data to optimize sample selection for rock properties analysis and reveals laminations, fractures and burrows.

2 Micro2D Plug Analysis

Micro-CT analysis provides information on fine-scale laminations and fracturing at a resolution of 10-40 microns.

Image analysis from 2D scanning electron microscope (SEM) data provides porosity and kerogen volume fraction at a resolution of a few nanometers and is also used as a screening process to ensure representative samples for the subsequent 3D special core analysis laboratory (SCAL) computations.



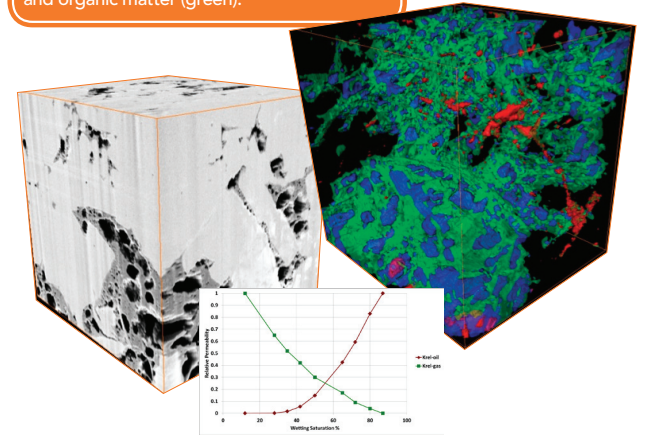
Plug-size samples are taken at multiple depths based on the high-resolution RhoB and Zeff data from Stage 1.

3 SCAL3D

The 3D SCAL analysis begins with nanometer-scale pore and matrix imaging. This process uses a focused ion beam SEM (FIB-SEM) system that acquires an SEM image of an ion-beam polished surface, then uses the ion beam to slice away a few nanometers of rock and takes another SEM image.

This is repeated several hundred times for each sample. All of the individual images are aligned and combined into a single 3D volume called a vRock®. Shale 3D vRocks are used for porosity and permeability analysis.

The image on the left shows the outer surface of a 3D FIB-SEM volume from an organic-rich shale. The image on the right shows a transparency view of the distribution of connected pores (blue), isolated pores (red) and organic matter (green).



[Unique Capabilities for Shale]

- Porosity; connected, total, kerogen, TOC
- Kabs; absolute perm (x, y, z)
- Pore size analysis
- Whole core 3D imaging for fractures, burrows, layering
- Rapid whole core facies identification from RhoB and Zeff
- Kg/Kw and Ko/Kg rel perm.
- Capillary pressure, drainage and imbibition

from **WHOLE CORE** to **CUTTINGS**