As seen in the July 2010 issue of E&P

Digital rock physics lab brings core analysis to the digital oil field

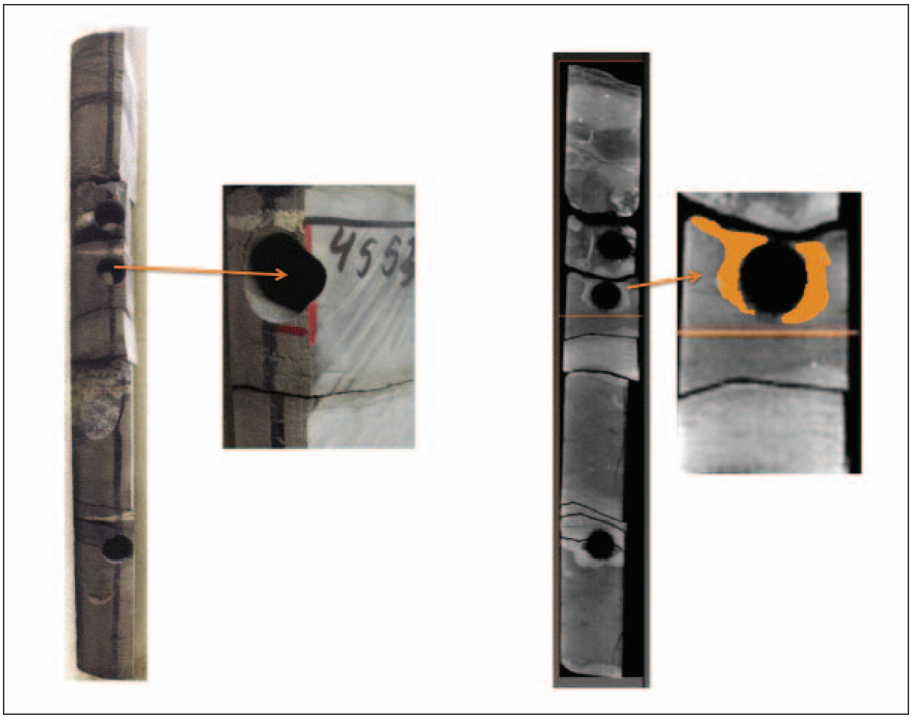
Accurate rock characterization improves understanding of technically challenging reservoirs.

AUTHORS

Elizabeth Diaz and ***John B. Elmer***, *Ingrain*

Accurate rock characterization is vital for maximizing hydrocarbon recovery and asset value during the exploration, appraisal, and development of a field. Oil companies routinely face the challenge of coring representative intervals that provide relevant information for reservoir understanding and modeling.

In today's digital oil field, 3-D digital imaging and computation of rock properties provide a valuable toolset for integrating data at scales ranging from feet or meters (seismic) to inches or centimeters (logs) to microns and nanometers (cores). Digital rock physics technology brings a new suite of tools to oil companies for better understanding of rock properties in technically challenging reservoirs.



The photograph on the left shows no visual evidence of density differences, but the CoreHD scan on the right reveals that the region from which the plug was taken is an anomalous, higher-density rock type. (Images courtesy of Ingrain)

Understanding gas shale heterogeneities

Rock samples must be obtained from correctly identified lithofacies for the resulting rock properties' measurements to be of value. A recent digital rock physics study on a Mississippian gas shale well illustrates the value of high-definition 3-D imaging and computation to characterize reservoir rocks.

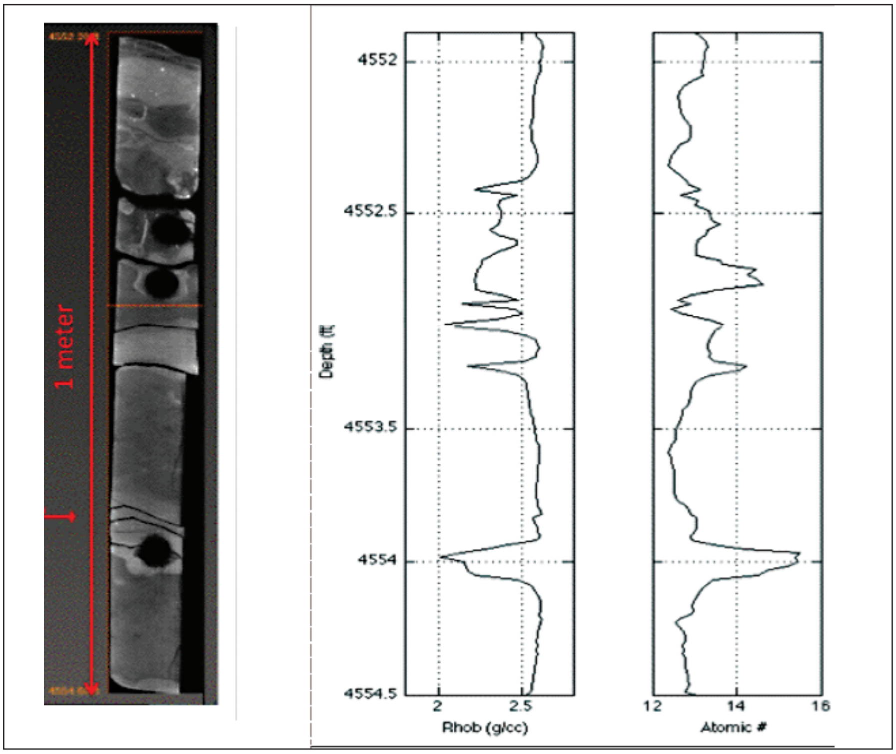
In the study, a shale core was slabbed, and core plugs were taken for physical core experiments. CoreHD high-definition CT imaging and logging were subsequently used to scan the core to understand the results of experiments on those plugs. The core plugs were taken from denser areas that were not representative of the main flow units present in the rock.

Beyond this simple example, high-definition CT imaging and logging of whole core provides a greatly enhanced set of tools for lithofacies classification compared to linescan images, medical-grade CT scanning, and other techniques for lithologic description.

Identifying rapid lithofacies

CoreHD outputs include detailed images and logs computed from CT scans of whole core. High-definition CT imaging reveals geological features such as sedimentary structures, textures, bedding planes, and fractures. Density and atomic number data can be cross-plotted to more accurately identify rock units within complex, heterogeneous reservoirs like shales and carbonates. This rich source of data, obtained while the core is still in the sleeve and before slabbing, offers a fast, accurate method for reducing uncertainty and optimizing selection of samples for further analysis.

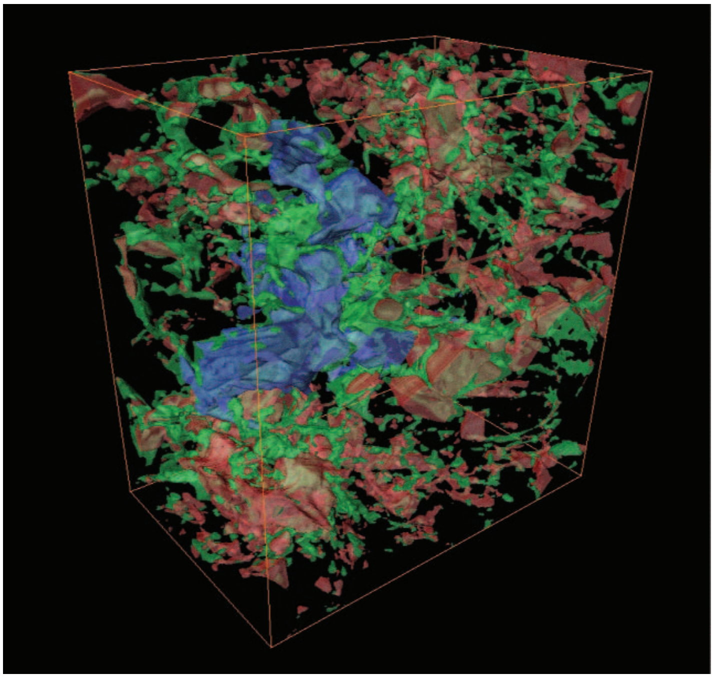
Two outputs from CoreHD reveal the following: A Z-axis image slice from the meter of slabbed core includes one digital cross-section selected from the higher-density plug location. This display gives an enhanced understanding of the density variations through the 3-D volume. Two logs can be computed



Dark areas in the CoreHD image on the left represent lower density. Light gray areas represent higher density. The logs on the right show bulk density and effective atomic number computed from CoreHD data. Abrupt spikes on the logs (lowest density and highest Zeff) correspond to either induced open fractures or areas where core plugs have been taken.

from the CoreHD scans that quantify the bulk density (Rho*b*) and effective atomic number (Zeff) averaged for each of the digital cross-sections. Alternative sampling locations would likely have been selected had CoreHD been used in this case.

Once the optimum sampling locations are identified and samples taken from the lithofacies of interest, the next step is to digitally image the rock samples at the appropriate resolution (ranging from microns to a nanometer). These 3-D images are segmented into pore space, matrix, and grains in preparation for computing basic and advanced rock properties.



An Ingrain vRock, a 3-D digital reservoir rock created from a shale rock sample, shows connected and isolated porosity.

Permanent, reusable rocks improve characterization

Imaging reservoir rock samples coupled with rock property and fluid flow computation allows for fast, accurate results in lithologies for which physical lab experiments have known limitations. In shale rocks, digitally capturing the internal pore architecture at a resolution of as high as 3 nanometers is crucial for determining porosity and pore connectivity; measuring total organic content and TOC connectivity; and accurately computing permeability.

VRocks are digital objects on which fluid flows can be repeatedly simulated using varying parameters for reservoir conditions. For this analysis, geologists examined an Ingrain vRock, a 3-D digital reservoir rock with connected and isolated porosity that was created from a shale rock sample using FIB SEM (focused ion beam SEM). Ingrain computes permeability of the 3-D pore space in the vRock in shale rocks (and all other lithologies).

Digital rock physics brings pore-scale rock characterization to the digital oil field. Using the latest-generation CT imaging and logging allows oil and gas companies to gain maximum value from investments in coring by optimizing the selection of samples for digital rock properties analyses. Digital imaging and computation of rock properties extends and complements the ability of physical core analysis labs to provide basic and advanced rock properties. Digitized reservoir rocks can play a key role in the digital oil field by making rock characterization faster, more accurate, and more readily available to the various technical disciplines involved in maximizing hydrocarbon recovery and asset value. E&P