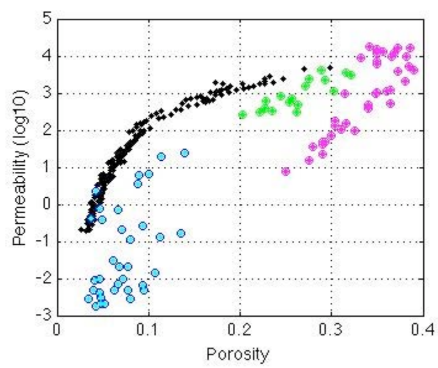
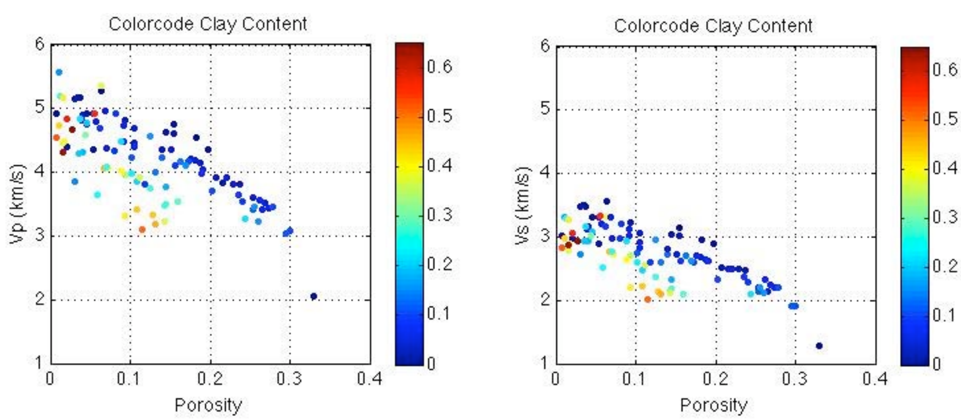
Measuring Sandstones

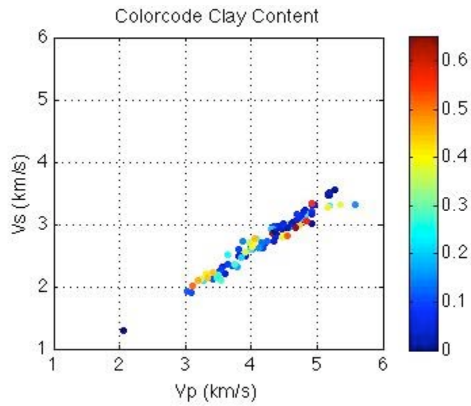
The most studied reservoir rocks, with respect to their transport and elastic properties, are, arguably, medium-porosity sandstones. Most of the knowledge gained from the studies comes from laboratory measurements of both permeability and elastic-wave velocity that have been conducted extensively over the last half-century.



Absolute permeability (decimal logarithm, mD) versus porosity for several sandstone datasets. Black: Fontainebleau sandstone; green and magenta: North Sea sandstone; blue: shaley low-to-medium porosity sandstones.



Velocity versus porosity for fast sandstones, color-coded by the clay content. Left: the P-wave velocity; right: the S-wave velocity.



S- versus P-wave velocity for the data displayed in the previous figure.

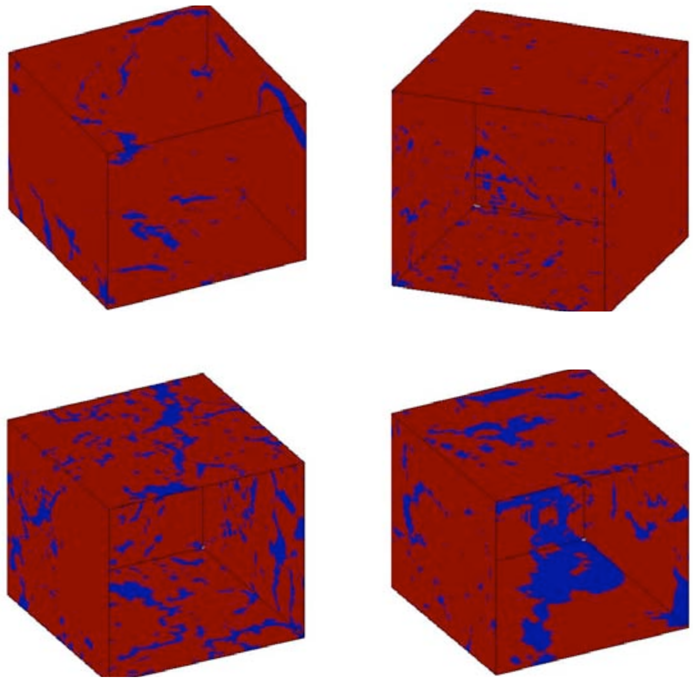
Yet, in spite of the existing extensive sandstone database, additional experimental knowledge is required to plan production in newly discovered fields and to tap undrained hydrocarbon pockets in the existing fields and, by doing so, increase the recovery rate.

Physical experiments on newly delivered sandstone samples require significant time, effort, and cost, which are associated with core recovery, core delivery to the laboratory, and operating somewhat complex laboratory equipment.

Because of these obstacles, more and more often the industry uses wells as a physical laboratory because modern well logging tools can provide fairly accurate assessments of the elastic properties, density, mineralogy, and porosity.

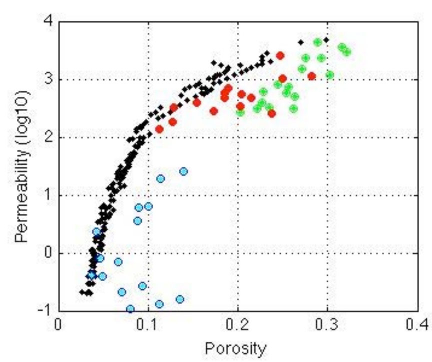
The only crucial property that cannot be unambiguously inferred from the well is permeability, especially relative permeability. This is where digital experimentation on accurately imaged fragments of rock becomes indispensable.

Accurate 3D digital imaging of the matrix and pore structure, with resolution as fine as dictated by the nature of samples under examination, can be conducted on essentially any rock material that is readily available at the drill site, whether it is sidewall percussion plugs or drill cuttings.



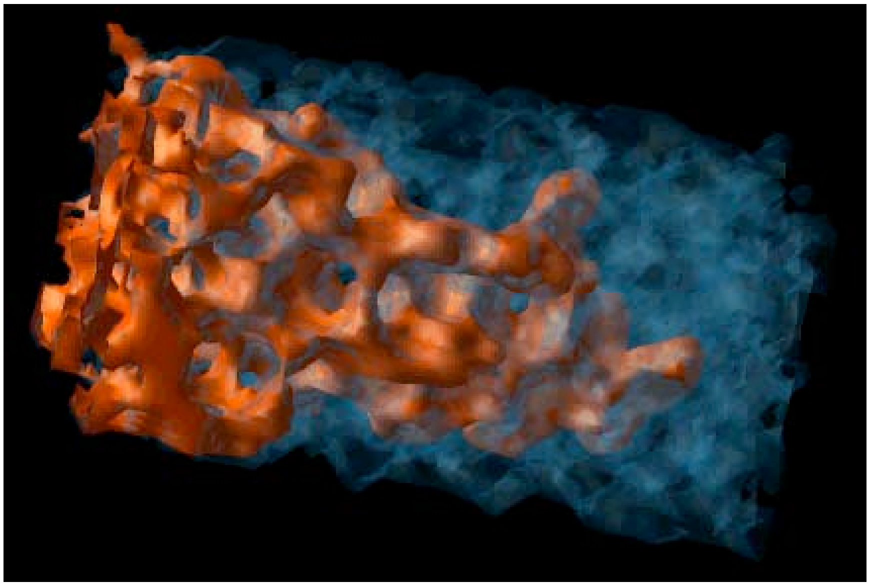
3D micro-CT images extracted from four drill cuttings, showing low porosity (top) and medium-to-high porosity (bottom).

Calculations are conducted on these digital objects to compute the elastic and, most importantly, transport properties of rock under examination. Such absolute permeability results are displayed below and appear reasonable, as they favorably compare with the previously generated physical data.



Absolute permeability (decimal logarithm, mD) versus porosity for several sandstone datasets (same as in the first figure) with digital results added (red). The digital results come from simulating one-phase flow on rock material from drill cuttings and fragments of core.

The most significant capability of the digital technology is perhaps the ability to simulate multiphase flow in the digital image of rock material, thus yielding transport properties such as relative permeability as well as providing insight into extremely complex processes of transient fluid displacement.



Computer simulation of oil dynamically displacing water in sandstone.

About Ingrain

Ingrain's digital rock physics lab computes the physical properties and fluid flow characteristics of oil and gas reservoir rocks. Our technology leads the industry in providing advanced rock properties analysis for shale, carbonates, tight gas sands and oil sands. Using core plugs or even drill cuttings, Ingrain can deliver accurate results as fast as 14 days.

A trained geologist uses micro- and nano- resolution CT scanners to digitize the fabric of each rock sample. Each set of scans is combined and segmented to create a vRock – a high resolution 3D image of the actual pore network and grain structure. Our supercomputing clusters use proprietary algorithms to computer rock properties and fluid flow characteristics from each vRock:

Physical Rock Properties

> Porosity

> Absolute permeability in three axes

> Electrical properties in three axes

> Elastic properties, including compression and shear acoustic velocities, Bulk modulus, Young's modulus, Shear modulus, and Poisson's ratio

Multiphase Flow

> Two-phase relative permeability: water-oil, gas-oil, and water-gas displacement at different wettability indices and viscosity values in three axes

To learn more about Ingrain's services and the science we use, please visit www.ingrainrocks.com
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