Aspect Imaging Geology MRI

Rock Core Analysis

Recently, there has been a paradigm shift in the use of MRI in core analysis: magnetic imaging techniques have been shown to be preferable in optimizing rock analysis, and results compare favorably and may exceed those derived from well-logging techniques.

The use of NMR/MRI in 'rock-core-analysis' has many potential applications and holds real, tangible and immediate benefits throughout the industry. Using NMR/MRI reduces formation damage, facilitates the extraction of higher proportions of hydrocarbons from the formations, and enables faster drilling into more optimal pay zones.

It is now possible to perform detailed and rapid rock precocity studies and obtain detailed information about the internal makeup of rock and core samples, thus maximizing extractions from drilling operations. This will, in turn, maximize returns on newly drilled and existing reservoir assets. Additionally, this technology complements existing logging tools, enabling extrapolation of results to provide real returns on existing technology investments.

The use of MRI for Rock-Core Analysis

In order to optimize the recovery of oil from reservoirs, the physical properties of the rock and the fluid contained within it, need to be analyzed so as to accurately assess remaining oil reserves and the practicality of extraction. With oil companies looking not only to economize, but to operate in more environmentally-friendly ways, enhanced oil recovery (EOR) methods are becoming increasingly economically viable. Such methods include polymer or CO2 injection.

Magnetic Resonance Imaging (MRI) is a widely-used and effective technique used in many clinical, life science and materials science applications. The proven effectiveness of this type of analysis could prove to be a valuable solution for the oil industry in its attempt to find an economical and efficient method of conducting rock-core analysis.

Unfortunately, laboratory-scale MRI did not prove to be the core analyst's panacea envisioned in the early 1990s. It was found that the higher magnetic fields used in typical MRI systems were unable to produce satisfactory image resolution when applied to heterogeneous porous media, such as oil or water-bearing rock, making it difficult or impractical to properly identify the relative make-up of the solid and fluid content of the rock sample. The main problem in the use of high-field systems is the strong magnetic susceptibility contrast between the solid and fluid, resulting in strong 'internal' gradients and image artefacts. As a result, using MRI to analyze core plugs came to be seen as an inappropriate and unnecessarily expensive method of analysis, and of limited use to the oil industry, resulting in the steady decline in the use of this type of magnet.

Recently however, there has been a paradigm shift in the use of MRI in the area of laboratory-scale petro-physical rock-core analysis. The focus is now on acquiring data in the laboratory that are directly comparable to data obtained from magnetic resonance well-logging tools. In technical terms, this means that the laboratory analysis of rock-core samples has to be consistent with well-logging instrumentation and be able to accurately measure distributions of transverse (T2) relaxation time—the industry-standard metric in well-logging—at the laboratory scale.

This is where the use of low- and mid-field magnets in the laboratory environment came to the fore. High-field magnets induce relatively large susceptibility-induced internal gradients, which in turn, reduce image quality and produce image artifacts. In contrast, low-mid field systems are optimal for core analysis as they minimize these susceptibility effects. Although an ideal analysis would involve on-site measurements of all the relevant rock properties, the current wireline technology utilized in the well-logging process is unable to accurately record certain key measurements. As such, laboratory-scale studies of cored reservoir material are a critical component in oil exploration, production, and monitoring.

Understanding of oil recovery processes at the laboratory-scale is vital for generating accurate models to predict field-scale performance in the reservoir. A variety of disciplines are encompassed by the broad term ‘‘NMR’’, the predominant being spectroscopy, imaging, and time domain analysis (spin relaxation and diffusion). All three concepts can be combined in a single measurement (although the hardware requirements of the acquisition modalities can be very different depending on the application).

Through combining MRI and NMR techniques, the core analyst is able study various petro-physical phenomena. Areas of current interest include the application of MRI to *in situ* monitoring of forced displacement of oil (including EOR methods), rapid capillary pressure curve measurements, and wettability alteration.

Briefly, the main applications of MRI in core analysis can be summarized as follows:

- Monitoring capillary adsorption.
- Monitoring forced displacement of oil
- Clay swelling and mud infiltration.
- Relaxation time mapping
- Heterogeneity mapping — Rapid (quantitative) imaging techniques.
- Structure and flow mapping—Rapid (qualitative) imaging techniques developed for medical MRI have been used to determine structure and fluid transport in core-plugs.

- Porosity and saturation mapping—Accurate measurements of local porosity and fluid saturation; ideal for monitoring forced displacement of oil.
- Capillary pressure curve measurement—Quantitative intermediate-field imaging using Single Point Imaging (SPI) for saturation profiling and measuring capillary pressure curves.
- Monitoring imbibition and recovery processes—This typically slow process is ideally monitored with MRI.
- Fluid transport—MRI has the capability to spatially resolve the distribution of multiple fluid-phases within a rock core-plug.

<u>Conclusion</u>

Our continued development of, and investment in, mid-field NMR hardware and techniques has enabled the possibility of low-field MRI methods to be used to determine a range of petro-physical properties, including porosity, wettability, and capillary pressure. Accordingly, low-field MRI is now gaining popularity in core analysis, and Aspect AI Ltd. is at the cutting edge of all the latest innovations in the field.

<u>Preliminary examples of dynamic heterogeneity mapping in rock cores:</u>

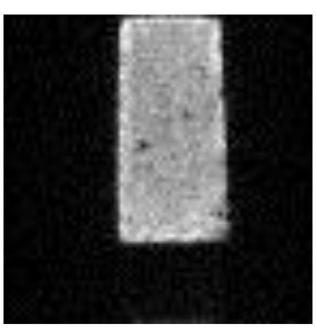
The images are of a core from Bentheimer Sandstone.

The core was immersed for several days in Brine (5% wt NaCl). Images were acquired after removing it from the solution and letting it dry out in the magnet. The images were acquired with a standard SE sequence, with TE = 10.5 ms. The slice thickness is 2 mm, and the in-plane resolution 1x1 mm.

7 minutes

2:24 hrs

6:31 hrs



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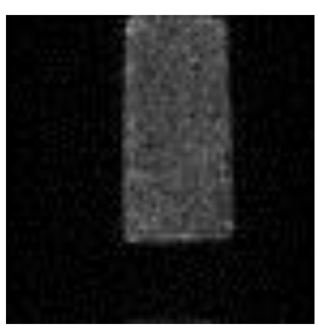

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6:22 hrs

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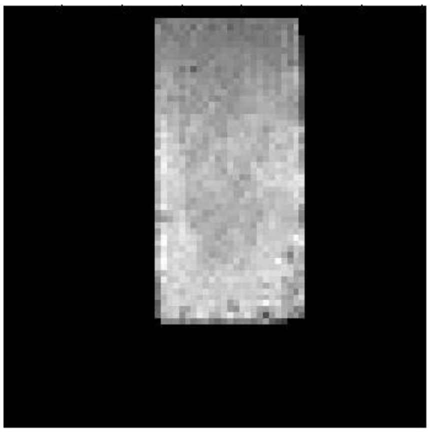
The following images are from T2-mapping experiments:

Spin-density map, obtained from the fitted intensity at TE = 0



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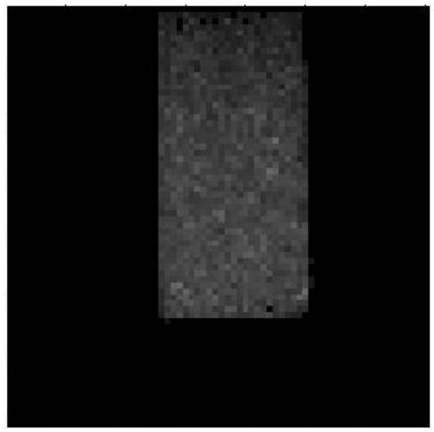

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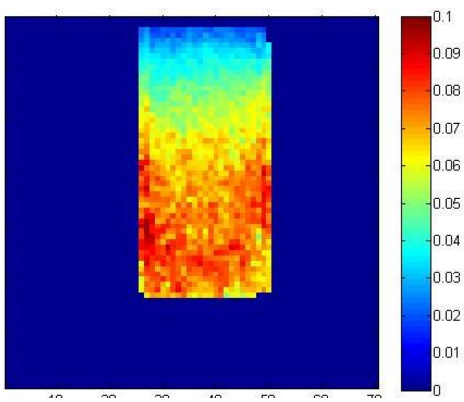
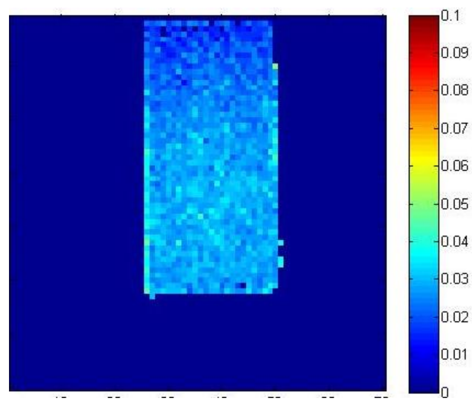
T2 map color-bar scale in seconds:





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