SCAL Workflow for Unconventional Reservoir Rocks

Customer Need

Core from Unconventional Shale-Oil Reservoirs present numerous challenges in the laboratory. The tight, fine-grain nature of these reservoir rocks present unique challenges for reliable and repeatable measurements of saturation and permeability.

The fragile nature of many shale cores affects how core plugs are prepared for analysis, in many cases results are dominated by fractures and partings in the sample, proper sample preparation techniques are critical for representative measurements.

Methods and Materials

Figure 1: The steady state permeability apparatus used in this example had the capacity to measure permeability on four 1" Ø core plugs simultaneously.

The Premier workflow was developed to handle a broad range of low-permeability (nano-Darcy) rock types; optional ancillary measurements define key petrophysical parameters such as organic matter bound residual hydrocarbon.

The initial step is to screen all core plug samples with Micro-CT at a resolution of 50µm to identify those samples with obvious cracks and flow barriers that would influence dynamic permeability tests. A specialized "trim and pot" technique was developed removing cracked sections and barriers encapsulating the remainder with resin forming cylindrical samples that fit in the permeability apparatus.

"Potting" increases the number of usable samples from damaged or fractured sections of core allowing more representative permeability measurements along the various geology of the core.

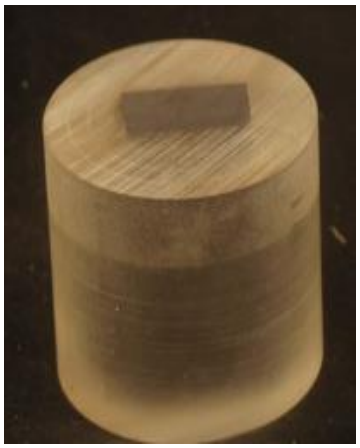

Figure 2: Example "potted" unconventional reservoir rock for permeability measurements.

Low-field NMR T_2 measurements are collected on the as-received core plugs to determine total liquid content. Often as-received samples have lost as much of 50% of the initial liquids during the coring and handling process. This information is combined with pore volume measured by helium gas porosimetry to provide a sum-of-fluids estimate of total pore volume and porosity.

Samples are pressure saturated with decane at 150°F and 2000psi for several days in order to fill all of the pore volume with liquid. A second

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low-field NMR measurement provides an estimate of total liquid-filled pore volume, i.e. total porosity. The T_2 relaxation time distribution provides volumetric measurement of oil and water in the sample.

A built-for-purpose apparatus measures steady-state permeability to oil on four unconventional core samples. Crude oil or a light mineral oil is injected at constant flow rates into the core plugs using very precise syringe pumps that monitor the injection pressure. A constant back pressure of 500psi is applied across all samples; along with a constant net confining stress of 3000psi. Samples are heated to 150°F, which has the advantage of solubilizing residual hydrocarbon into the decane. The pressure difference along the core plug is measured at multiple flow rates. The pressure gradient data is used to determine permeability using the graphical solution to the Darcy's law equation. Effluent from the flow test is collected for mass balance QC considerations and is made available for chemical analysis, if required.

A final low-field NMR measurement is acquired after the SSK_{Oil} measurement to verify total fluid volumes and saturations did not change during the permeability test.

A number of ancillary tests can be run on these samples or companion trim pieces at various stages of the workflow. These include high-resolution SEM to characterize the pore space, mineralogy and texture of the sample at nanometer resolution. X-ray fluorescence, low-pressure gas adsorption for pore size distributions, thermal analysis for clay-bound water and hydrocarbon residuum, and advanced NMR techniques like T_1-T_2 mapping to infer relationships between oil/water and pores.

Results of the Analysis

This workflow highlights a four-year cumulative effort of many renowned scientists in the core analysis field. Rigorous validation studies were performed for each step. NMR T_2 measurements were validated against conventional extraction techniques. Round-robin studies of the permeability measurement found it is 95% reproducible. High resolution X-Ray Micro-CT and tracer flow-through tests verified perfect adhesion between the rock and resin for "potted" samples.

Discussion

The unconventional reservoir workflow (outlined in Figure 3) at Premier is the most comprehensive analysis of shale available and is customizable to address specific customer needs. This workflow has been used on thousands of unconventional reservoir rock samples all over North America. Ancillary measurements add value to the workflow providing additional petrophysical and geologic information. The Premier professional staff are available to assist in the interpretation of the results.

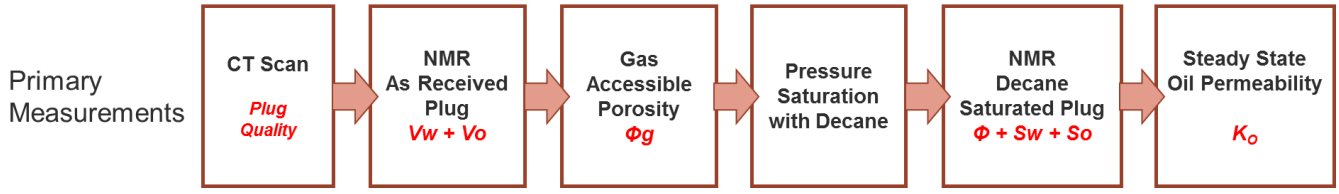

Figure 3: Primary steps in the Premier Oilfield Laboratories SCAL workflow for unconventional reservoir rock. Optional measurements include high-resolution imaging, gas adsorption pore size distributions, XRF, thermal analysis, and advanced NMR techniques.

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