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Regional Report: INDIA

BALANCING ACT
Risk management strategies promise firmer foundation
New approach describes the indescribable

An innovative application of advanced mathematics has provided geoscientists and engineers with an accurate, model-independent way to predict critical reservoir properties from well log data.

For centuries, inventors have used models to predict the behavior of their inventions under various environmental conditions. Model airfoils convinced the Wright brothers that heavier-than-air flying machines could transport people into the heavens. Model hulls proved the viability of offshore vessels, including drilling rigs, long before the actual vessel was built and launched. Today, dynamic reservoir models and mechanical earth models help engineers characterize the way reservoirs will behave under production or stimulation.

Yet the model-based approach has its disadvantages. Whereas reservoir behavior can be characterized using models constructed from evolving formation data, reservoir description still depends on painstaking, time-consuming analysis of rock and fluid samples, both involving discrete parameters. Application of models to predict accurate discrete parameters in complex media has proven to be impractical; there are too many possibilities.

About 10 years ago Bob Freedman, a scientific advisor and project manager at Schlumberger, developed a new method based on radial basis function (RBF) mapping for accurately solving complex reservoir characterization problems. The method was first introduced to the industry in a paper published by Freedman in the SPWLA Petrophysics Journal, V. 47, pp. 93-111, 2006. The new method relies on databases acquired on reservoir rocks and fluids to accurately represent the complex physics. Over the past few years, considerable success has been experienced in the accurate prediction of critical rock and fluid properties that are difficult to impossible to measure in situ.

Successes exemplify value

In the recent past, determination of the properties of live oil samples was time-consuming and problematic. Physical and empirical model-based methodologies were used to relate crude oil properties to nuclear magnetic resonance (NMR) measurements. Nevertheless, critical properties were difficult to determine because of the inherent complexity of crude oils. The physics connecting the NMR measurements to the oil properties are contained within a laboratory database of NMR and pressure-volume-temperature measurements performed on a representative suite of live oil samples. By mapping NMR measurements such as $T_2$, for example, to live oil properties such as viscosity or molecular composition, properties of samples not in the database can be estimated with accuracy. A mapping function that is a linear combination of Gaussian radial basis functions is calibrated using the database and is applied to predict the desired properties.

The power of RBF mapping for crude oil description is just the tip of the iceberg. The technique can be used to...
predict virtually any parameter for which a representative database can be developed.

**From innovation to breakthrough**

The RBF technique has been applied to the prediction of effective permeability from well log data. Effective permeability has been one of the most elusive parameters facing reservoir and production engineers. Complexities in mineralogy, lithology, and pore geometry, to name a few, have made determination of this fundamental mobility parameter virtually impossible to predict. Formation testers can provide spot measurements of fluid mobility; however, these are only valid at the exact spot of the test. Connecting the dots has been pure guesswork.

The famous Archie saturation relationship is the basis of modern well log interpretation. Yet this relationship contains saturation and cementation exponents that are just now beginning to be determinable. For NMR interpretation, petrophysicists have had to choose between the Timur-Coates and Schlumberger-Doll Research empirical models to estimate effective permeability to oil. These model-based techniques work reasonably well under a limited set of conditions. Elimination of models provides for the first time the ability to predict effective permeability to oil under any condition.

To develop and prove this application, a worldwide database of 104 whole core samples (79 sandstone and 25 carbonate) was developed from precise laboratory testing. Parameters such as irreducible water saturation, effective permeability to oil, and NMR T2 distributions were measured under tightly controlled conditions. From these data, radial basis mapping functions were developed whereby effective permeability to oil could be accurately predicted from readily available well log information. Extending the application of RBF mapping techniques, such parameters as molecular compositions, saturations, aromatics, resins, and asphaltenes; fractions; and viscosities of live crude oils have been estimated with unprecedented accuracy.

**Field examples prove the point**

A complex lithology example is represented by a well drilled using synthetic oil-based mud. Density, neutron, and resistivity logs were acquired while drilling. NMR and formation pretest fluid mobilities were acquired using wireline tools. Figure 1 shows the results. The lithology is a highly complex mixture of sandstones, clays, muscovite, and dolomite (right-hand track). Oil is predominately indicated in the clean high-porosity sands. The computed effective permeability to oil (mobility) is shown in Track 2, with good agreement to the oil mobility test points from the pretest pressure tool (green dots). While the effective permeability curve appears as a continuous black line, it is only valid in the oil sands. A completion design that focuses on the high-permeability peaks should provide the highest productivity.

A deepwater well provides the second example (Figure 2). While the sand body that represents the target reservoir is relatively large and contiguous, porosity and permeability are much lower than the previous example. Despite the uniform appearance of the sand body, the mobility curve shows several breaks with very low relative permeability. Accuracy of the permeability prediction is confirmed by good agreement with the pretest pressure mobility points in Track 2. Selective perforating can avoid the tight spots and maximize flow into the completion, especially in the shaly portion seen at the bottom 15 m (50 ft) of the reservoir.

**A new paradigm**

The success in accurate prediction of critical parameters in complex situations is highly encouraging. It has proved to resolve issues that have plagued producers for decades. In a macro sense, the application of RBF mapping heralds a breakthrough in formation and fluid characterization and hints at potential applications in well stimulation analysis and prediction as well as enhanced recovery design and evaluation.