MULTIWELL DIGITAL WIRELINE TECHNOLOGIES

TECHNOLOGY CONNECTIONS
PETROLEUM TECHNOLOGY TRANSFER COUNCIL

BOTTOM LINE

There are many cost-effective approaches to quantitatively describe reservoirs to help operators select and implement improved recovery technologies. They include digital capture of existing wireline log data, analysis through digital maps and cross-sections, and calibration of wireline petrophysical data using core analysis results.

PROBLEM ADDRESSED

A large amount of petroleum remains in geologically complex reservoirs in a mature to super-mature state of development. Accurate reservoir models on a well scale, and even on an interwell scale, are necessary to target, contact, and retrieve this remaining petroleum. Building such reservoir models requires a consistent and accurate analysis of multiple wells that quantitatively describe changes in petrophysical properties throughout the 3-D extent of the reservoir. Techniques that make use of existing log data are necessary to maintain cost effectiveness.

KEY WORDS:
Digital Logs
Log Analysis Software
Core-Log Models
Rock-Typing
Reservoir Characterization
Permeability Prediction

TECHNOLOGY OVERVIEW

New techniques, based on neural networks, are available for converting wireline logs from paper to digital format. As a result, data analysis is more accurate and cost-effective. Using low-cost, PC-based software tools, operators can digitize a large number of logs, thus facilitating reservoir-wide analysis. New multiwell-focused log analysis software makes it possible for operators of most US reservoirs to quickly complete the voluminous data-processing tasks associated with field-wide wireline log analysis.

The software package, PfEFFER (**P**etrofacies **E**valuation of **F**ormations **F**or **E**ngineering **R**eservoirs), developed at the University of Kansas/Kansas Geological Survey, is an "add-in" program to Microsoft Excel. The software provides basic log analysis capabilities for general reservoir description by the non-log analyst. Its options allow the highly integrated and iterative study of reservoir data, and multiple wells can be handled collectively. Its capabilities include: reservoir zonation, flow-unit identification, mapping, cross sectioning, and gridding for simulation. Comparative evaluations of multiple interpretations can be performed using best case/worst case extremes, in addition to sensitivity analysis on logging equation parameters.

Core-log modeling attempts to develop correlations between wireline log response and properties observed in reservoir samples. Several core-log modeling activities have been undertaken in developed reservoirs using existing logs in digital form to predict petrophysical properties, such as permeability and/or remaining oil saturation (pay). Once developed and verified, core-log models can be used to predict those properties over the expanse of the reservoir.

In some instances, the approach taken is only slightly more sophisticated than the traditional reservoir-wide scatter plotting of core porosity vs. permeability. This includes looking at porosity-permeability relationships within mappable reservoir zones or facies. In some cases, however, a fundamental study of the reservoir's basic pore systems (including fluids present, and the physics of wireline tools used) is necessary to develop a usable model.

Primarily based on the following PTTC workshops:

"*Advanced Applications of Wireline Logging for Improved Recovery*," held November 13, 1997, in Midland, TX (Texas Region), and January 13, 1998, in Denver, CO (Rocky Mountain Region), and

"*Modern Techniques in Wireline Logging*," held November 19, 1998, in Wichita, KS (North Midcontinent Region)

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LESSONS LEARNED

1. There is no single recipe for developing a reservoir-wide quantitative petrophysical model from wireline log data. In many, if not most, cases, several attempts were made before finding an approach that worked. This is especially true for core-log models.

2. In developing these models, operators have learned the value of maintaining consistency in logging programs within a given reservoir, particularly the importance of obtaining the best data possible by adhering to proper protocol and hole conditions during data collection.

3. From these observations, the seeds for future development of more useful tools, combinations of tools, and logging procedures for reservoirs are being planted.

FIELD RESULTS

PfEFFER played a critical role in developing a reservoir model for simulation at the Schaben Field in western Kansas. Drilling infield locations and performing recompletions resulted in an initial production increase of 350 barrels of oil per day (bopd) in this field producing from shallow shelf dolomites of Mississippian age.

A rock-log model was developed to obtain continuous permeability profiles at the North Robertson Clear Fork Unit (Permian) in west Texas. It was based on gamma ray, photoelectric capture cross section, compensated neutron porosity, compensated formation density, dual LateroLog, and caliper curves This process involved studying pore geometries and identifying the end-member rock types containing those geometries, using digital log data in a series of cross plots. It also involved assembling conventional scatter plot relationships of core porosity vs. core permeability for each of the identified rock types. The appropriate scatter plots were used to convert log porosity to permeability after a foot-by-foot identification of rock type using the developed cross plots. Permeability profiles served as the basis for establishing flow units and, ultimately, a 3-D reservoir model.

In the West Welch San Andres Unit (a Permian shallow shelf carbonate) in west Texas, pore systems were studied in detail and laboratory analyses of multiphase fluid flow properties were performed. Laboratory data were used in conjunction with the Carmen-Kozeny equation. This equation relates permeability to porosity through pore geometric factors—such as tortuosity and surface area. The approach arrived at a digital-log-based method for predicting continuous permeability curves from existing logs. The resulting reservoir description is vastly improved.

In the Nash Draw reservoir in New Mexico, the operator used sidewall core and conventional core data to develop a core-log model based on resistivity and gamma ray logs to identify thin pay zones in Delaware (Permian age) turbidite sands. In terms of resolution and accuracy, the results matched those obtained from an NMR log.

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