NEW WIRELINE TOOL CAPABILITIES

BOTTOM LINE

New wireline logging technologies make it possible to collect reservoir property information critical to reservoir decision-making that used to be obtainable only from riskier, more expensive oriented and native-state coring.

PROBLEM ADDRESSED

Detailed and accurate reservoir and wellbore descriptions in mature reservoirs are needed to profitably implement improved recovery technologies. In many such reservoirs, critical data have been lost (e.g., core samples) or were not collected during reservoir development. Alternately, existing data may be too sparse or the quality too poor for reservoir decision-making. The supplemental data needed are obtainable by oriented and native-state coring. However, these options are often prohibitively expensive and they tend to put wellbores at much greater risk than wireline tool methods.

KEY WORDS:

Borehole Imaging
Nuclear Magnetic Resonance (NMR)
Cased Hole Logging
Fluid Saturations
Anisotropy
Reservoir Characterization

TECHNOLOGY OVERVIEW

Rapid improvements in resolution, versatility, and reliability, plus substantial decreases in cost, have made borehole imaging logs the "logs of choice" for obtaining a wide variety of geological and petrophysical data. Multipad microresistivity tools have evolved from the dipmeter tools of the 1980s, and now provide nearly complete circumferential coverage of the borehole at high vertical and lateral resolution. The new tools measure differences in resistivity of the formation at the borehole face and present the information as computer-processed pseudo-images. Acoustic-based imaging tools measure differences in acoustic impedance at the borehole surface and computer processing of that information leads to similar high-resolution pseudo-images.

Primarily based on the following PTTC workshops:

"*Structural and Stratigraphic Interpretation of Borehole-Imaging Logs*," held on October 22, 1997, in Denver, CO (Rocky Mountain Region)

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

This summary also includes information from: "*Modern Techniques in Wireline Logging*," held November 19, 1998, in Wichita, KS (North Midcontinent Region)

The choice of a resistivity versus an acoustic imaging tool is dependent upon borehole conditions and the types of lithology and features of interest expected in the formation under scrutiny. Both types of tools yield information on vugs, fractures (e.g., density, orientation, and aperture), regional stress direction, faults, sedimentary structures and bounding surfaces. Both provide insight into interwell scale heterogeneity, identification of thin pay zones and cemented areas, and borehole condition (e.g., washouts, keyseats). Acoustic imagers also have application for inspecting casing conditions. Both types can be used in vertical and horizontal wells.

Nuclear Magnetic Resonance (NMR) tools measure the radio-frequency response of protons in reservoir fluids as they re-align after introducing a pulsed magnetic field. The timing of these emissions is sensitive to characteristics of fluid type and rock-fluid interaction. Information with high (6 in) resolution can be obtained on fluid types (both water and type of hydrocarbons present), mobility/immobility of fluids, porosity, and permeability.

These tools provide more robust measurements of clay-bound water and microporosity, leading to more accurate distinctions between sandstones and shales compared to conventional neutron and density tools. The main strengths of NMR technologies involve better identification of pay zones (including gas) and more accurate reserves calculations.

Until recently, a disadvantage of NMR tools has been that they must be run as much as 10 times slower than

conventional neutron and density porosity tools. Recent trials, however, enabled successful identification of bound fluids and permeability prediction by running NMR tools at high speed. Conventional neutron and density tools were run simultaneously to capture porosity information.

LESSONS LEARNED

(1) Plan ahead. Operators should know what kind of information they are seeking before starting. The appropriate borehole environment and tool combination should be designed with the help of a logging service provider.

(2) Pay attention to logging protocols and borehole conditions when the tools are being run.

(3) Calibration is always the key to success for a first-time tool application in any reservoir. Most tools cannot be applied universally. Operators should take the time and effort to compare tool results to core data and to other logs.

FIELD RESULTS

Borehole imaging logs identified unconformities and sediment package bounding surfaces that define critical reservoir compartmentalization on the inter-well scale and larger scales. Examples include the Bakken Shale in the Williston Basin and the Tensleep Sandstone in the Bighorn Basin.

Microresistivity imagers were used to obtain fracture orientation and stratigraphic distribution. These tools also helped to identify thin pay zones for future development in a new, successful Green River Formation waterflood in Utah's Monument Butte area. Waterflooding of this high-heterogeneity, low-permeability reservoir has increased reserves from 330,000 to 1.2 million barrels of oil, even though the fluvial-dominated-deltaic sandstone reservoir contains highly paraffinic oil.

In the west Texas Spraberry Trend, fracture orientation is being studied by borehole imaging in horizontal wellbores. The goal is to determine the best orientation to maximize recovery from CO_2 flooding of these low-permeability turbidite sandstones.

NMR logs have been run on selected wells in the turbidite reservoirs of the Spraberry Trend and Nash Draw Field in west Texas and New Mexico, respectively. They have enabled the operator to gather information on wettability/hydrocarbon mobility and to identify thin bypassed pay zones. In each case the NMR log was used as a confirmation tool by comparing its identification of pay intervals with those from core-log models developed with conventional logs.

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