Downhole Geological Technology: Evolution, Breakthroughs and Emerging Solutions to Assessing Discoveries and Finding New Oil In and Around Old Fields

By

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There have been technology breakthroughs in nearly every phase of "downhole technology" which are and will change the way exploration geologists do wildcat assessments and development geologists characterize, model and help manage reservoirs in the next century.

When well logging began 70 years ago, the petroleum industry made no core permeability measurements and had no knowledge of irreducible water within oil zones. Today, however, nuclear magnetic resonance (NMR) is beginning to be used for permeability profiling, a dream come true, and is revealing micropores filled with water. The use of NMR is resulting in less early water and thus more oil production. Moreover, 70 years ago cores were not used just for formation evaluation and petrophysics, but often for geological correlation, an application soon replaced by electric logging. Another dream about to come true is the use of well logging detection and correlation of magnetic reversals and continuous logging of chronostratigraphic markers, which are being scientifically tested as part of the Ocean Drilling Program. Thus, magnetic well logging research and development which began in the 1950's is finally solving long standing problems of petroleum geologists.

The very first logging measurements, spontaneous potential (SP) and resistivity were tested for the first dipmeters in the 1930's, but it was resistivity that became the workhorse measurement for future dipmeter tools and later for the first commercial imagery tool. Dipmeters went from stationary measurements to three continuous resistivity measurements for correlation and these later were replaced by tools with four measurement electrodes and then six and finally with 8 electrodes for correlation. During the field tests of the prototype 8 electrode dipmeter (SHDT) in 1979 it became clear that adding a few more electrodes was not enough to define highly complex structure not to mention thorough fault characterization, fracture analysis, or the most common sedimentary structures encountered. In the very last field test well the numerous repeat logging runs when merged together resulted in total measurement coverage of the borehole wall. This data when compared to the core confirmed the need for an electrical image or a scanning tool. Thus, the evolution of electrical imagery which has culminated in the 192 electrode imagery with greater than a centimeter vertical resolution began 20 years ago. And because of this evolution and insight standard dipmeters are now an obsolete technology because of their undersampling of formation resistivity characteristics and geometrical uncertainties, although still run in areas of very simple structure or in oil-base mud.

The immediate challenge in borehole imagery of any type is for better geological interpretation and quantification for formation evaluation. Just a few years ago no one asked for a one centimeter or even a one inch resolution to borehole measurements. With the recent discovery of major turbidite reservoirs in the Gulf of Mexico and other areas of the world such a resolution is now being asked requested. Fortunately, pioneering work by a few companies is going on in this area.

The success of resistivity imagery logging has led to its use in logging-while-drilling (LWD) and GeoSteering for directing well trajectories with real time dips and images while the well is being drilled. The demonstrated value of resistivity imagery while drilling and the ever increasing use of horizontal and extended reach wells will lead to many other developments. Although little known, a new LWD tool which provides imagery of density/porosity and also lithology variations has just been introduced.

The new large-scale insight gained from imagery in horizontal and extended reach wells is that there are more faults in reservoirs and exploration prospects than are generally mapped. And it is also confirmed by newer 3-D seismic and some of the latest processing techniques. The uncertainty is whether these smaller faults will behave as conduits, barriers or baffles. Is their geometry and orientation similar to the larger faults defined by seismic? The integration of seismic and borehole technologies is beginning to show that their properties and behavior are not random but rather have some order that can be geologically characterized when adequate data is available. In some reservoirs these faults are creating compartments with by-passed oil while in other areas of the same reservoir they can be serving as permeable conduits. Fortunately, the amount of research and development being addressed to fault characterization suggests that many of our present uncertainties will be eliminated.