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Technique adds to reservoir understanding

Advanced technologies such as crosswell imaging are being used more often to provide a level of ultra-high resolution information that can reliably support drilling, production and EOR operations.

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It is commonly understood that one of the true focuses of today's oil and gas industry is optimized production throughout the lifecycle of a field. Along with that focus, there is a growing understanding that the ability to better visualize the structure and characteristics of a reservoir and the interwell space surrounding it is one of the keys to realizing true production optimization of a reservoir throughout its lifecycle. A better understanding of the reservoir, including its structural and fluid dynamic characteristics, is essential to optimizing its production value at all phases of its life — exploration, primary recovery, secondary recovery, tertiary recovery and abandonment. Given the market impetus, the technology available to assist in the visualization of reservoir characteristics has evolved to meet that need. And this expanding ability to generate a more detailed view of the reservoir and its structural characteristics is now providing for a more accurate drilling effort and optimized production over the life of the reservoir.

Crosswell imaging

One technology currently being effectively used to assist in the visualization of the reservoir and its interwell environment is crosswell imaging. Crosswell imaging is on the leading edge of reservoir visualization technology, providing for the first time a true high-resolution view of the interwell area, including the reservoir and its structural characteristics. In contrast to conventional surface seismic, crosswell imaging goes beyond providing a basic aerial view of the reservoir, filling in what has been a dearth of information concerning the vertical space between wells.

Crosswell imaging produces a heretofore unheard-of depth of data to generate this high-resolution view, up to 100 times greater than the imaging resolution of surface seismic. Crosswell operations normally employ a transmitting source, which is lowered into one well, and a series of receivers, which are lowered into one or multiple adjacent wells. Specially engineered sound waves (typically 100 to 2,000 Hz) are passed between the source and receiver, traveling through the interwell section. Positioned at appropriate locations within a given reservoir, the source and receivers are moved vertically through the well bore, passing sound waves through the interwell area at various depths. This vertical movement of the source and receivers allows the sound waves to project across the interwell area at various angles, providing even more detail of the interwell environment between them. Since this data can be generated for up to a kilometer between wells, detailed information concerning the interwell section and reservoir is provided over a broad expanse of space.

The specially engineered crosswell sound waves that are transmitted from the source to the receivers attenuate at different rates, depending on the material they pass through in their travel through the interwell area. The changes in those sound waves as they are transmitted from the source to the receiver provide detailed imaging of the interior of that interwell area since the attenuation level of the signal correlates to specific reservoir properties. Of special interest is the fact that attenuation response is an accurate indicator of such key reservoir properties as porosity, permeability and saturation conditions. Armed with this knowledge, production personnel are now better equipped to more precisely locate and more efficiently exploit areas of the reservoir that project the optimum permeability conditions and offer the greatest production potential.

***Figure 1.** Soundwaves are transmitted from sources to receivers in the crosswell process. (Images courtesy of Z-Seis)*

Better reservoir understanding

With the increased use of crosswell imaging in the development of highly detailed attenuation studies, reservoir engineers now have an effective tool for accurately compartmentalizing reservoirs. These same studies also provide a better understanding of partially saturated reservoirs and rock permeability. In addition, crosswell imaging is capable of detailing fluid mobility and reservoir dynamics during enhanced oil recovery (EOR) operations.

Historical attempts at gauging permeability using surface seismic tools have delivered mixed results, due for the most part to the inherently thin nature of permeable zones. These critical zones can escape notice in the context of lower-reso-

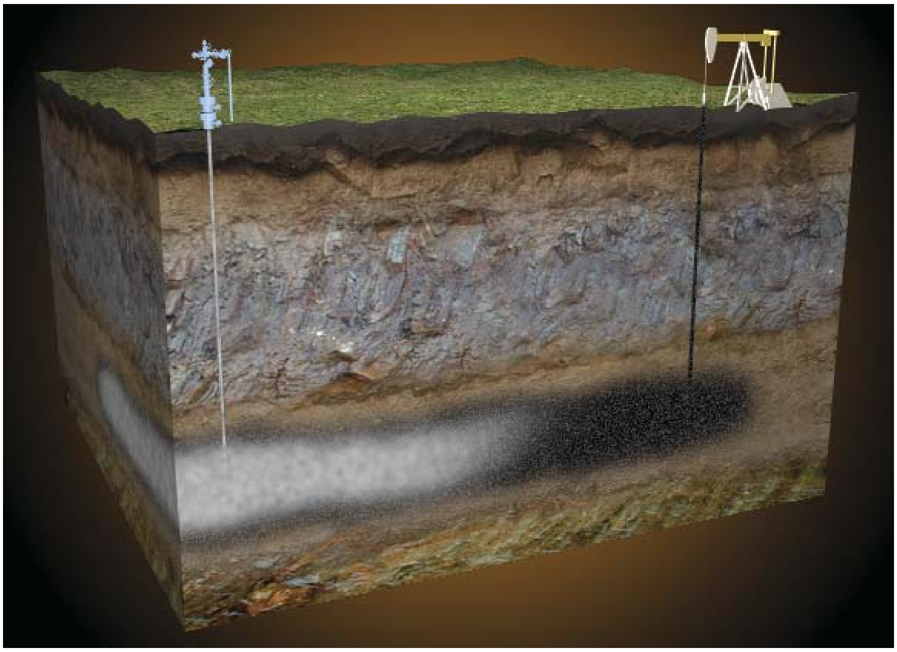

Figure 2. A successful CO_2 operation as modeled by crosswell imaging.

lution surface seismic operations. Crosswell techniques, by contrast, provide the high-resolution imaging that is capable of detailing these zones.

Using surface seismic to pinpoint changes in reservoirs is problematic as well, based on the fact that its limited aerial view almost pre-supposes homogeneity in a primarily heterogeneous environment. By comparison, crosswell imaging provides a true multilayered view, including a detailed visualization of structural changes and permeability. The benefit to be realized from this vastly improved view of the reservoir is the ability to directly identify reservoir characteristics as opposed to having to rely on the complex extrapolations that are part of surface seismic visualization technology.

Characterizing carbonate reefs

A recent application of crosswell imaging involving the Silurian Pinnacle Reef in the Niagaran Trend of the Michigan Basin provides an outstanding example of the value of this technology. This two-week project used crosswell sources and receivers spaced at 2,000 ft (610 m) apart. The project design called for the sources to transmit at frequencies ranging from 40 Hz to 300 Hz. Output from the crosswell data shot provided an accurate tomograph of the frequency attenuation in the interwell region, resulting in a rich characterization of the targeted carbonate reefs. Using the information derived from crosswell imaging activities, the operator was able to locate previously hidden hydrocarbon accumulations trapped in the Northern Niagara Reef at depths as low as 4,700 ft to 5,000 ft (1,433 m to 1,525 m).

The results from the crosswell imaging were critical to the identification of the additional production opportunities available in this region. A direct velocity correlation between sonic data was determined in addition to the development of a detailed, accurate tomograph. Also, differences were observed in zones that exhibited significantly more density contrast. This contrast was established as being generated by salt layers as compared to the high velocity output imaging recorded from carbonate and dolomite structures. Lateral velocity changes also were identified within the reservoir, and the top reservoir layer was determined to be located at 4,700 ft, with the bottom at approximately 5,000 ft.

The future

The industry is increasingly focused on maximizing the production potential of both new and existing reservoirs. In response to this focus, exciting advanced technologies such as crosswell imaging are being used more often to provide a level of ultra-high resolution information that can reliably support drilling, production and EOR operations. As demands for more in-depth understanding of interwell and reservoir structures increase, these productive technologies will continue to grow as an accepted tool for the geophysicist and reservoir engineer. E&P

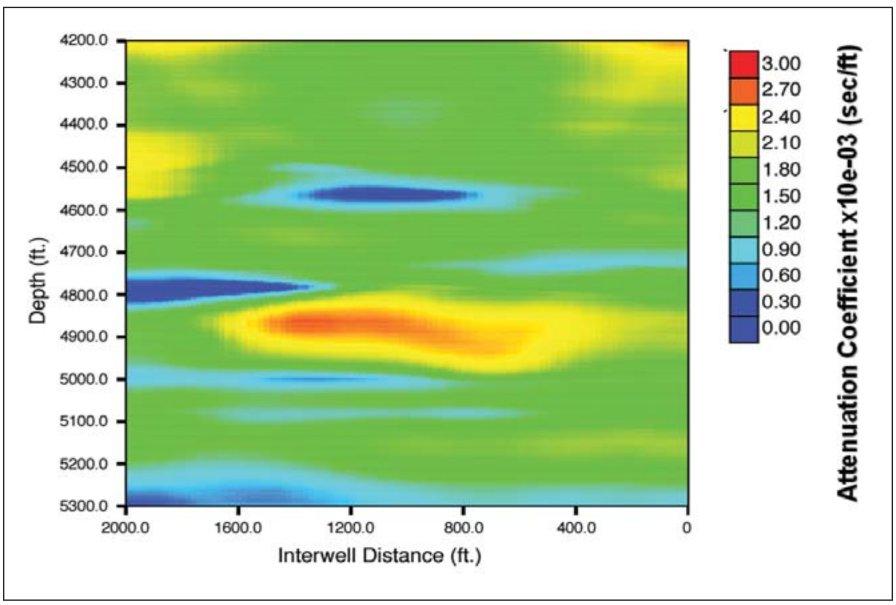

Figure 3. A crosswell image tomograph provides an indication of a carbonate reef in the Niagaran Trend area.