

## Crosswell Seismic Technology Optimizes Reservoir Development By Capturing Subsurface Details

By Bruce Marion

HOUSTON—At critical junctures in the life of a reservoir, development decisions are made that can dramatically increase value, if they are based on a precise understanding of reservoir architecture. During the last decade, 3-D surface seismic has been counted on to supply information about the reservoir that has driven exploration and development decisions. However, today crosswell seismic technology is emerging as an effective new tool in characterizing the reservoir and optimizing its development.

The secret to improving reservoir development is, quite literally, in the details. Crosswell seismic is the only technology proven to provide the detailed data necessary to ensure a true understanding of the reservoir at the scale that describes both reservoir flow, and more importantly, flow barriers. This advanced process offers unmatched detail in its characteriza-

tion of the reservoir between wells, delivering an unprecedented resolution of a few feet.

Each time crosswell seismic is employed, it is as if the operator is able to make a detailed study of an outcrop right in the reservoir (Figure 1).

Today, many operators are using the in-depth data generated by crosswell seismic technology to formulate developmental strategies that significantly enhance production, increase reserves, and lower overall production costs.

There are two key times in the life of a reservoir when having access to detailed reservoir information supplied by crosswell seismic is most critical: the initial development

FIGURE 1

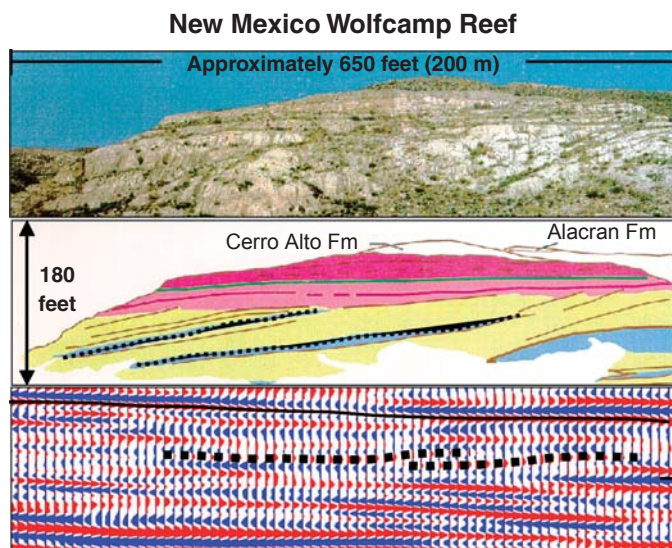
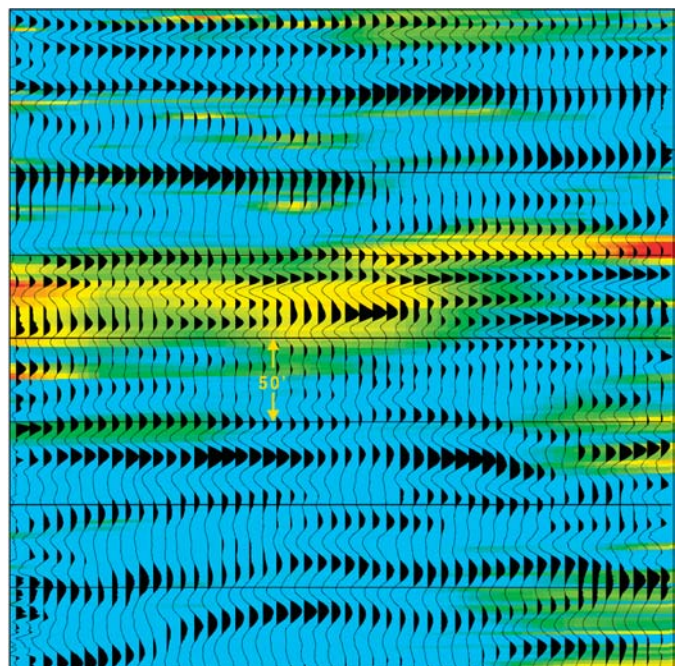


FIGURE 2

West Texas CO<sub>2</sub> Pilot





stage, and redevelopment programs.

In developing new fields, accurate and in-depth information concerning the reservoir is critical for making the right assessments of such key elements in the development strategy as well density and completion methods. Just as important, an improved picture of reservoir architecture can lead to more accurate reserves assessment. An inaccurate description of the reservoir can result in a poor return, and possibly, expensive redevelopment costs in the future. With only surface-based 3-D seismic and well data from a few sparsely spaced wells, the operator must depend on educated guesses and extrapolation to characterize the reservoir. This guesswork is based on existing models, historical data, surface seismic data, and a “gut feel.”

If, however, early wells in the development program are appropriately placed, crosswell seismic operations can be employed as an integral component in the development process. With this advanced technology, valuable snapshots of detailed reservoir architecture are available to guide the long-term development strategies, and better overall development decisions can be made based on significantly more in-depth information. For instance, the continuity of the reservoir or unexpected small-scale compartmentalization can be determined from data generated by crosswell seismic operations. And with outcrop-quality snapshots from crosswell, the geologist and reservoir engineer can more readily develop high-resolution geologic and reservoir models.

**Reservoir Redevelopment**

When redevelopment programs such as aggressive infill strategies or secondary and tertiary recovery plans are implemented, the success of these operations can depend on having a true understanding of reservoir architecture. For the operator contemplating redevelopment strategies, the information derived from conventional seismic operations offers a gross structural picture. At the same time, data acquired from logs, cores and production operations provide high detail at the wells, but little additional spatial understanding of the reservoir.

What is missing from these technologies is in-depth information concerning the reservoir-scale fabric between the wells. This information gap is traditionally filled with inferences

from production history and geostatistics, textbook-based geological models, or outcrops that may be hundreds of miles from the actual reservoir. No method (or combination of methods) meets the critical requirement for reservoir information between wells as thoroughly as crosswell seismic.

As an example, the crosswell images in Figure 2 were used to characterize the heterogeneity of a carbon dioxide pilot area in West Texas. These images were a key element in the decision process to determine whether to invest hundreds of millions of dollars to expand the pilot to full-field operation.

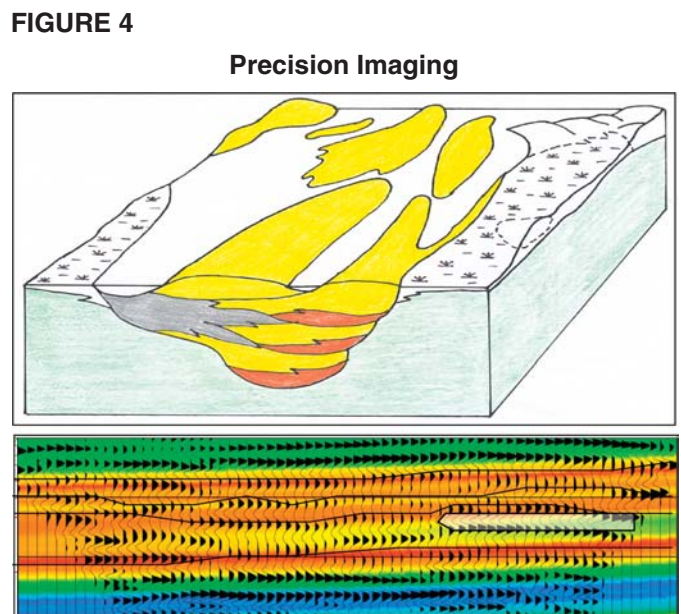
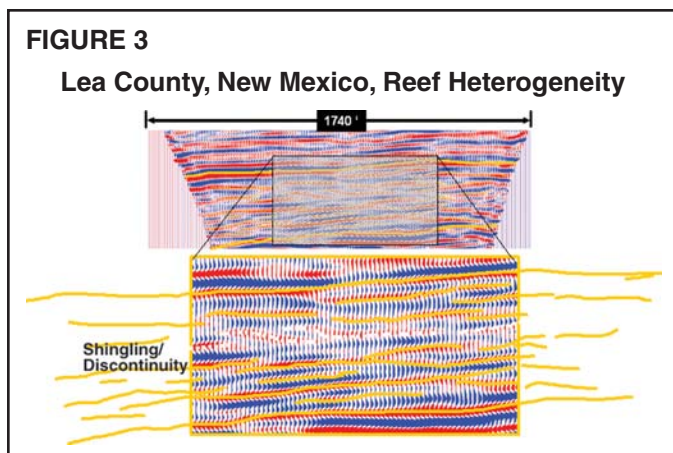
Crosswell seismic is often used to explain variable production performance in a mature field. Based on a better characterization using crosswell seismic in a Permian Basin reef reservoir a potential waterflood was cancelled. The key information provided by crosswell was the unexpected levels of heterogeneity in the reef at a scale not visible with surface seismic data (Figure 3). In addition, new drilling locations were defined.

In Egypt, a revised interpretation based on an updated geologic model, derived from crosswell information led to the operator significantly revising the development strategy for the area. Replacing a planned horizontal drilling program with precisely targeted deviated wells resulted in both cost savings and increased reserves.

**Inside View**

Crosswell seismic technology is designed to provide the well operator with a real and in-depth view of the fabric of the reservoir, compared to the limited view provided by conventional approaches. Conventional approaches normally generate a low-resolution, broad areal view, or high detail at the wells. However, these methods only provide a limited understanding of the complexities of the interwell space. By contrast, crosswell seismic offers an “inside view” of complex interwell architecture.

For complex channel systems, each element is delineated

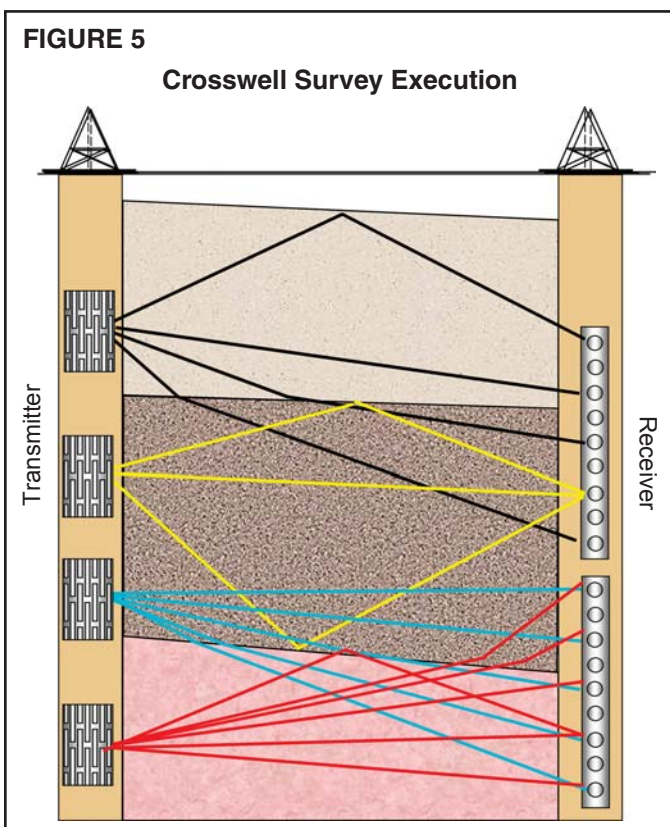




in a crosswell image, allowing direct targeting of high-porosity intervals (Figure 4). In the Canadian tar sands, for instance, low-contrast shale barriers as thin as one meter, capable of impeding steam growth in steam-assisted gravity drainage (SAGD) projects, are imaged using crosswell seismic. Crosswell imaging also provides detailed reservoir information to assist in planning hydraulic fracture programs in tight gas reservoirs.

The crosswell concept is simple: perform the seismic survey from inside the reservoir instead of from the surface. To execute a crosswell survey, standard wireline technology is used to deploy a seismic transmitter or source into one well and a receiver array (or arrays) into one or more adjacent wells (Figure 5). The signal from the transmitter to the receiver(s) generates high-bandwidth data, which details the nature of the reservoir between the wells when processed. By imaging from the reservoir via crosswell techniques, many practical advantages are realized:

- Vertical resolution between two and five feet—10-100 times better than surface seismic techniques—to provide otherwise unattainable detail of the reservoir;
- Measurements are directly referenced in depth and co-located with well log data, removing uncertainties associated with time-depth conversions in surface seismic data;
- Highly repeatable measurements provide unparalleled precision for 4-D time-lapse monitoring; and
- Near-surface and overburden effects are bypassed, eliminating an inherent problem in conventional seismic operations.



## Defining Features

Many features that define reservoir architecture can be more accurately identified with crosswell seismic, including sub-seismic faulting, subtle pinchouts, properties variations in thin layers (porosity, permeability and saturation), fracture properties, and thin channel features and shale barriers.

The in-depth understanding of the reservoir fabric provided by crosswell seismic can supplement the conventional analytical tools used by reservoir development teams. Crosswell technology provides direct measurements of reservoir heterogeneity for more complete geostatistical models. The result is more accurate reserves estimates. A few detailed crosswell images can also be used to better leverage the investment in 3-D seismic data by providing ground truth to calibrate subtle, attribute-based interpretations of surface seismic data.

In many reservoirs, crosswell seismic can also play an ongoing role in reducing production costs once a new development strategy is being implemented. When reservoir heterogeneities make strategic infill well trajectory planning difficult, crosswell data can provide a roadmap for the new wells.

In reservoirs undergoing secondary or tertiary recovery, crosswell is also commonly used to provide detailed monitoring of the flood processes, such as steamflood monitoring and CO<sub>2</sub> flooding in fields worldwide.

Whether undertaking the initial development of a field or redeveloping an existing reservoir, crosswell seismic is a powerful tool that provides oil and gas experts with a detailed view of the reservoir's architecture, ensuring quality development decisions that can lead to the realization of the full value of the asset. □



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