Crosswell Imaging in Canadian Reservoirs

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Abstract

New challenges are being faced by Canadian oil and gas producers as conventional hydrocarbon resources continue to dwindle. New and unconventional resources such as oil sands, tight gas and coal bed methane have moved to the forefront in the continuing search for ways to meet the growing demand for hydrocarbons. Additionally, mature fields are typically at the decision point requiring initiation of a strategic redevelopment program or settling for continued decline. In both development of new resources and redevelopment of mature fields, crosswell seismic can deliver unprecedented resolution to uniquely solve reservoir issues in the interwell space.

This talk describes the crosswell method and describes Canadian reservoir solutions in both developing new resources and the redevelopment of mature fields. The focus is on applications of crosswell seismic in Canadian reservoirs.

Why Crosswell

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 supplied 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 unconventional resource reservoir and in optimizing the development of mature fields.

The secret to improving reservoir development for unconventional resources or mature fields is, quite literally, in the details. Crosswell seismic is a technology proven to provide the detailed data necessary to ensure a better 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 characterization of the reservoir between wells, delivering an unprecedented resolution of 1 to 3 meters.

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). Crosswell seismic data is inherently logged in depth and allows formulation of 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 perhaps most critical: the initial development stage and while formulating redevelopment programs.

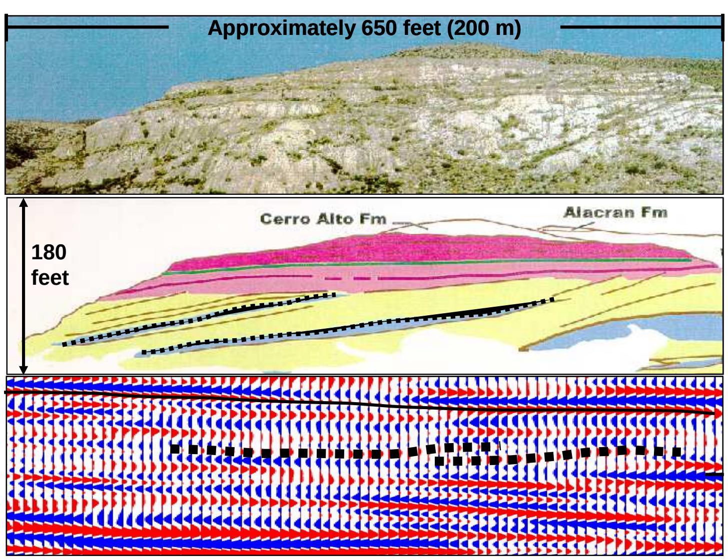

Figure 1. Carbonate reef outcrop and crosswell image.

In developing new fields, accurate and in-depth information concerning the reservoir is critical in making the right assessment of such key elements in the development strategy as well density and completion methods. Just as important, an improved picture of the reservoir architecture can lead to more accurate reserves assessment. Crosswell seismic provides additional information to enhance the view developed with surface-based 3-D seismic and well data from the initial wellbores in a field. Three new unconventional resources in Canada are applications for crosswell seismic to provide additional detailed information with which to plan the reservoir development: oil sands, tight gas sands and coal bed methane.

Oil Sands

Crosswell seismic has been applied for five years and more in Canada's Athabasca Oil Sands play. In the process, insight has been gained as to the value produced by the crosswell method. Crosswell was initially applied as another geophysical methodology to monitor steam growth. However the unique ability of crosswell to image small features with unexcelled resolution has positioned crosswell to become an integral element of the Oil Sands development process rather than only another means of estimating steam growth. Three key roles have been defined for crosswell in the Oil Sands development process:

Delineation. The unprecedented resolution advantage of crosswell allows the continuity of shale stringers that may be a barrier to the vertical rise of steam to be imaged.

Diagnostics. Monitoring inherently requires a baseline survey to infer changes in the reservoir. Recent experience has shown that crosswell in a diagnostic mode with no baseline survey can delineate shale barriers as well as detect velocity variations from regional models to zonate steam growth.

Monitoring. With a baseline survey and using the unprecedented vertical resolution of the crosswell seismic method, precise measurements of reservoir changes due to steam injection can be imaged and localized. The resolution advantage of crosswell allows changes in velocity to be better localized in depth and provides quantitative detail that mandates better rock physics analyses that relate these precise velocity change measurements to the changes in reservoir properties such as temperature, pressure, stress and gas properties.

The resolution advantage of the crosswell measurement is highlighted in Figure 2 where typical well logs from the Athabasca Oil Sands are used to produce synthetic responses for surface seismic, crosswell at 200 meter well separation and 400 meter well separation. The experience in the Athabasca has provided a detailed understanding of the attenuation factors in these highly attenuative formations.

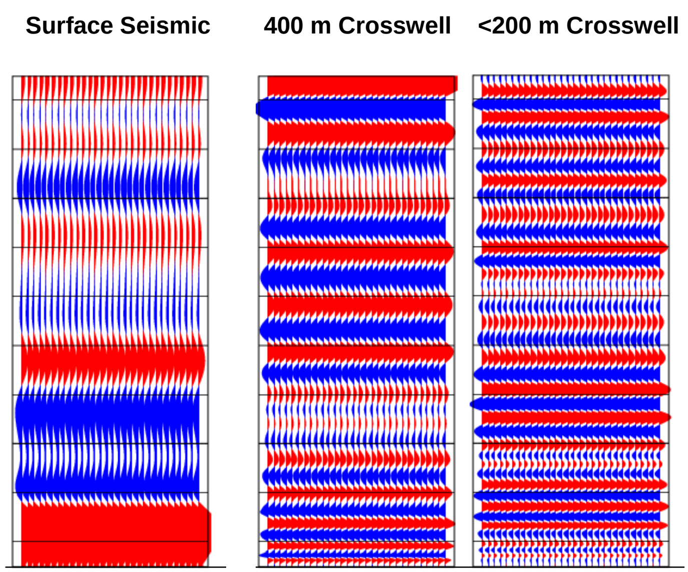

Figure 2. Comparative resolution for surface seismic, crosswell at 400-meter well separation and crosswell seismic at 200-meter well separation for a typical Athabasca reservoir.

Early crosswell images from the Athabasca Oil Sands were reported by Zhang et al. (2002).

Tight Gas Sands

In addition to the unique advantages in the Oil Sands play, crosswell seismic also offers the ability to delineate small-scale structures such as channel systems that dominate some tight gas sand plays. Figure 3 shows how individual elements of a channel system can be delineated and interpreted. The comparative 3-D surface seismic data shows only the channel system and not the individual elements of the *channel.*

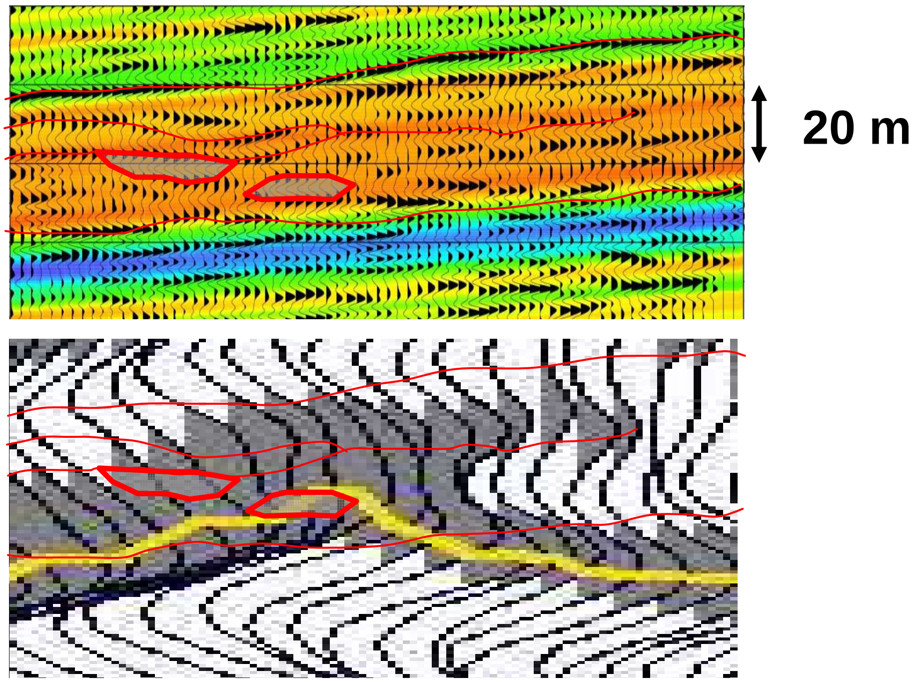

Figure 3. The same slice of earth in a channel system showing the crosswell view (top) and 3-D surface seismic view (bottom). The extra resolution of crosswell is a key to better defining the reservoir architecture in stacked channel systems.

Coal Bed Methane

Another example of using crosswell seismic to optimize development of an unconventional resource is in coal bed methane (CBM) development. As CBM development has moved into areas with multiple thin coal seams, the issues of coal bed thickness and continuity have become more important. The images in Figure 4 demonstrate the ability of crosswell seismic to image coal seams as thin as 1 to 2 meters. With a thickness of 3 meters or more, both the top and bottom of the seam can be easily delineated. For seams thinner than 3 meters, the wavelet variation is a good indicator of seam thickness. Small-scale faults or other discontinuities in the coal seam can be imaged. Porosity variation can be seen in the crosswell velocity image, as well as in the reflectivity image. Crosswell can be used in the initial development of areas with thin coal seams to select the seams for development and to better quantify the reserves.

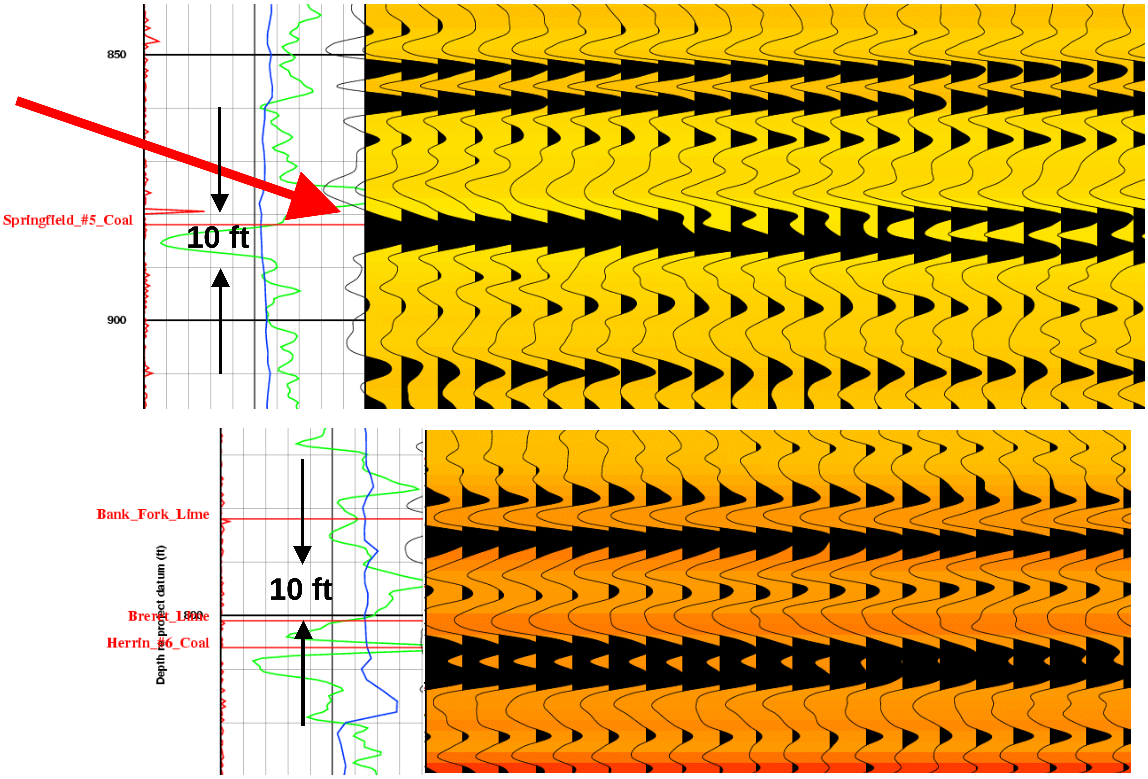

Figure 4. Two detailed views of crosswell images of thin coal seams. Crosswell can define both the top and bottom of the coal seam, the coal seam continuity, and the porosity of the coal.

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 the 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 provides 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.

Many features that define the 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 road map for the new wells. As an example, Figure 5 shows a detailed crosswell image of the channel system within the Crystal Viking Pool. Such detailed images were used as the roadmap to target a horizontal well as described in Hatch et al. (2001).

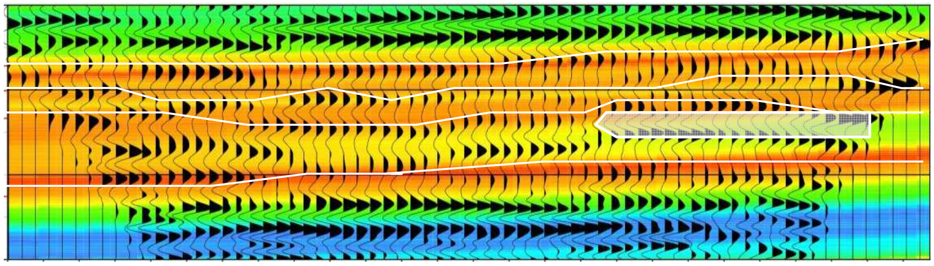

Figure 5. Two crosswell sections in a channel system. The individual sand bodies within the channel system are delineated, both top and bottom, allowing better understanding of reservoir continuity and quality.

Summary

The resolution benefit of crosswell seismic has been applied in a number of Canadian reservoirs. Development of oil sands, tight gas and coal bed methane and redevelopment of mature fields may benefit from the increased resolution available using crosswell seismic.

References

Zhang, W., et al., May 2002, Understanding reservoir architectures at Christina Lake, Alberta, with crosswell seismic imaging: CSEG Recorder.

Hatch, R. and Meyer, J., October 2001, Strategic infill drilling targeted using crosswell seismic: CSEG Recorder.