Full-wave imaging solves gas test

Multicomponent sensors have been successfully utilized to image clastic gas reservoirs in the Carpathian Foredeep in Poland.

AUTHORS

Maciej Gorski, Artur Przybylo* and *Marian Wilk*, *Geofizyka Torun Sp. z o o.; and* ***Paul Brettwood* and *Joe Jacquot*, *Input/Output Inc.

Today's new generation of digital full-wave seismic technology enables acquisition of improved seismic images and identification of reservoir parameters that have proven useful in solving exploration and production problems, including improved structural interpretations and validation of amplitude anomalies in onshore clastic gas reservoirs. One onshore gas trend with these interpretation challenges is the Miocene gas trend in the Carpathian Foredeep of southern Poland. This article covers how Geofizyka Torun, a Polish seismic acquisition contractor active for the last 40 years, is using full-wave imaging technology to address these imaging challenges. Geofizyka Torun began experimenting with full-wave seismic surveys 5 years ago using seismic field acquisition equipment developed by Input/Output (I/O) and internally developed multicomponent processing techniques. For the last few years, I/O has been developing next-generation land seismic acquisition equipment to accelerate the digital full-wave era of seismic imaging.

Geological overview

The Carpathian Foredeep (Figure 1) is the second most important gas region in Poland with more than 100 gas reservoirs discovered to date. Gas fields at depths ranging from 600 ft to 3,050 ft (185 m to 1,000 m) are structurally controlled and located over basement fault blocks. Exploration over the last 50 years has resulted in identification and discovery of the largest structures and fields. Lower-relief structures are now the exploration targets and have a number of imaging challenges related to their more subtle structural relief compared to existing fields.

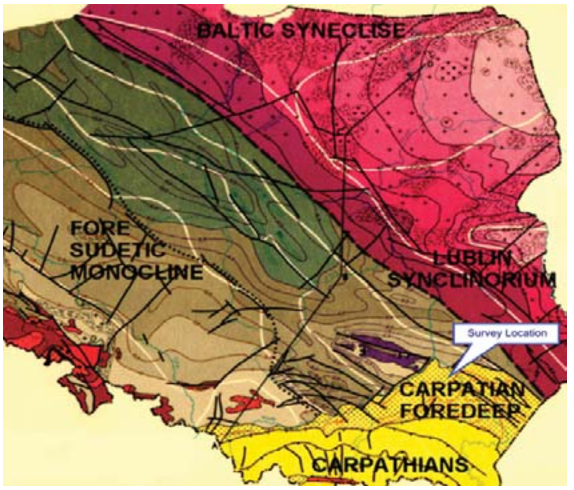

Figure 1. Geological index map of Poland. Lower-relief structures are now the primary exploration targets in the Carpathian Deep.

Challenges

A number of wells drilled several years ago to test stacked gas objectives in lower-relief structures turned out to be non-commercial but did contain numerous strong gas shows. Exploration risks for these gas prospects come from insufficient understanding of the compressional (P) wave and converted (C) wave amplitude responses from commercial gas accumulations. An additional risk is posed by the "gas effect" created by multiple stacked gas reservoirs. This creates a "time delay" for P-wave energy as it propagates through multiple gas reservoirs and can partially to completely mask low-relief structures by introducing a velocity induced-structural "push-down" effect over the prospect. The presence of gas can also attenuate P-wave energy and obscure imaging of basement fault blocks. Because shear (S) waves are relatively unaffected by laterally varying reservoir gas saturations, C-wave data has the potential to more accurately image the true prospect structure at the reservoir level and to better image the basement fault blocks.

Full-wave imaging overview

Unlike conventional seismic imaging in which only the vertical motion component is measured and recorded,

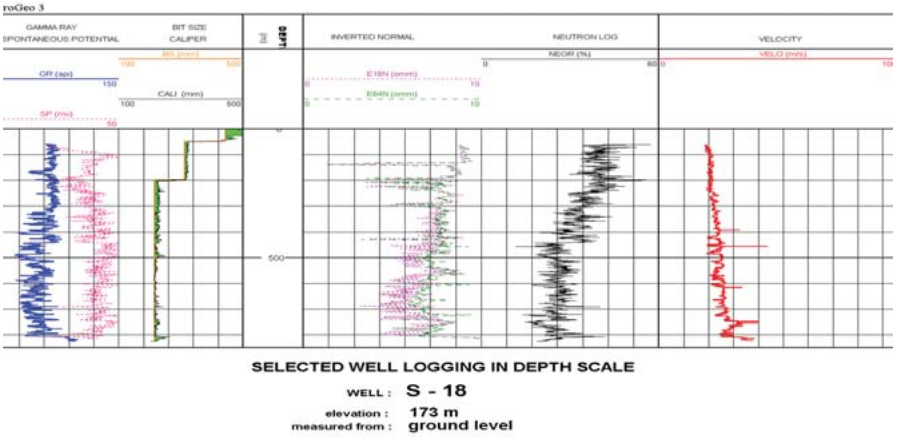

Figure 2. A typical Nowa Deba well log shows relatively little P-wave reflectivity in the prospective reservoir section.

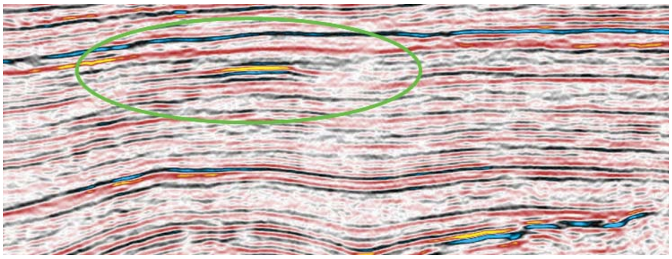

Figure 3. P-wave section from Nowa Deba prospect area. Possible hydrocarbon accumulation is indicated by the bright spot on the crest of the structure.

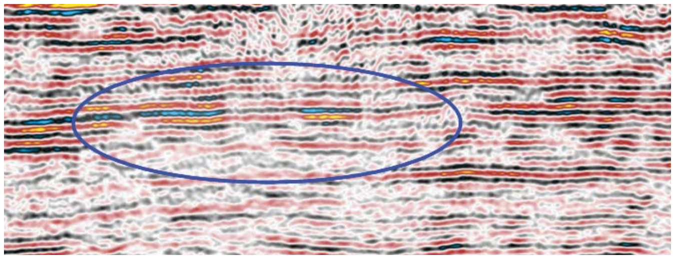

Figure 4. C-wave section from Nowa Deba prospect area, same line as above. C-wave data has no corresponding amplitude anomaly over the structure, validating the gas interpretation.

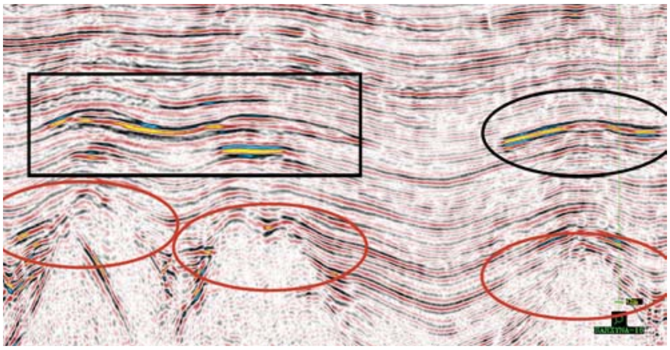

Figure 5. A full-wave 2-D P-wave seismic line (L2) in the Nowa Deba area shows excellent reflector continuity and structural imaging. (All images courtesy of Input/Output)

full-wave acquisition involves:

- Faithfully recording the complete ground motion in 3-D by recording all the seismic signal, including source-generated noise;
- Recording the full bandwidth of frequencies that the Earth will return; and
- Obtaining an unaliased spatial sampling of the imaging target(s) for a given dip, frequency and velocity.

Full-wave imaging delivers:

- Broader bandwidth, higher resolution seismic images; and
- Improved P-wave images and cost-effective S-wave and C-wave images.

Full-wave imaging requires high-fidelity, multicomponent, single-point receivers and high capacity acquisition systems to handle the increased data transmission and recording requirements from three-component receivers as well as the demands for sufficiently dense spatial sampling to avoid aliasing imaging objectives.

Vector filtering techniques identify, characterize and attenuate source-generated noise. Because they are single-trace techniques, they perform well, even in the presence of spatial aliasing

Rock properties

In the Nowa Deba area of the Carpathian Foredeep , P-wave sonic logs reveal a lack of strong acoustic contrasts in the prospective Miocene reservoir section (Figure 2); therefore, one would not expect any strong P-wave reflectors in that part of the section. Because P-wave propagation is sensitive to layer rigidity, density and compressibility, and given the unconsolidated or slightly cemented nature of the prospective reservoir sandstones, gas in a reservoir should generate a bright spot on P-wave data. Because S-wave propagation is sensitive only to layer rigidity and density, the addition of gas into a reservoir will not change the reflectivity with respect to S-wave energy and thus will not generate a bright spot.

Acquisition

Two-dimensional P-wave and C-wave data were acquired with an 450 station I/O System Four with VectorSeis full-wave single-point receivers.

The near surface is characterized by S-wave static challenges that were solved by generating a near-surface model derived from P-wave first-break inversion plus S-wave velocities from multicomponent upholes. From this model, the near-surface P velocity divided by shear velocity (Vp/Vs) coefficient was calculated and S-wave static corrections for both the radial and transverse components were computed using P-wave receiver statics scaled with an average near-surface gamma coefficient.

Processing

GT processing procedures include space-variant receiver statics, vector filtering of ground roll suppression, estimation and compensation for anisotropy, common conversion point (CCP) binning, gamma distribution, non-hyperbolic normal moveout (NMO) analyses, surface-consistent two-component amplitude scaling, and modeling and correlation to well data.

Interpretation

Detailed analysis of both P-wave and C-wave images show that gas accumulations are associated with bright spots on P-wave images (Figure 3) and a lack of bright spot response on C-wave images (Figure 4).

Figure 5 is a P-wave image of line L2 acquired with full-wave imaging technology. Notice excellent reflector continuity and structural imaging (right black ellipse) that is consistent with the gas producer. Also note excellent imaging of basement fault blocks (lower red ellipses) and structures in the overlying prospective section (top left rectangle). E&P

All seismic data shown courtesy of Geofizyka Torun Sp. z o o. and Polish Oil and Gas Company.