GCWell Logs Invaluable to Interpreting Limited-Quality Seismic of Complex Structures*

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General Statement

The methodology described here may benefit those who are confronted with the problem of interpreting complex structures from limited-quality 3-D seismic images. The objective of this study was to characterize deep (20,000 feet/6,000 meters) Ellenburger gas reservoirs in West Texas. In addition to the Ellenburger reflection signals being weak because of the great depth of the target, the top of the Ellenburger across the area was a gentle, ramp-like increase in impedance that did not produce a robust reflection event.

A further negative influence on data quality was that the area was covered by a variable surface layer of low-velocity Tertiary fill that was underlain by a varying thickness of high-velocity salt/anhydrite. These complicated near-surface conditions made static corrections of the data difficult; in fact, the combination of all of these factors has caused some explorationists to consider the region to be a no-record seismic area for imaging deep drilling targets.

Example

The interpretation of 3-D seismic data across the project area led to the conclusion that the strongest influence on pre-Pennsylvanian reservoir compartmentalization was the numerous fault systems that distort Ordovician and Mississippian rocks. For this reason, a principal focus of the seismic interpretation was to create a correct structural picture of the pre- Pennsylvanian section. The challenge: Produce this accurate structural picture from a 3-D seismic volume that was of limited quality.

The overturned Simpson (Ordovician) section documented in study well 78 was particularly important because of its impact on the position of targeted Ellenburger reservoirs in the 3-D seismic volume. Gamma-ray and acoustic logs recorded in well 78 are shown as (Figure 1.) Labeled are:

- The interpreted top of the Simpson.
- The fold axis about which beds are overturned within the Simpson section.
- The three arbitrary stratigraphic intervals (1, 2, 3) that emphasize the bedding symmetry about the fold axis.

In this area the Ellenburger is dolomite, not limestone. Cross-plots of neutron and sonic porosities showed that the industry-provided top of Ellenburger was a limestone facies, which led to the conclusion that the unit was incorrectly identified as top of Ellenburger. This conclusion then led to the recognition that overturned bedding was present in the log responses.

Note that the log data show units below the fold axis are thicker than their equivalents above the fold axis. This apparent thickening of the deeper repeated bedding is caused by the borehole-to-formation geometry that results when a vertical well bore penetrates an overturned section. As illustrated on (Figure 2) , log data from a vertical well measure correct bed thicknesses in undisturbed strata between A and B, where the bedding is nearly horizontal. However, logs will show exaggerated bed thicknesses in the overturned section between B and A', where the beds are slanted at a high dip angle relative to the borehole.

(Figure 3) shows a vertical section from the 3-D seismic volume that passes through well 78. The major faults in the well's vicinity and the interpreted geometry of the overturned bedding are labeled on the image.

Conclusion

The principal point is that although overturned strata cannot be interpreted from this limited-quality seismic image, the recognition of overturned beds on log data allows the proper structure to be imposed on the seismic data. Petrophysical analyses and interpretations of logs can be invaluable when interpreting complicated structure with any seismic data, regardless of seismic data quality – and particularly so when strata are overturned in the dramatic manner illustrated by this example.

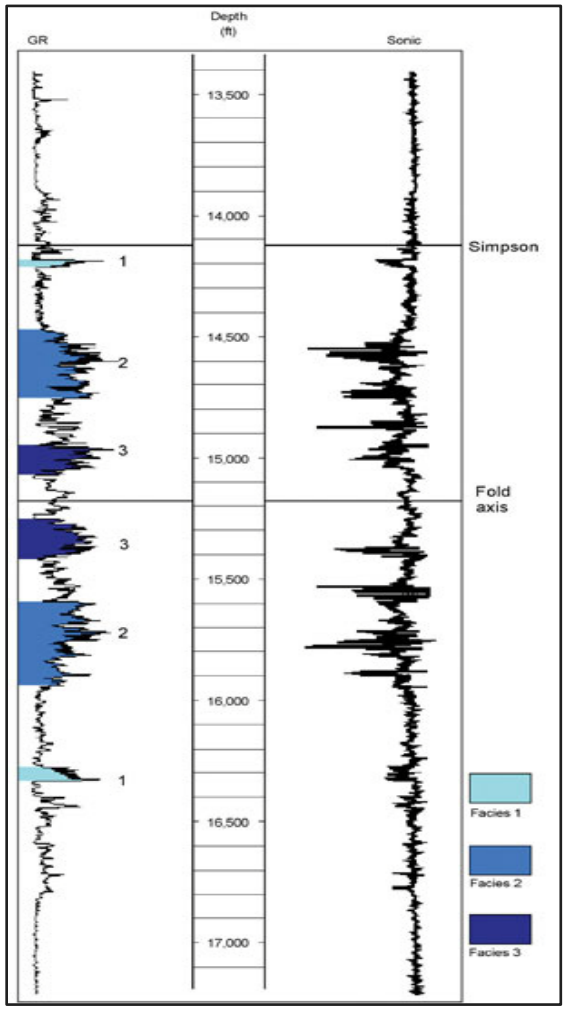

Figure 1. Example of overturned Simpson section, well 78.

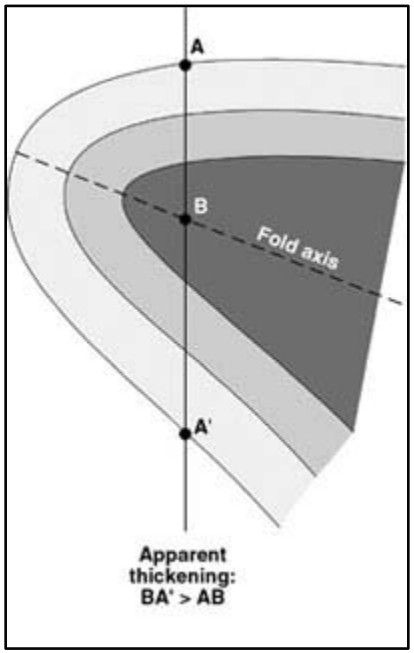

Figure 2. Apparent bed thickening of repeated strata measured in a vertical well penetrating overturned bedding. A vertical well will measure true bed thickness when strata are near-horizontal (A to B) but exaggerated thickness when folded strata intersect the well at a dip angle (B to A').

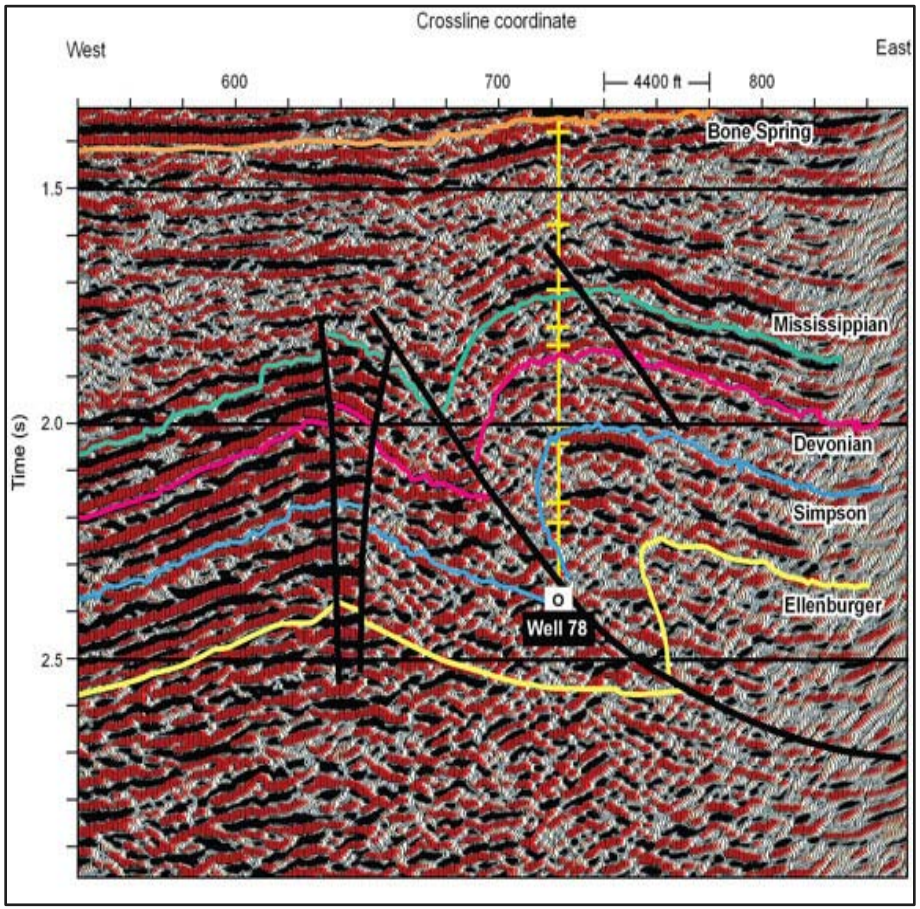

Figure 3. Seismic section passing through well 78. This seismic profile illustrates the overturned Simpson section that would have been incorrectly interpreted as Ellenburger if industry-provided formation tops were honored. The original (but incorrect) log-defined top of Ellenburger was the well tic at 2.22 sec. After imposing the overturned geology identified by log analysis, well 78 did not penetrate the Ellenburger – and the seismic interpretation was modified to emphasize this fact. Each labeled horizon identifies the top of the particular unit, regardless of whether the label is above or below the horizon. Phantom horizons must be constructed across some image areas.