Using Petrophysics and Cross-Section Balancing to Interpret Complex Structure in a Limited-Quality 3-D Seismic Image

Bob A. Hardage, Bureau of Economic Geology, Austin, Texas
Virginia M. Pendleton, Bureau of Economic Geology, Austin, Texas
Richard P. Major, Formerly Bureau of Economic Geology, now at the University of Mississippi, Oxford, Mississippi
George B. Asquith, Center for Applied Petrophysical Studies, Texas Tech University, Lubbock, Texas
Dan Schultz-Ela, Bureau of Economic Geology, Austin, Texas
David E. Lancaster, S. E. Holditch & Associates Inc., College Station, Texas

ABSTRACT

A study was undertaken to determine structural controls on deep, prolific Ellenburger gas reservoirs at Lockridge, Waha, West Waha, and Worsham-Bayer fields in Pecos, Reeves, and Ward Counties in West Texas. Ellenburger (Ordovician) reservoirs occur at depths of 17,000 to 21,000 ft (5200 to 6400 m) over most of the study area. A major component of the data base for the study is a 176-mi^2 3-D seismic survey.

The 3-D seismic data acquired in this study are some of the best-quality data produced over these fields, yet the 3-D seismic images of many deep pre-Pennsylvanian reservoirs are of limited quality, at best, because of the combined effects of complex, attenuating, near-surface layers and weak reflection signals from deep seismic targets. The eastern half of the 3-D seismic survey is covered by a layer of low-velocity Tertiary fill that varies in thickness from 500 to 2000 ft (150 to 600 m). The low-velocity layer is underlain by high-velocity salt/anhydrite of varying thickness. These near-surface conditions attenuated seismic reflection signals from deep targets and made static corrections of the data difficult.

The principal interpretation objective was to unravel the complicated tectonic structure of these fields to determine genetic relationships between faults and deep gas production. The challenge was to resolve the structural "picture" from 3-D seismic that did not provide clear, unambiguous resolution of the fault systems.

We found that petrophysical analyses of logs from wells drilled at key structural locations were invaluable in interpreting fault geometry by identifying overturned beds and repeated stratigraphic sections. Key lithofacies could be identified by appropriate crossplotting of the limited logs suites that were available.

The role of the balanced-cross-section analyses is twofold: 1) to verify that the general structural picture developed from the 3-D interpretation is correct, and 2) to determine the accuracy of the structural depth maps that were produced.

Once fault interpretations from 3-D seismic were done across the entire 176-mi^2 area, depth maps of key pre-Pennsylvanian horizons were made, and vertical depth sections were constructed across critical structural areas. We then restored the seismic-interpreted structures to pre-deformation conditions to verify if the pre- and post-deformation lengths of these key horizons were consistent, and thereby determined if the seismic fault interpretations were structurally valid.

We are convinced that our interpretation of the 3-D seismic data across the greater Lockridge-Waha area would not have been accurate for the more structurally complex areas if we had not relied on a robust petrophysical analysis technique to identify the critical overturned beds and repeated stratigraphic sections that needed to be incorporated into the structural model. More extensive logging suites, such as dip-meter logs and borehole imaging logs, would have been invaluable, but the great well depths and high temperatures that occur through the reservoir targets have discouraged operators from recording extensive log data. Perhaps now that operators see the severe structural complexity revealed by the 3-D seismic data, they will be more willing to pay the cost and to risk the hazards of recording additional petrophysical information in future wells.

Even through the petrophysical analyses provided confidence that the general structural picture is correct and that major structural features are not overlooked in the limited-quality seismic data, there is still a concern that the structural interpretation might not be as accurate

as we desired.

Our conclusion is that cross-section balancing verified that the seismic-based depth maps are sufficiently accurate for drilling purposes. We recommend that others who interpret complex structure from marginal-quality seismic data use petrophysical data to confirm structures in well bores, and use balanced-cross-section analysis to verify and adjust the final interpretation, as shown in this study.