

Subsurface Modeling of Directional Well Bores at Fidelity Exploration & Production Company

By Barbara Shields, Esri Writer

Petroleum geologists have honed skills and technology to understand oil production and subsurface relationships such as formation properties, sources of petroleum, and how well bores are engineered. They study how a rock formation is fractured to create fissures that allow petroleum to seep through the formation to the well bore. John Farrell, GIS manager at Fidelity Exploration & Production Company, has been studying one such factor—rock units. By using geographic information system (GIS) technology to model rock layer data, he created visualizations that suggest relationships between rock units and well

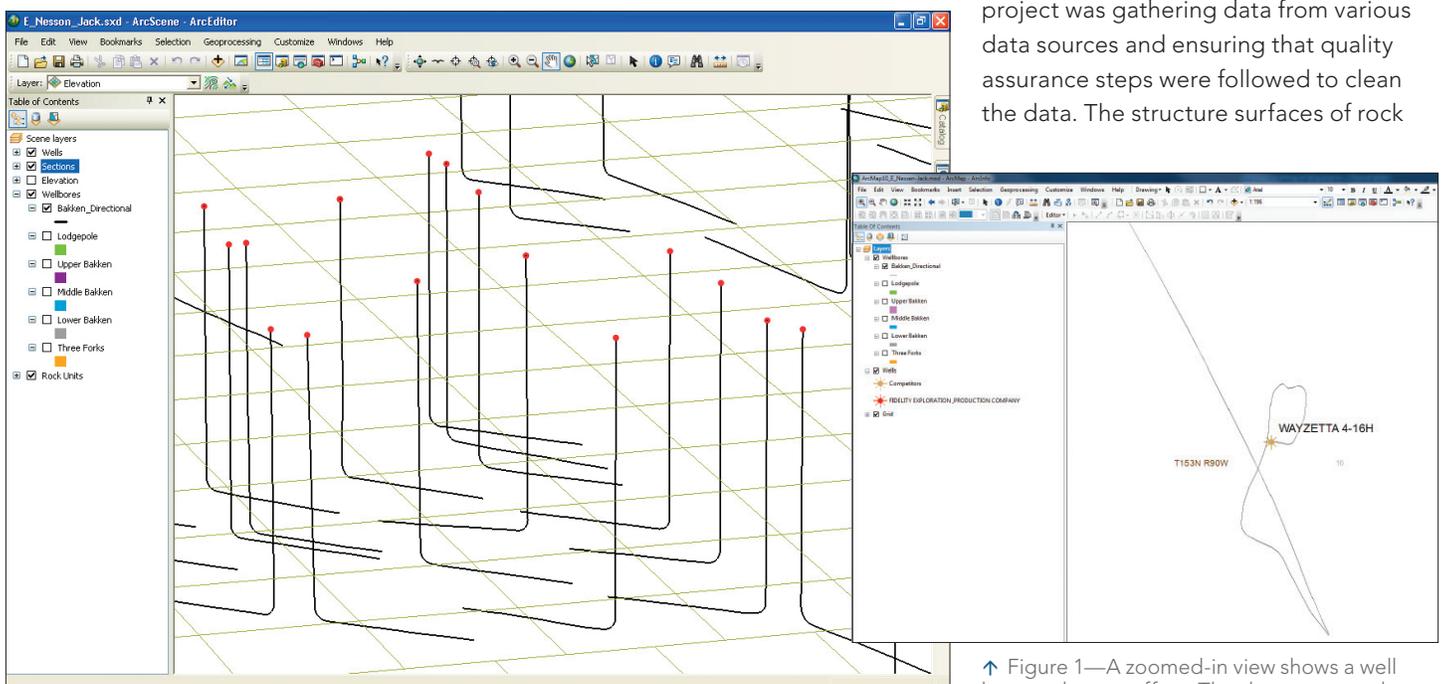
bore productivity. Looking at what happened in the past adds to the exploration department's understanding of where to drill in the future.

Rock data collected at the time a well was drilled is a history of a subsurface event that can be visualized on a map. After running this data through a model in ArcGIS, one can create 3D maps that show where well bores corkscrew their way down through the earth's crust (figure 1). This phenomenon is difficult to see on a two-dimensional map or cross-section view. The 3D map is more intuitive to people in exploration and production who are accustomed to thinking in three dimensions.

Farrell and his team of GIS specialists created subsurface modeling of directional well bores in the Bakken Formation, Mountrail County, North Dakota.

"It is useful to see which rock unit was penetrated by which well bore and the oil production rates," said Farrell. "This type of model is interesting to potential drillers because it shows that a well bore went down this way and intersected a particular rock unit. By knowing that the well was a good producer, geologists might infer that this combination of engineering factors and well bore path through the rock unit are probably related."

The most difficult component of this project was gathering data from various data sources and ensuring that quality assurance steps were followed to clean the data. The structure surfaces of rock



↑ Figure 2—An Oblique View of Several Digital Well Bores

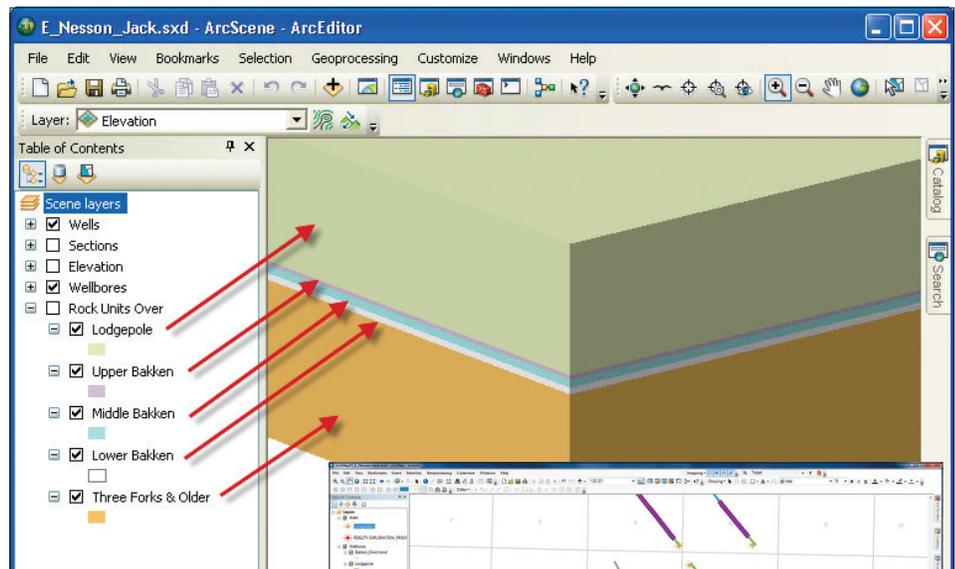
↑ Figure 1—A zoomed-in view shows a well bore corkscrew effect. The sharp turn northwest corresponds to the horizontal kickoff.

units used in the study are the product of well-by-well identification and correlations of wire line log data or mud log samples by the corporation's geologists as well as GPS surveys of as-built well locations. Other data resources included commercial data sources; proprietary data sources such as PETRA projects; and North Dakota Industrial Commission (NDIC)/ Department of Mineral Resources survey plats, directional survey records, and planning reports. Pulling this data together and categorizing it was a meticulous process that accounted for at least half the project's time. Geotechnical specialists copied the data to the Directional Survey Data table in PETRA, making it convenient to export it to other applications.

The project team customized an application to normalize the coordinate reference systems for all the spatial data. The team exported data from PETRA to ArcGIS to hang well bore points for each well vertically from the well's location. These locations are recorded in the XML file exported from the well location feature class. The vertices of each well bore are positioned relative to the surface location of the well. Custom software written by Fidelity Exploration & Production Company is used to construct the spatial representation of the well bores.

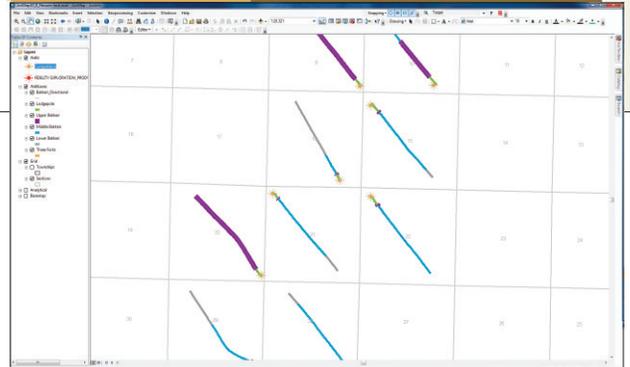
The resultant polyline feature class includes one polyline per well and is z aware to render it in 3D using ArcGIS 3D Analyst extension. The team also used this 3D tool to view a solid model of the rock units and see which solids are penetrated by the digital well bores.

Based on wire line and mud log data, the company's geologists interpreted the subsea depths of the structure tops of rock units. From these interpretations, the team created triangulated irregular network (TIN) datasets and used them as the starting point to construct a 3D solid



↑ Figure 3—Multipatch Features Representing Rock Units

→ Figure 4—Map of Well Bores Penetrating Specific Rock Units



model of the rock units in the Bakken Formation.

PETRA software made it possible for the geographic coordinates and subsea depth of grid values representing each structure top to be exported to an ASCII file. Grid cell attributes, including longitude-latitude and z options, were loaded into dBASE files via Microsoft Access and then conveniently loaded into ArcGIS tables for processing.

The Make Feature Layer and Create TIN tools in ArcMap were used to create georeferenced points with z-values for each member of the Bakken Formation. The Extrude Between tool in ArcGIS 3D Analyst specified stratigraphically adjacent TINs as the input values to create solid volumes for rock units. Using ArcGIS modeling tools, the team produced maps showing which well bores intersect or

terminate in specific rock units (figures 3 and 4).

"The use of ArcGIS for subsurface geologic modeling is demonstrated with this project," said Farrell. "Given the advancement of the solid modeling tools introduced with ArcGIS 10, the possibilities for additional analyses are attractive to both geologists and GIS specialists."

For more information and to get the white paper Use of ArcScene 10 for Subsurface Modeling of Directional Well Bores in the Bakken Formation, Mountrail County, North Dakota, contact John Farrell, Fidelity Exploration & Production Company, Denver, Colorado, at John.Farrell@fidelityepco.com.

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