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The Role of Outcrop Models in the Subsurface Characterization of Deep-Water Reservoirs

by
Michael H. Gardner - Montana State University; Bozeman, Montana
AAPG Distinguished Lecturer

ABSTRACT

The derivative source of geology imaged by subsurface data imposes limitations on its veracity because we can only confirm that which we can measure directly. Seismic data is constrained by vertical resolution limits, artifacts and noise, and non-unique processing. Providing higher vertical resolution and direct measurements, the sparse distribution and spacing of well data limits its spatial correlation. Geostatistical and stochastic methods used to manage these uncertainties introduce random effects. For these reasons, the geology being modeled cannot be verified. Furthermore, the modeling procedures that most impact data retention, including information that must be preserved for verification, are largely unknown. Modeling subsurface geology is simply done with too little information; therefore, analogs and probabilistic approaches are used to generate multiple scenarios, which minimizes the risk of an uncertain geologic model.

The twelve-year (1995-2006) study of the Permian Brushy Canyon Formation (BCF) illustrates the application of outcrop analogs to subsurface reservoir characterization. An integrated suite of three-dimensional geological, petrophysical, and geophysical models were generated from 488 sedimentological profiles and detailed mapping (20-m thick intervals) of continuous shelf-to-basin outcrops. Geologic mapping of this stratigraphy and sedimentary architecture across the multiple fault blocks that dissect the 245-km2 outcrop area provides a nearly complete three dimensional view of the BCF sedimentary system. Advanced GIS technology and 3D subsurface mapping software was used build 3D geological models with meter-scale, resolution for over half the outcrop. Conversion of the outcrop data to subsurface data formats facilitated outcrop to well and seismic data correlations (355 well logs and 3300 km of 2D seismic) across the 33,500-km2 Delaware Basin of West Texas.

Generating outcrop models is substantially different from subsurface modeling because outcrops lack the geospatial framework embedded in the collection of subsurface data. Nonetheless, outcrop geologic models provide a verifiable reference case derived directly from the rocks. Displayed as digital, geo-referenced subsurface data, the BCF models can be used to evaluate how well subsurface modeling methods reproduce known sedimentary architecture. These models provide a target, or benchmark model of the outcrop transformed into subsurface well and seismic data. Because the outcrop geologic models can be verified, they can be interrogated to better determine how (1) model building methods, (2) different data sources, and (3) differences in geologic interpretation affect the model. These are key areas where the introduction and retention of geologic information most impacts modeling results.

BIOGRAPHY

Michael H. Gardner is an Associate Professor at Montana State University in Bozeman, Montana and a geological advisor to Marathon Oil Company. He received his B.A. in Geology from the University of Colorado and his Ph.D. from the Colorado School of Mines. Refined through outcrop studies conducted since 1983, his applied research focuses on outcrop characterization of sedimentary architecture by integrating "old-school" field methods with three-dimensional, geospatial visualization technology. Mike teaches and leads the Slope and Basin Consortium at Montana State University, where his current research focuses on developing, testing and verifying geological rules for deep-water reservoir prediction through the Geological Analogs and Information Archive (GAIA) project.