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Reservoir Characterization and Geostatistical Modeling for a New Mexico Waterflood Project

MEDDAUGH, W. SCOTT, RAYMOND GARBER, MAURICIO VILLEGAS, and JASPER RING, Chevron Petroleum Technology Company, Houston, Texas

A full field study involving reservoir characterization, geostatistical reservoir modeling, and fluid flow simulation was completed in early 1999. This presentation will focus on the reservoir characterization and earth modeling aspects of the project. The Waterflood Project is located in extreme southeast New Mexico. The field produces from the Permian (Guadalupian) Grayburg formation. The reservoir consists of dolomitized grainstones and mud-poor packstones deposited in high-energy shelf-crest shoals. These shoals were deposited on a carbonate ramp as a series of shallowing-upward fifth order cycles of carbonate sediments with only a very minor siliciclastic component. The more shoreward sediments are lower porosity and lower permeability mud-rich packstones and wackestones that were deposited in a lagoonal setting. Further up-dip are non-porous mudstones of tidal flat origin that form the lateral up-dip reservoir seal. The reservoir is divided into eight layers separated by thin, very fine-grained aeolian sandstones that were deposited during lowstands.

This reservoir model differs from previous reservoir models in that a deterministic facies distribution was used to generate stochastic lithology distributions. The lithology distributions in turn were used to guide the stochastic distribution of porosity and permeability. Available core descriptions for 25 wells (among the more than 400 wells in the field) were used to map the distribution of three facies—deep water, shoal, and lagoon. The core descriptions were also used to determine the relative amounts of seven lithologies (sandstone, mudstone, wackestone, mud-rich packstone, mud-poor packstone, grainstone, and rudstone) within each of the facies. Each of the seven lithologies has a unique porosity-permeability relationship.

The GOCAD-based geostatistical modeling workflow consisted of: (1) deterministic mapping of facies distribution; (2) geostatistical analysis to determine semivariogram models for lithology, porosity, and permeability distributions; (3) stochastic distribution of lithologies by facies using multi-binary sequential indicator simulation (SIS); (4) lithology-controlled porosity distribution using sequential Gaussian simulation (SGS); and, (5) permeability distribution from porosity using lithology-dependent transforms. The “permeability by transform equation” approach was found to be better for fluid flow simulation than permeability models obtained by a cloud-transform based algorithm or by a collocated cokriging with SGS algorithm using the FE processed permeability well logs as hard data and the SGS porosity distributions as soft data. The fluid saturation distribution in the field could not be calculated from logs due to the high resistivity of the formation waters. The geostatistical workflow was used to generate a stratigraphic grid (Sgrid) for each of the eight reservoir layers. The final merged Sgrid contained about 21,000,000 cells (200 x 220 x 472 cells) averaging 200’ x 200’ x 2’. The finely layered geostatistical model was ultimately up-scaled using SCP to a 3D, black-oil, finite difference, CHEARS® fluid flow simulation model with about 84,000 active cells.