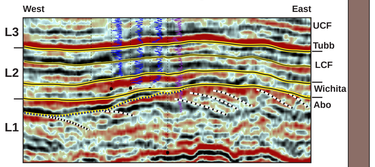
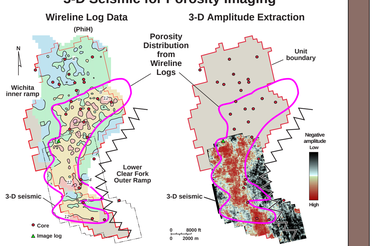
ROLE OF 3-D SEISMIC IN RESERVOIR CHARACTERIZATION

3-D Seismic for Defining Architecture



3-D seismic data are important for distinguishing the subhorizontal nature of the Lower Clear Fork from the clinoformal architecture of the Abo but are misleading with respect to the position of the L1 - L2 sequence boundary.

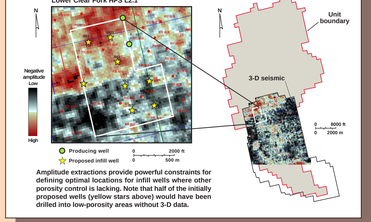
3-D Seismic for Porosity Imaging



Simple amplitude extractions provide superior imaging of porosity distribution in both interwell areas and areas where modern wireline data are lacking. Note that contours based on wireline data are inaccurate.

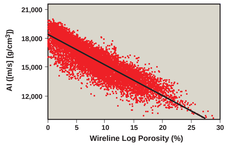
3-D Seismic for Siting Infill Wells

AMPLITUDE EXTRACTIONS



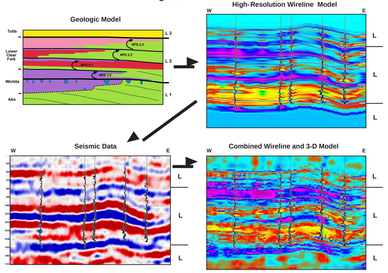
Amplitude extractions provide powerful constraints for defining optimal locations for infill wells where other porosity control is lacking. Note that half of the initially proposed wells (yellow stars above) would have been drilled into low-porosity areas without 3-D data.

3-D Seismic Inversion Modeling



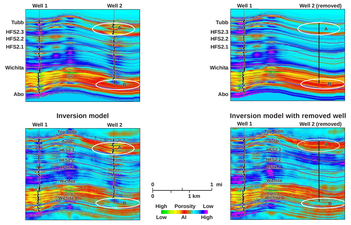
3-D seismic inversion has value only if a strong relationship exists between 3-D data and porosity. At Fullerton field, there is a good relationship between acoustic impedance (AI) and wireline log porosity.

Progressive Inversion



Progressive inversion entails four steps:
1. construction of detailed, cycle-based geological model.
2. development of high-resolution, wireline log model.
3. definition of geological framework in tuned, 3-D seismic data volume.
4. Merging of wireline model and 3-D seismic volume.

Blind Testing of Inversion Model

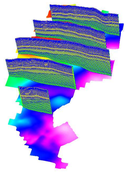


Blind testing demonstrates predictive ability of 3-D seismic in areas where wells are absent. When well 2 (above) is removed, wireline log model predicts too little porosity at A and too much at B. Inversion model does a much better job of defining true porosity in both areas.

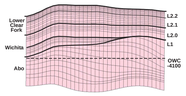
RESERVOIR MODELING AND SIMULATION

Full-field Reservoir Modeling

Model Framework



Cycle-based Layers



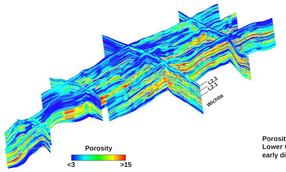
Lower Clear Fork (L2.1, L2.2) and upper Wichita (L2.0) sequences comprise cycle-based, subparallel layers (7, 7 and 5, respectively) that extend across the model area. The lower Wichita contains five layers that terminate at the Wichita-Abo facies transition. Abo layers are conceptually modeled clinoforms.

Model Attributes

Model Dimensions
35,000-acre Model

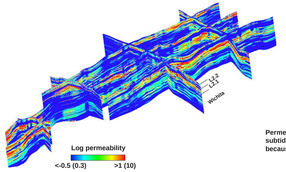
	Fine-grid Model		Simulation Model	
	Dimension (ft)	Cells	Dimension (ft)	Cells
X	150	140	150	239
Y	150	462	150	462
Z		380		36
Total		42 million		3.7 million

Field-wide Porosity Trends



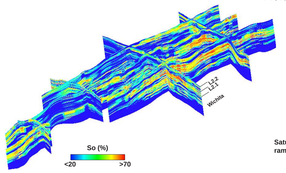
Porosity is a function of diagenesis. Porosity is high in much of the Wichita tidal-flat succession and in the Lower Clear Fork L2.1 subtidal. Lateral changes in porosity are more the result of structurally controlled early diagenesis than changes in depositional facies.

Field-wide Permeability Trends



Permeability is a function of facies. Note that in contrast to porosity, permeability is much higher in the subtidal Lower Clear Fork than in Wichita tidal-flat facies. The Wichita exhibits much lower permeabilities because of the dominance of Type 3 (mud-rich) rock fabrics.

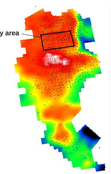
Field-wide Saturation Trends



Saturation is a function of rock fabric. Like permeability, oil saturation is highest in limestone-rich, ramp-crest facies of the subtidal Lower Clear Fork L2.1. Compare with porosity maps above.

Flow Simulation

Flow Modeling Area



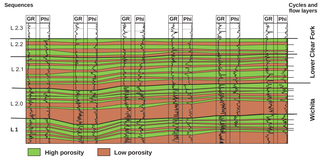
Flow-Model Attributes

Model Dimensions
2,000-acre model

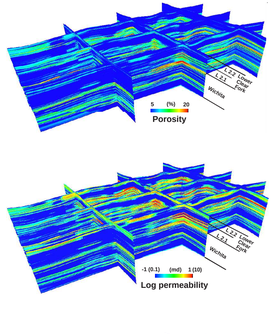
	Fine-grid Model		Simulation Model	
	Dimension (ft)	Cells	Dimension (ft)	Cells
X	103	140	200	73
Y	105	90	200	48
Z	2.2 (0-16)	254		39
Total		3.16 million		136,656

Sensitivity flow modeling was performed on a 2,000-acre area selected for high-data quality and representative setting. The area includes 140 wells on 10- and 20-acre spacing. Modeling and simulation were based on 86 wells, all with modern log suites. Model framework contains 38 cycle-based flow-unit layers.

Flow-Unit Architecture

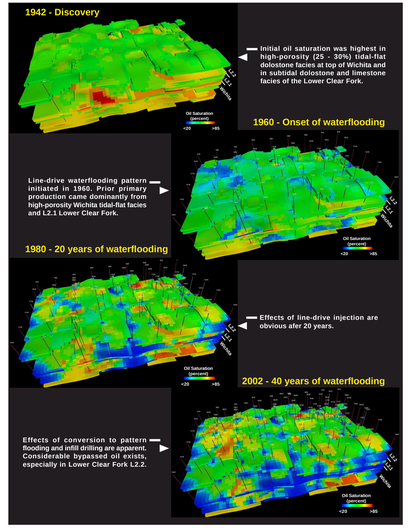


Model Area Petrophysics



The flow-simulation model area exhibits nearly the entire range of petrophysical and stratigraphic relationships observed in the full-field model. Results are thus applicable to most of the reservoir.

Simulation Results



IMPORTANT FINDINGS

Stratigraphic Architecture
- 3-D seismic data can provide inaccurate image of reservoir architecture
- Sequence boundary karst is widespread
- Porosity is a function of diagenesis, but permeability is a function of facies
- Porosity development is partially controlled by deep structure

Petrophysics
- Peritidal successions contain high-porosity, low-permeability rock fabrics
- Subtidal successions contain higher permeability rock fabrics
- Peritidal limestones are flow baffles; subtidal limestones are high-flow zones
- A single porosity cutoff or permeability transform is inadequate
- Permeability and water saturation models must consider rock-fabric distribution
- Petrophysical classes and rock fabrics can be mapped throughout the field using stratigraphic framework

3-D Geophysics
- Strong relationship between amplitude and porosity
- Amplitude extractions provide robust qualitative guide to interwell and extrawell porosity distribution
- Progressive 3-D inversion provides quantitative measure of interwell and extrawell porosity distribution
- Seismic response controlled by porosity (facies and diagenesis)
- Seismic architecture must be vetted by geological models
- Continuing and differential fault motion through Permian

Flow Modeling and Simulation
- Key insights to sweep and remaining oil distribution
- Recovery efficiency controlled by rock fabric, continuity, and completion coverage

Reservoir Resources
- Peritidal facies contains 55 percent of the total pore volume but only 43 percent of the original hydrocarbon pore volume

ACKNOWLEDGMENTS

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PUBLISHED RESULTS

A complete report on the findings of this study, entitled "Multidisciplinary imaging of rock properties in carbonate reservoirs for flow unit targeting", has been released by the Bureau of Economic Geology. Contents are listed below.

Ruppel, S. C. and Jones, R. H., Facies, Sequence Stratigraphy and Porosity Development in the Fullerton Clear Fork Reservoir, p. 1-124, 52 figures.

Jones, R. H. and Lucia, F. J., Integration of Rock Fabric, Petrophysical Class, and Stratigraphy for Petrophysical Quantification of Sequence-Stratigraphic Framework, Fullerton Clear Fork Field, Texas, p. 125-162, 23 figures.

Kane, J. A. and Jennings, J. W. Jr., Development of the Wireline-Log Database and Determination of Porosity Using Wireline Logs, p. 163-187, 9 figures.

Lucia, F. J., and Kane, J. A., Calculations of Permeability and Initial Water Saturations from Wireline Logs, p. 189-216, 16 figures.

Wang, Fred and Lucia, F. J., Reservoir Modeling and Simulation of Fullerton Clear Fork Field, Andrews County, Texas, p. 219-304, 56 figures.

Zeng, Hongliu, Construction and Analysis of 3-D Seismic Porosity Inversion Models, p. 305-342, 17 figures.

A pdf copy of this report is available from:

The Bureau of Economic Geology website
<http://www.beg.utexas.edu/resprog/fullerton/index.htm>

The U.S. Department of Energy website
<http://www.osti.gov/servlets/purl/837750-7tCynd/webviewable/>

A more complete CD publication of all results is being prepared and will be published and distributed by the Bureau of Economic Geology in 2006.