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TECHNICAL PROGRESS REPORT

Title:

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APPLICATION OF ADVANCED RESERVOIR
CHARACTERIZATION, SIMULATION, AND
PRODUCTION OPTIMIZATION STRATEGIES TO
MAXIMIZE RECOVERY IN SLOPE AND BASIN
CLASTIC RESERVOIRS, WEST TEXAS
(DELAWARE BASIN)

Cooperative Agreement No.:

DE-FC22-95BC14936

Institution:

Bureau of Economic Geology
The University of Texas at Austin
University Station, Box X
Austin, Texas 78713-7508

Date of Report:

July 30, 1996

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Anticipated Completion Date for this Budget:

March 30, 1997

Government Award for this Budget Period:

\$1,010,208

Program Manager:

Edith C. Allison

Principal Investigator:

Shirley P. Dutton

Permanent Contracting Officer's Representative: Edith C. Allison

Temporary Contracting Officer's Representative Jerry Casteel

Reporting Period:

April 1, 1996 - June 30, 1996

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OBJECTIVES

The objective of this project is to demonstrate that detailed reservoir characterization of slope and basin clastic reservoirs in sandstones of the Delaware Mountain Group in the Delaware Basin of West Texas and New Mexico is a cost effective way to recover a higher percentage of the original oil in place through strategic placement of infill wells and geologically based field development. Project objectives are divided into two major phases. The objectives of the reservoir characterization phase of the project are to provide a detailed understanding of the architecture and heterogeneity of two fields, the Ford Geraldine unit and Ford West field, which produce from the Bell Canyon and Cherry Canyon Formations, respectively, of the Delaware Mountain Group and to compare Bell Canyon and Cherry Canyon reservoirs. Reservoir characterization will utilize 3-D seismic data, high-resolution sequence stratigraphy, subsurface field studies, outcrop characterization, and other techniques. Once the reservoir-characterization study of both fields is completed, a pilot area of approximately 1 mi² in one of the fields will be chosen for reservoir simulation.

The objectives of the implementation phase of the project are to (1) apply the knowledge gained from reservoir characterization and simulation studies to increase recovery from the pilot area, (2) demonstrate that economically significant unrecovered oil remains in geologically resolvable untapped compartments, and (3) test the accuracy of reservoir characterization and flow simulation as predictive tools in resource preservation of mature fields. A geologically designed, enhanced-recovery program (CO₂ flood, waterflood, or polymer flood) and well-completion program will be developed, and one to three infill wells will be drilled and cored. Through technology transfer workshops and other presentations, the knowledge gained in the comparative study of these two fields can then be applied to increase production from the more than 100 other Delaware Mountain Group reservoirs.

SUMMARY OF TECHNICAL PROGRESS

Geophysical Characterization

Seismic interpretation continued on the Ford Geraldine Unit 3-D survey. A good synthetic seismogram tie from the Ramsey 22 #6 well was achieved in Syntool™. The top of the Lamar Lime and the top of the Manzanita Lime have been picked and interpreted across the survey. Interpretation using the Coherence Cube™ from Coherence Technology Corporation has shown encouraging results in the Lamar/Ramsey Interval. Preliminary work on the seismic attributes of Instantaneous Phase, Instantaneous Frequency, and Reflection Strength are in progress.

Reservoir Characterization

Subsurface Field Studies.— Reservoirs in the Delaware Mountain Group have low producibility (average recovery <14 percent of the original oil in place) because of a high degree of vertical and lateral heterogeneity caused by depositional processes and post-depositional diagenetic modification. Detailed correlations of the Ramsey sandstone reservoirs in Geraldine Ford field suggest that lateral sandstone continuity is less than interpreted by previous studies (Ruggiero, 1985, 1993). The degree of lateral heterogeneity in the reservoir sandstones suggests that they were deposited by eolian-derived turbidites, following the model of Gardner (1992 and in press) for Screwbean field. According to the eolian-derived turbidite model, which was first proposed by Fischer and Sarnthein (1988), sand dunes migrated across the exposed shelf to the

shelf break during sea-level lowstands and provided well sorted sand for turbidity currents or grain flows into the deep basin.

Cyclic changes in sea level were an important cause of vertical heterogeneity in the reservoir interval at Geraldine Ford field. Ramsey sandstones were deposited during periods of relative sea-level fall in high-order cycles. Laterally continuous organic-rich siltstones, which were deposited in periods of relative sea-level rise during the high-order cycles, create vertical flow barriers within the reservoir. The sealing facies above the Ramsey sandstone is interpreted to be a particularly effective trap because it was deposited at a time of sea-level rise at three scales of cyclicity (Gardner, in press).

Genetic models of basinal sandstones and mapped sandstone-body geometry indicate that dimensions of reservoir flow units are commonly smaller than the distances separating even the most closely spaced wells (20-acre well spacing). Reservoir strata comprise thin, higher permeability sandstone lenses encased in nonreservoir siltstones. The internal arrangement and stacking patterns of the Geraldine Ford sandstones suggests that they may have been deposited as compensation lobes that formed by individual beds being deposited in the adjacent topographic depression created by deposition of the immediately preceding bed (Gardner, in press). The amount of channelization in these distal, basin-floor deposits is uncertain. The reservoir facies may represent submarine-channel deposits encased within lower permeability lobe deposits or, alternatively, the reservoirs may be thick-bedded sandstone lobes and the nonreservoir facies are interbedded thin-bedded lobe-fringe deposits.

This depositional model is being tested and refined using log, core, and outcrop data. Of the cores received from Conoco for this study, four are from West Ford field (Cherry Canyon) and 69 are from Geraldine Ford field (Bell Canyon). Thirty-seven cores were slabbed this quarter. Eighteen cores have been described, and selected intervals have been photographed and sampled for petrographic and SEM analysis.

Bell Canyon sandstone units are predominantly massive, but structures such as horizontal to contorted laminations, soft-sediment deformation, cross-bedding and ripples, vertical "pipe" structures (burrows?), organic clasts, and dewatering features are present. The sandstones are mostly fine grained. Calcite-cemented zones, up to 1 ft thick, are more indurated and are located toward the top and bottom of the massive sandstone units, although cemented zones can occur throughout. Individual laminae in the laminated siltstone intervals (laminites) range in thickness from < 1 mm in the more organic intervals to ≥ 5 mm in the silt-rich intervals. Bioturbation is rare to absent in the organic-rich laminites and common to abundant in the silt-rich laminites. Lutites (dark, fissile, organic-rich siltstones) appear to contain abundant organic debris and some silt-size grains and can be massive, laminated, or contorted. Contacts between units are mainly sharp, but gradational grain size change can occur between the massive sandstones and laminites.

Examination of the four Cherry Canyon Sandstone cores from Ford West field began this quarter, and samples are being prepared for thin-section and SEM analyses. Compared with the overlying Bell Canyon Sandstone in Geraldine Ford field, the cored interval of the Cherry Canyon in the Ramsey 22-11 well is coarser grained (up to fine sand) and contains 5-mm-diameter cemented patches or blebs that are probably gypsum or anhydrite. Calcite-cemented intervals are uncommon in the 22-11 Cherry Canyon core, as are laminae of fine dark material; no dark lithoclasts were seen. SEM investigations will resolve the composition of the cement patches and of the dark fine-grained material (most likely organic matter, sulfides, or clays).

Inspection of the Cherry Canyon sandstones under binocular microscope reveals the dominance of euhedral to subhedral, clear, colorless quartz grains; grain-size distribution appears bimodal, the two fractions being silt and very fine to fine sand. Less than one-third of the sand

is frosted, which bears significantly on interpretations of provenance, transport, and depositional processes. This percentage of frosted grains is less than would be expected if all the sandstone were derived from an aeolian source. Whereas the aeolian turbidite model may hold for the basal sand package of the Delaware Mt. Group, the Brushy Canyon Sandstone (Gardner and Sonnenfeld, 1996 and in press; Dutton and others, 1996), it may not fully explain deposition of the overlying Cherry Canyon Formation.

Outcrop Characterization

Regional facies mapping of outcrops located on the Cowden Ranch, Culberson County, Texas, has been initiated. The purpose is to refine current models for the architecture, geometry, and distribution of lithofacies in the Bell Canyon Formation. A case study site, located north of Willow Draw and south of Cow Mountain, has been selected for detailed mapping and analysis of specific facies important to reservoir production. Vertical and lateral exposures, aligned perpendicular and parallel to the depositional strike of the system, provide an excellent opportunity for determining the three-dimensional geological structure of Bell Canyon sandstones.

Preliminary stratigraphic mapping and interpretation indicate several large channel-form sandstone bodies are present. The sandstone bodies are elongate in a north to south direction and display a broad, funnel-shaped geometry that is over 60 ft thick and several thousand feet across. The channel-form bodies are incised into interbedded successions of lutite, siltstone, and sandstone that are 5- to 15-ft thick and display a sheet-like geometry.

Producibility Problem Characterization

Tertiary development was initiated in the southern part of the field in 1981, but the northern part of the field still has not been CO₂ flooded. Effective reservoir sweep was reduced by early CO₂ breakthrough. Injected CO₂ ponded near the structural axis of the field, with CO₂ ineffective at mobilizing oil from more heterogeneous strata along the flanks (Ruggiero, 1985, 1993). To alleviate early CO₂ breakthrough, production rates were balanced and reservoir pressures were maintained above 900 psi, the minimum pressure needed for miscibility. As of 1994, cumulative tertiary production has been 5.5 million barrels.

Technology Transfer

A poster session titled "Application of advanced reservoir characterization, simulation, and production optimization strategies to maximize recovery in slope and basin clastic reservoirs, West Texas (Delaware Basin)" by S. P., Dutton, A. G. Cole, and S. D. Hovorka was presented at DOE workshops on Class II and III Oil Projects at the Center for Energy and Economic Diversification (CEED) in Midland on May 15 and 16.

The draft annual report for the first year of the project was submitted for review. Upon receiving review comments, the report was revised and the final report submitted.

PLANNED ACTIVITIES

Activities in the upcoming quarter will focus on four major areas: (1) using synthetics to tie the 3-D seismic survey to wells in West Ford and Geraldine Ford fields, (2) continuing field

studies of Bell Canyon sandstones in outcrop, (3) characterizing depositional heterogeneity in the Geraldine Ford and Ford West reservoirs by integrating core descriptions with log and core-analysis data, and (4) conducting petrophysical review and analysis of Bell Canyon and Cherry Canyon sandstones in Geraldine Ford and West Ford fields.

REFERENCES

- Dutton, S. P., Hovorka, S. D., and Cole, A. G., 1996, Application of advanced reservoir characterization, simulation, and production optimization strategies to maximize recovery in slope and basin clastic reservoirs, West Texas (Delaware Basin): Bureau of Economic Geology, The University of Texas at Austin, Annual Report prepared for the Department of Energy under contract no. DE-FC22-95BC14936, 81 p.
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- Gardner, M. H., in press, Reservoir characterization of deep-water siliciclastic reservoirs in the upper Bell Canyon and Cherry Canyon Formations of the northern Delaware Basin, West Texas, in Major, R. P., ed., *Oil and gas on Texas State Lands: an assessment of the resource and characterization of type reservoirs*: The University of Texas, Bureau of Economic Geology Report of Investigations.
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- Pittaway, K. R., and Rosato, R. J., 1991, The Ford Geraldine Unit CO₂ flood—Update 1990: *SPE Reservoir Engineering*, v. 6, no. 4, p. 410-414.
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**U.S. DEPARTMENT OF ENERGY
MILESTONE LOG**

ELEMENT CODE	DESCRIPTION	PLANNED COMPLETION DATE	ACTUAL COMPLETION DATE	COMMENTS
ACTIVITY 1.	Geophysical Characterization			
Task 1.	Design 3-D Seismic Program	6/30/95	5/25/95	100% Complete
Task 2.	Acquire 3-D Seismic Grid	12/31/95	7/25/95	100% Complete
Task 3.	Process 3-D Seismic Data	3/30/96	12/31/95	100% Complete
Task 4.	Interpret 3-D Seismic Data	3/30/97		40% Complete
ACTIVITY 2.	Reservoir Characterization			
Task 1.	Data Base Design and Construction	9/30/95	11/10/95	100% Complete
Task 2.	Subsurface Field Studies	9/30/96		75% Complete
ACTIVITY 3.	Outcrop Characterization			
Task 1.	Establish Sequence Stratigraphy	11/31/95		67% Complete
Task 2.	Petrophysical and Statistical Characterization	6/30/96		50% Complete
ACTIVITY 4.	Producibility Problem Characterization			
Task 1.	Review of Waterflood History	3/30/96		83% Complete
Task 2.	Review of CO ₂ Flood History	9/30/96		33% Complete
Task 3.	Review of Ford West Production History	3/30/97		
Task 4.	Analysis of Reservoir Heterogeneity	3/30/97		
ACTIVITY 5.	Recovery Technology Identification and Analysis			
Task 1.	Reservoir Simulation	3/30/97		
Task 2.	Develop Guidelines for Site Selection-Infill Wells	3/30/97		
Task 3.	Develop Guidelines for Site Selection- Injector Wells	3/30/97		
ACTIVITY 6.	Technology Transfer			
Task 1.	Publish Results	3/30/97		40% Complete
Task 2.	Workshop	3/30/97		
ACTIVITY 7.	Management and Administration			
Task 1.	Reports and Deliverables	3/30/97		63% Complete
Task 2.	DOE Contractor Review Meetings	3/30/97		63% Complete
ACTIVITY 8.	Project Continuation			
Task 1.	Prepare Project Plan	3/30/97		
Task 2.	Prepare Budget	1/31/97		

U.S. DEPARTMENT OF ENERGY
MILESTONE SCHEDULE ☐ PLAN ☐ STATUS REPORTFORM APPROVED
OMB NO. 1901-1400

1. TITLE Application of Advanced Reservoir Characterization, Simulation, and Production Optimization Strategies to Maximize Recovery in Stope and Basin Clastic Reservoirs, West Texas (Delaware Basin)		2. REPORTING PERIOD April 1-June 30, 1996		3. IDENTIFICATION NUMBER DE-FC22-95BC14936																								
4. PARTICIPANT NAME AND ADDRESS Bureau of Economic Geology The University of Texas at Austin Box X, University Station Austin, Texas 78713		5. START DATE 3/31/95		6. COMPLETION DATE 3/30/97																								
7. ELEMENT CODE	8. REPORTING ELEMENT	9. DURATION												10. PERCENT COMPLETE														
		1995												1996			1997											
		A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	Plan	Actual	
ACTIVITY 1.	Geophysical Characterization																											
Task 1.	Design 3-D Seismic Program																										100%	100%
Task 2.	Acquire 3-D Seismic Grid																										100%	100%
Task 3.	Process 3-D Seismic Data																										100%	100%
Task 4.	Interpret 3-D Seismic Data																										40%	40%
ACTIVITY 2.	Reservoir Characterization																											
Task 1.	Data Base Design and Construction																										100%	100%
Task 2.	Subsurface Field Studies																										75%	75%
ACTIVITY 3.	Outcrop Characterization																											
Task 1.	Establish Sequence Stratigraphy																										100%	67%
Task 2.	Petrophysical and Statistical Characterization																										100%	50%
ACTIVITY 4.	Producibility Problem Characterization																											
Task 1.	Review of Waterflood History																										100%	83%
Task 2.	Review of CO2 Flood History																										66%	33%
Task 3.	Review of West Ford Production History																											
Task 4.	Analysis of Reservoir Heterogeneity																											
ACTIVITY 5.	Recovery Technology Identification and Analysis																											
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Task 1.	Publish Results
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ACTIVITY 7.	Management and Administration																											
Task 1.	Reports and Deliverables																										63%	63%
Task 2.	DOE Contractor Review Meetings																										63%	63%
ACTIVITY 8.	Project Continuation																											
Task 1.	Prepare Project Plan																											
Task 2.	Prepare Budget																											
11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE		S. P. Dutton 7/23/96																										