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**IMPROVED RECOVERY DEMONSTRATION FOR  
WILLISTON BASIN CARBONATES**

**QUARTERLY TECHNICAL PROGRESS REPORT**

Cooperative Agreement DE-FC22-94BC14984

Luff Exploration Company  
Denver, Colorado

Award Date: June 10, 1994  
Completion Date: December 31, 1997

Government Award: \$1,778,014

Project Manager:	Larry A. Carrell Luff Exploration Company
DOE Project Officer:	Chandra Nautiyal Bartlesville Project Office

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## IMPROVED RECOVERY DEMONSTRATION FOR WILLISTON BASIN CARBONATES

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Luff Exploration Company  
Denver, Colorado

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Principal Investigators:  
Mark A. Sippel  
Larry A. Carrell

Project Manager:  
Chandra Nautiyal  
Bartlesville Project Office

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### Objectives

The purpose of this project is to demonstrate targeted infill and extension drilling opportunities, better determinations of oil-in-place, methods for improved completion efficiency and the suitability of waterflooding in certain shallow-shelf carbonate reservoirs in the Williston Basin, Montana, North Dakota and South Dakota.

Improved reservoir characterization utilizing 3-dimensional (3D) and multi-component seismic area is being investigated for identification of structural and stratigraphic reservoir compartments. These seismic characterization tools are integrated with geological and engineering studies. Improved completion efficiency is being tested with extended-reach jetting lance and other ultra-short radius lateral technologies. Improved completion efficiency, additional wells at closer spacing and better estimates of oil-in-place will result in additional oil production by primary and enhanced recovery processes.

## Summary of Technical Progress

### Field Demonstrations - Ratcliffe

The drilling of a horizontal lateral in the Ratcliffe reservoir from a cased hole was unsuccessfully attempted during January in the Trudell M-17, section 17, T. 26 N., R. 58 E., Richland Co., MT. The drilling technology was developed by Amoco<sup>1</sup>. The drilling failed immediately upon initiating drilling the curved portion of the hole through the casing window. A mechanical failure of the bottom-hole drilling assembly was the reason for unsuccessful results. The drilling depth of 8,500 ft is apparently beyond practical limits for this technology.

A pair of Ratcliffe completions in sec. 16, T. 26 N., R. 58 E., Richland Co., MT, were found to offer the greatest potential for additional recovery by improved completion efficiency and water-injection. Nearly 5,000,000 bbl (795,000 m<sup>3</sup>) was estimated for OOIP from material-balance calculations aided by computer simulation and production type-curve analysis. Recovery from these wells is approximately 150,000 bbl (23,800 m<sup>3</sup>) with remaining economic reserves of only 40,000 bbl (6400 m<sup>3</sup>). This recovery represents only 4 percent of the potential OOIP. Oil productivity and porosity development at these two wells is normal for the area. Distance between these wells is approximately one-quarter mile (0.4 km) and should be suitable for testing water-injectivity and secondary response.

Preparations are being made to drill a lateral from the 2-16 State with steered-motor technology. The well will be used for water injection in a pilot waterflood evaluation. Contingent upon the mechanical success of drilling operations at the 2-16 State, the technology may be used at the M-17 Trudell.

### Field Demonstrations - Buffalo field (North Area)

Engineering studies are completed for evaluation of horizontal drilling and waterflooding in the north area of Buffalo Field, Harding Co., SD. Luff Exploration Company has petitioned the South Dakota Oil and Gas Conservation Board for a hearing in June to drill a horizontal well in section 20, T. 22 N., R. 4 E. The well will commence drilling soon after the Board grants approval. Re-processed 2D seismic data will be used to guide placement and trajectory of

the lateral. The horizontal well will test water injectivity and is to be drilled mid-way between two existing wells in section 20. These wells are spaced on 320-acre (129 ha) production units. The horizontal injection well and two producers will comprise a pilot waterflood for the Red River "B" reservoir.

#### Geophysical Evaluations - Ratcliffe

A 2D multi-component seismic line was acquired over Cattails (Ratcliffe) field in Richland Co., MT. It is concluded that adequate data do not exist on the processed horizontal components to evaluate applicability of converted-wave methodology for fracture detection and characterization or to measure shear-wave splitting because processing was halted prior to achieving an optimal final product.

Feasibility evaluations are underway to have the data processed again by Pulsonics Seismic Processors in conjunction with other nearby 2D conventional P-wave data. From these data sets, an evaluation would be made of the merits of shear (S) and compressional (P) wave data as discriminators of Ratcliffe reservoir development. The Cattails study will guide future seismic-characterization efforts for the Ratcliffe. A 3D seismic survey over North Sioux Pass is scheduled for this year. Pending results from the Cattails multi-component re-processing and evaluation, additional shear-wave recordings may be included in this acquisition.

#### Geophysical Evaluations - Red River

The 3D seismic data acquisition at Cold Turkey Creek, Bowman Co., ND, were given to two geophysical interpretation companies for analysis. Seismic picks were made at the Greenhorn, Mission Canyon, Duperow, Interlake, Red River and Winnipeg. Time structure and isochron interpretations were made. Faulting was picked at Winnipeg and Red River events. Both interpreters found that it was necessary to rotate the 3D data volume to match the synthetic seismograms. One group rotated the data -120° and the other determined that a -90° rotation provided a normal polarity, zero-phase data volume. The Cold Turkey Creek data were acquired with dynamite shots as sources. Faulting was interpreted by both groups to affect the Winnipeg to a greater degree than the Red River and most faults

terminate in the Red River or slightly above the Red River. The predominant fault orientation is slightly west of north (315°). Faults are low relief and are generally one-quarter to one-half mile in length (0.4 to 0.8 km). P-wave attributes and isochrons were used for geostatistical correlation with thickness and porosity development in the Red River. Conclusions regarding stratigraphical correlations of Red River development with 3D seismic attributes were mixed and inconclusive from both groups.

The 3D data from Cold Turkey Creek were processed by Coherency Technology Corp. for incorporation with conventional faulting and stratigraphic interpretations. The coherency-cube transform is generated by analyzing localized waveforms in both the inline and crossline directions. Coherence is lower where traces are less similar. Displays of coherency values in map-view of time or horizon slices can depict stratigraphic changes or subtle faults<sup>2,3</sup>. However, it was determined from both interpretation groups that the coherency-processed data did little to enhance the final fault interpretation or stratigraphical analysis of the Red River.

It has been concluded that a well should be drilled in the northern area of the Cold Turkey Creek 3D survey; however, the 3D data are being re-processed and will be re-interpreted before the final location is to be selected.

A 3D seismic survey will be acquired at the Grand River School (Red River) field in Bowman Co., ND. Permits are being obtained and the shoot will probably occur in late-May pending weather and planting of crops.

Re-processing of 2D seismic data from the 1980's is underway across portions of Buffalo field (North Area). The purpose of the re-processing is to help delineate subtle faulting or other reservoir development trends which could impact the length and direction of a horizontal well in section 20, T. 22 N., R. 4 E.

#### Petrographical Evaluations - Ratcliffe and Red River

Luff Exploration Company will be drilling a Red River replacement well in section 17, T. 26 N., R. 58 E. (Richland Co., MT) in early summer and plans to obtain a core from the Ratcliffe in this well. Petrographical evaluations of the Ratcliffe and Red River have been resumed through Hendricks and

Associates, Englewood, CO. Completion of the petrography report is anticipated for June 1996.

### References

1. T.M. Warren, W. J. Winters and H.B. Mount, "Short-Radius Lateral Drilling System," *Journal of Petroleum Technology*, 45(2) : 108-115 (February 1993)
2. Mike Bahorich and Steve Farmer, "3-D Discontinuity for Faults and Stratigraphic Features: The Coherency Cube", *The Leading Edge*, 14(10): 1053-1058 (October 1995)
3. Daniel S. Morris, "A Revolution in 3D Seismic", *The Journal of Petroleum Technology*, 48(1): p. 28 (January 1996)

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