

**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

Reporting Period: July through September 30, 1996

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Larry A. Carrell

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additional oil production by primary and enhanced recovery processes.

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 are 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 short-lateral and horizontal drilling technologies. Improved completion efficiency, additional wells at closer spacing and better estimates of oil-in-place will result in

Summary of Technical Progress

Ratcliffe Core Analysis

An oriented core (10.2 cm, 4 inch diameter) was obtained through the Ratcliffe interval (2676.9 to 2703.1 m, 8783 to 8869 ft) at the Federal 1-17 R, North Sioux Pass Field (see Fig. 1 for location of well). A Schlumberger Formation Micro Imaging (FMI) log was also run across the interval. Several fractures were observed in the core. Core Lab ran fracture analysis of the core and established an orientation for the fractures. The FMI log was able to image the fractures which are observed in the core and produced a fracture orientation similar to the work performed by Core Lab. Conventional porosity-permeability studies were done with special core studies for wettability, capillary pressure and oil-water relative permeability. Evaluation of the electrical logs indicate a productive thickness of 4.6 m (15 ft), average porosity of 8.8% and water saturation of 46%. The majority of the productive rock is in a 2.1 m (7 ft) interval at 2684 m (8806 ft). Core porosity of this interval averages 12.9% with a geometric-mean permeability of $4.9\text{E-}4 \mu\text{m}^2$ (0.5 md) and maximum permeability of $1.3\text{E-}3 \mu\text{m}^2$ (1.3 md). See figure 2 for porosity log and core interval of the Ratcliffe in the Federal 1-17R well.

The core was slabbed for petrographical analysis which is in-progress by Mike Hendricks and Associates. The core has been photographed and several thin sections were also obtained.

Ratcliffe Re-Entry Lateral Completions

Two wells in the North Sioux Pass Field have been selected for re-entry lateral completion in the Ratcliffe. These wells are the M-17 Trudell and 2-16 State (Fig. 1). The laterals will be drilled out from 14 cm (5-1/2 inch) casing with steered-motor technology with planned extensions of 610 m (2000 ft). Orientation of the laterals will be normal to the fracture orientation observed from the 1-17R Federal core and FMI log data. The re-entry

lateral drilling activity has been delayed because of limited availability of special tubulars for the work string. These tubulars are now available and the work is scheduled to commence on about November 1.

Red River Targeted Drilling

Drilling operations are underway at the B-27 State-Muslow well in Bowman Co., ND (Fig. 3). The vertical well was targeted from a 3D seismic survey over Cold Turkey Creek Field. The well is expected to be at total depth by November 1. Contiguous cores will be cut across the entire upper Red River section (64 m, 210 ft). These cores will cover all four porosity benches (A, B, C and D zones) in the Red River. Sonic and density logs will be obtained for further synthetic-seismogram study and evaluation of the 3D seismic survey.

Luff Exploration Company participated in drilling a horizontal completion in the Red River B zone reservoir at State Line Field, Bowman Co., ND (Fig. 4). The 1-26H Greni well is the fourth well on a small Red River feature. The well is completed as a producer and will provide important production data for the evaluation of incremental reserves through horizontal completions from older fields which were previously depleted by vertical wells.

Red River Lateral Drilling

Drilling operations for a horizontal injection well at Buffalo Field (North Area) will commence in November after completion of the B-27 State-Muslow well. The Red River B zone is the target of the horizontal completion at the M-20H Stearns well (Fig 5.). The Red River B zone will be logged and drillstem tested through a vertical hole. The well will then be plugged-back and the horizontal section drilled. The state of South Dakota has approved a four-week water injection test. The lateral extension is planned to be 1219 m (4000 ft) and will be between two existing vertical wells. The success of the water-injectivity test will be an important step toward unitization and developing a field-wide waterflood project. The project has obtained

water injectivity data and pressure buildup data from nearby wells. These hard data will be used in construction of computer simulation models for projected waterflood recovery with horizontal completions.

Red River Geophysical

A 3D seismic survey was acquired over Grand River School Field in Bowman Co., ND (Fig. 3). Data processing is completed. Interpretation work is integrating the new data with the nearby Cold Turkey Creek 3D survey and waiting on the new sonic and density log to be obtained at the B-27 State-Muslow (Cold Turkey Creek) well. Re-processed 2D seismic data are being integrated into both the Cold Turkey Creek and Grand River School 3D surveys.

Ratcliffe Geophysical

A 3D seismic survey is underway at North Sioux Pass Field, Richland Co., MT (Fig. 1). Seismic evaluations of the Ratcliffe from this survey will be included as part of the Ratcliffe reservoir characterizations for the project.

Summary and Conclusions

Field demonstrations are in progress to collect data for evaluation of horizontal completions in both the Red River and Ratcliffe. A vertical well in the Red River will test attribute analysis of 3D seismic data for prediction of porosity development. Additional seismic acquisitions and interpretation are in progress for both the Ratcliffe and Red River. A water-injectivity test in a new horizontal completion in the Red River B zone at Buffalo Field is scheduled for next quarter.

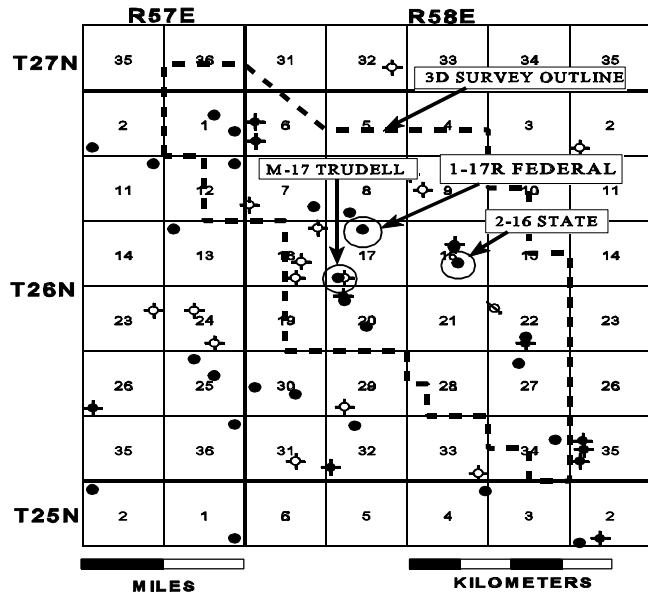


Figure 1: Map of North Sioux Pass Field, Richland Co., MT.

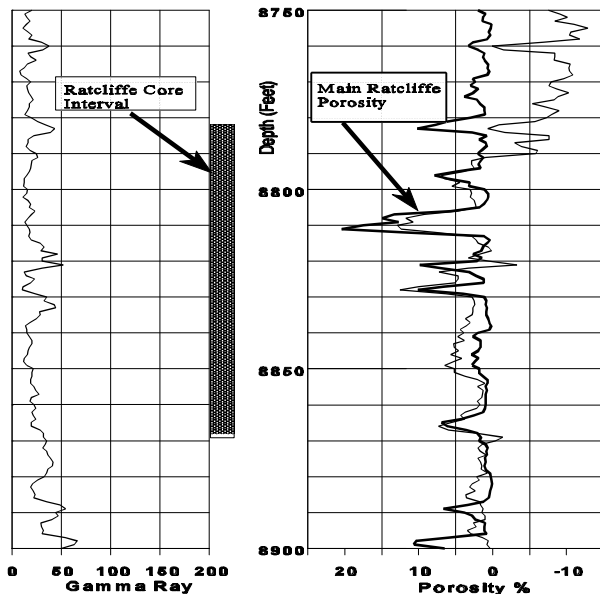


Figure 2:: Porosity log across the Ratcliffe interval from 1-17R Federal, North Sioux Pass Field.

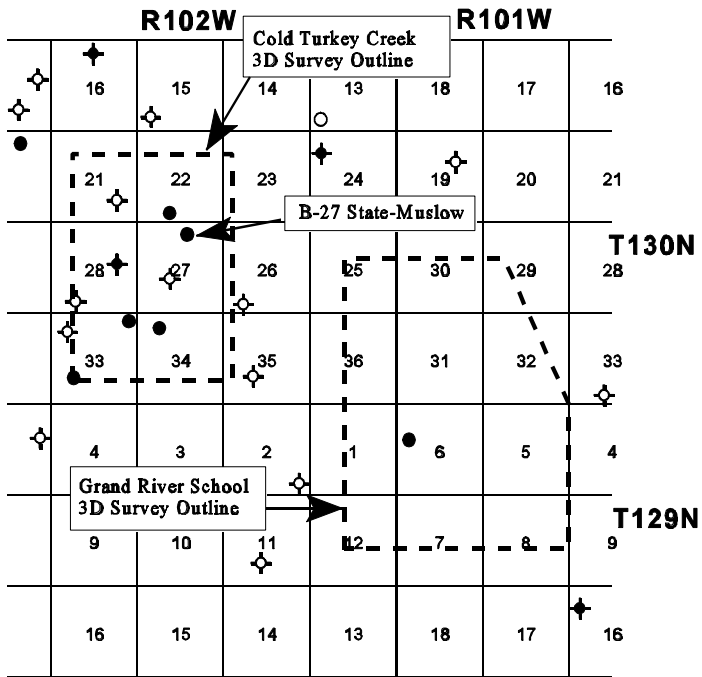


Figure 3: Map of Cold Turkey Creek and Grand River School Fields, Bowman, Co., ND

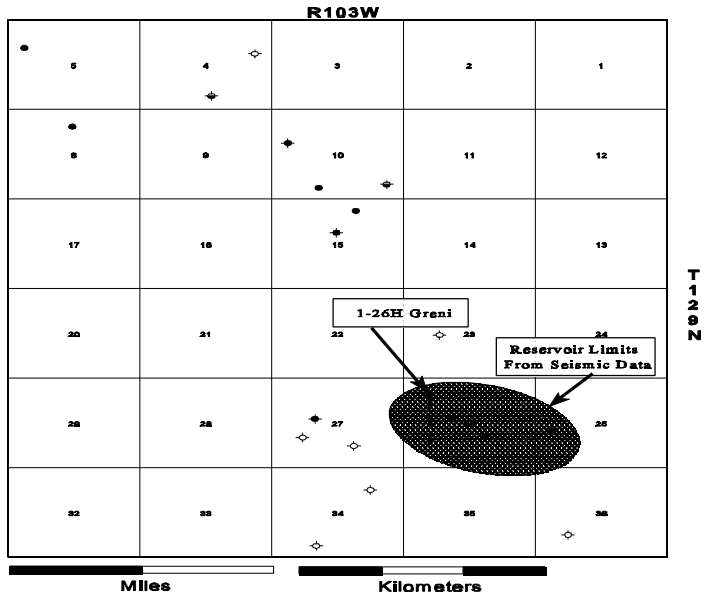


Figure 4: Map of State Line Field, Bowman Co., ND.

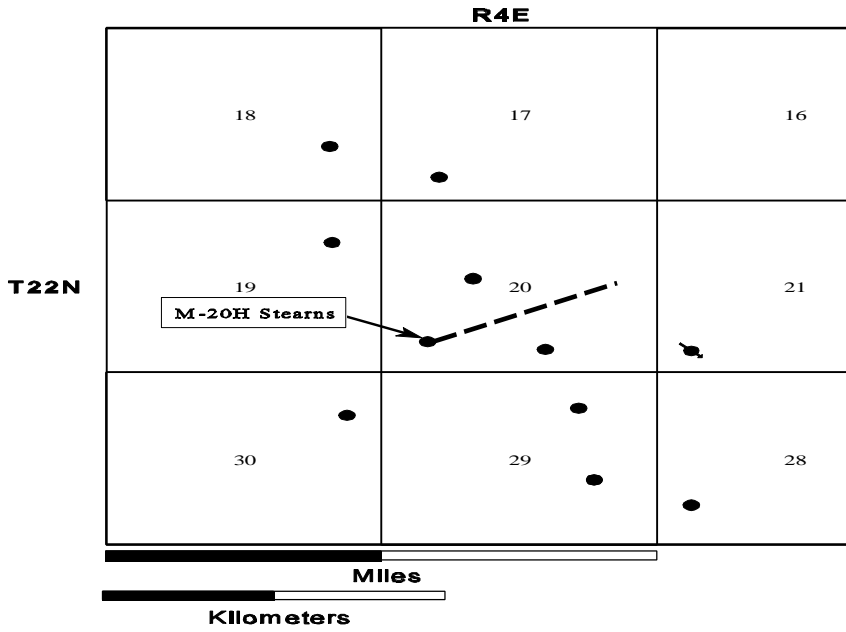


Figure 5: Map of Buffalo Field (north area), Harding Co., SD.