Quarterly Technical Report

ADVANCED RESERVOIR CHARACTERIZATION AND EVALUATION OF CO₂ GRAVITY DRAINAGE IN THE NATURALLY FRACTURED SPRABERRY RESERVOIR

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New Mexico Petroleum Recovery Research Center
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Program Manager:	Paul McDonald Parker and Parsley Petroleum USA, Inc.
Principal Investigator:	David Schechter New Mexico Petroleum Recovery Research Center
Contracting Officer's Representative:	Edith Allison Bartlesville Project Office
Reporting Period:	January 1, 1996-March 31, 1996

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Midland, Texas
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Project Manager: Paul McDonald, Parker and Parsley Petroleum USA, Inc.

Principal Investigator: David Schechter, New Mexico Petroleum Recovery Research Center

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url: <http://baervan/projects/spraberry.html>

Objectives

The objective of this research and the pilot project planned is to test the feasibility of CO₂ for recovering oil from the naturally fractured Spraberry Trend Area in the Midland Basin. This notoriously marginal reservoir has confounded operators for 40 years with rapid depletion, low recovery during primary, disappointing waterflood results and low ultimate recovery. Yet, the tremendous areal coverage and large amount of remaining oil (up to 10 Bbbl) warrants further investigation to expend all possible process options before large numbers of Spraberry wellbores need to be plugged and abandoned.

CO₂ injection on a continuous, pattern-wide basis has not been attempted in the Spraberry Trend. This is due to the obvious existence of a network of naturally-occurring fractures. However, it has become clear in recent years that neglecting CO₂ injection as an option in fractured reservoirs [1] may overlook potential projects which may be viable.

The 15-well pilot field demonstration and supporting research will provide the necessary information to quantify the conditions whereby CO₂ flooding would be economic in the Spraberry Trend.

Summary of Technical Progress

Field Demonstration

The E.T. O'Daniel #37, the central production well in the projected 15 well CO₂ pilot, was spud by Parker and Parsley Petroleum Co. Sept. 27, 1995. This core well confirmed the 1U and 5U zones are the primary reservoir zones in the Upper Spraberry. Thus, the 1U and 5U were the only zones that were perforated and stimulated. The well was completed after extensive open hole logging and has been pumping since December, 1995. Oil, water and gas production is found in Figs. 1 and 2. Production has been steady at about 11 bopd.

Currently, the well has been shut-in and a pressure build-up test is being conducted. A pulse test utilizing current wells outside the proposed pattern area will be performed in the third quarter. The pulse test will confirm the in-situ direction of the local fracture trend and verify either an E-W direction as indicated by FMI and core data or the traditional NE-SW trend measured in past surveys. The pulse test could also help to determine whether the stress state of the reservoir has been altered. It is important to align the pilot injection wells along a line parallel to the dominant fracture trend. The pulse test should also provide indication of the permeability anisotropy in the pilot area.

Open-Hole Logging

Open hole logs were run in the Upper Spraberry, both for net pay correlations, fracture identification and core-log correlation.

Fracture Identification

Results of FMI and core observed fracturing from the 5U pay zone is shown in Fig. 3. Samples taken for paleomagnetic orientation are also shown in Fig. 3. Generally, all data is in agreement in regard to E-W fracture orientation (N85°E). The pulse test will demonstrate whether or not the E-W orientation is a near well-bore phenomena created by induced fractures as a result of the stress state changing over time or a NE-SW orientation that was observed and documented in the 60's.

Net Pay Identification

We previously demonstrated [2] that classic shaly-sand analysis could accurately quantify thin, fractured pay zones which characterize the Spraberry Trend. The acquisition of core data proved that the 1U and 5U contain a majority of the hydrocarbon storage and although other thin intervals, with a greater clay content than the 1U or 5U and less than one foot in thickness, are also present.

Another revelation was the sharp contrast seen between pay and non-pay as observed by fluorescence. Identification and mapping of thin pay zones that comprise the Spraberry sands is an important first step when considering any IOR technique in the future. Geografix Inc. has donated their log and seismic analysis software to the project. QLA2 was used for developing a shaly-sand model specifically for the Spraberry Trend Area and the results are presented in the following section.

Shaly-Sand Model

Upper Spraberry core from the DOE pilot well E.T.O'Daniel # 37 was available for this investigation. The cores were examined to determine gross lithologic properties and to correlate core properties with the wireline log response in addition to development of a rock model. Thin-sections were made to determine the distribution of microscopically visible porosity and for investigation of diagenesis, cementation etc. Porosity, water saturation and permeability were obtained from whole core analysis.

Permeability distribution in the main pay was measured by minipermeameter and found to correlate well with whole core analysis. Minipermeameter measurement of the entire pay zone indicated that the matrix by itself is relatively homogeneous, usually in the range of 0.1 to 1.0 md. Two main pay zones, 1U & 5U (each is approximately 10 ft in thickness separated by 150 ft of non-pay) were clearly identified by oil fluorescence and are indicated in the log shown in Fig. 4.

Effective water saturation and effective porosity were calculated from shaly-sand log interpretation (Fig. 4) using both conventional m & n ($m=2$, $n=2$) and core derived m & n ($m=1.66$, $n=1.46$). It has been observed that conventional m & n values overestimate the water saturation, whereas water saturation calculated using core derived m & n values shows good agreement with core measured water saturation. It has also been observed that for the Spraberry Trend, the Automatic Compensation Method (ACM) and the Fertl method of shaly-sand interpretation performs better than the Dual water method. Effective water saturation calculated from the Dual Water method is much higher than the effective water saturation calculated from the ACM and the Fertl method.

Volume of shale (Fig. 4) was calculated from the gamma ray log using the Larionov non-linear relationship shown in Fig. 5. The result was compared with ultraviolet observations of fluorescing intervals. The fluorescing photographs show a clear distinction between oil bearing sand and muddy zones containing no oil due to sharp contrast seen at the interface between these lithologies. Shaliness factor q and effective porosity were calculated from log, and were cross-plotted on a shaly-sand producibility chart (q -plot) (Fig. 6) to determine if the volume of shale is high enough to drastically reduce producibility. Based on fluorescing intervals observed in the core along with q -plot analysis, we contend that shale volume $< 15\%$, $q < 0.15$ and effective porosity higher than 7% provide accurate cut-off criteria for identification of fluorescing intervals in Spraberry Trend Area reservoirs. Thin section analysis confirms the cut-off criteria by observation of visible porosity in oil bearing intervals whereas no visible porosity is observed in the non-pay muddy zones.

Matrix minerals were identified by thin section petrography, scanning electron microscopy and X-ray diffraction and compared with matrix minerals derived from open-hole logs. The pay-zones are composed predominantly of quartz and feldspar with some dolomite. Clay minerals are mostly illite.

The success of shaly-sand analysis now provides quantitative methodology to map the thin pay sands that comprise the Spraberry Trend reservoirs. This technique can be applied to the entire Trend to understand pinch-off and thinning of the sands near the fringe of the basin. We are currently attempting to apply the analysis to old case-hole logs.

Technology Transfer

Papers were presented at the Permian Basin SPE meeting in Midland, March 1996 (SPE 35469 and SPE 35224) and a poster was also prepared (SPE 35443). Another SPE paper is being presented at the DOE/SPE EOR meeting in Tulsa, April 1996 (SPE 35170). The PRRC and the Department of Petroleum and Natural Gas Engineering Department are hosting the 2nd Annual Naturally Fractured Reservoir Forum in Socorro, NM April 19, 1996. The forum includes presentations covering all the work performed on the Spraberry project in addition to other topics of concern in fractured reservoirs. A poster will be presented at the SSC Class II Workshop held at the UTPB-CEED in Midland May 15-16, 1996. The poster will be modified and presented at the 1996 SPE ATCE in Denver.

A brief description of the Spraberry Class III Field Demonstration along with a photograph of a mineralized natural fracture is found on the project home page: <http://baervan/projects/spraberry.html>. Links to the Class III Technical Proposal submitted to the DOE along with all DOE quarterly reports are also found on the Spraberry home page.

References:

1. Schechter, D.S., McDonald, P., Sheffield, T., and Baker, R.: "Reservoir Characterization and CO2 Pilot Design in the naturally Fractured Spraberry trend Area," paper SPE 35469 presented at the Permian Basin Oil & Gas Recovery Conference, Midland, Texas, 27-29 March, 1996.
2. Banik, A.K., and Schechter, D.S.: "Characterization of the Naturally Fractured Spraberry Trend Shaly Sands Based on Core and Log Data," paper SPE 35224 presented at the Permian Basin Oil & Gas Recovery Conference, Midland, Texas, 27-29 March, 1996.
3. Saleta, C.J., Banik, A.K., Cather, M.E., and Schechter, D.S.: "Application of Analytical Techniques to Evaluate the Heterogeneities of the Upper Spraberry Formation (Permian) and its Influence on the Quality of the Midland Basin Reservoirs in West Texas," poster SPE 35225 presented at the Permian Basin Oil & Gas Recovery Conference, Midland, Texas, 27-29 March, 1996.
4. Schechter, D.S., and Guo, B.: "Mathematical Modeling of Gravity Drainage After Gas Injection into Fractured Reservoirs," paper SPE/DOE 35170 presented at the SPE Improved Oil Recovery Symposium held in Tulsa, Oklahoma, 22-24 April, 1996.

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Fig. 1: Monthly Production Report of the DOE Pilot Well E.T. O'Daniel # 37

Fig. 2: Daily Production Report of the DOE pilot well E.T. O'Daniel # 37

Fig. 3. (Following page) FMI fracture identification and core fracture identification from the E.T. O'Daniel #37 5U pay zone (7227.5–7238.5). Rose diagram shows orientation to be N85°E. This agrees with paleomagnetic orientation of core observed fractures.

(2) natural fractures: strike 330° relative to MOL—top terminations at gradual muddy contact (larger frac oozing oil)

a: natural fracture relative strike 310°
b: petal fracture, parallel to a

c: petal fracture, relative strike 340°, extends downhole as centerline, probably connects with fracture sliver d

petal fracture; relative strike 320°

TD:80/217
TD:76/142
TD:86/128
TD:83/351

Correlation		Lithology	
GR	Vshl		
42.51 (GAPI)	133.29	0.0	1.0
Vshl		Siltstone	
0.0 (Equation)	1.0		
		Pay (Vshl < 15%)	Clay(Gray)
Fluorescing Intervals

Resistivity		Porosity		Saturation	
AORX	PHIE			SwFertl	
0.2 (OHMM)	2000.0	0.0	0.3	0.0	1.0
AORT		Pay(eff. por > 7%)		Water	
0.2 (OHMM)	2000.0				

7030

7040

7050

7060

7070

7080

7090

7100

7110

7120

7130

7140

7150

7160

7170

7180

7190

7200

7210

Fig. 4. Open-hole log interpretation using Fertl method of shaly-sand analysis for the DOE Pilot well E.T.O'Daniel # 37, Upper Spraberry.

Fig. 5: Comparison of the linear and non-linear model of shale volume calculated from Gamma Ray
(Upper Spraberry, E.T.O'Daniel # 37)

q-factor

Fig. 6. Shaly-Sand Productivity Chart (q-plot) for the DOE Pilot well E.T.O'Daniel # 37, Upper Spraberry. Intervals (1U & 5U) appearing in the box fluoresced strongly under ultraviolet light.