

DOE/BC/14990-6

TITLE: APPLICATION OF RESERVOIR CHARACTERIZATION AND ADVANCED TECHNOLOGY TO IMPROVE RECOVERY AND ECONOMICS IN A LOWER QUALITY SHALLOW SHELF CARBONATE RESERVOIR

Cooperative Agreement No.: DE - FC22 - 94BC14990

Contractor Name and Address: Oxy USA, Inc. (Oxy), Midland, Texas

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Anticipated Completion Date: June 14, 1996 - Budget Period 1

Government Award for Current Fiscal Year: \$2,023,000

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Reporting Period: October 1, 1995 - December 31, 1995

OBJECTIVES

The Class 2 Project at West Welch was designed to demonstrate the use of advanced technologies to enhance the economics of improved oil recovery (IOR) projects in lower quality Shallow Shelf Carbonate (SSC) reservoirs, resulting in recovery of additional oil that would otherwise be left in the reservoir at project abandonment. Accurate reservoir description is critical to the effective evaluation and efficient design of IOR projects in the heterogeneous SSC reservoirs. Therefore, the majority of Budget Period 1 was devoted to reservoir characterization. Technologies being demonstrated include:

1. Advanced petrophysics
2. Three dimensional (3-D) seismic
3. Cross-well bore tomography
4. Advanced reservoir simulation
5. Carbon dioxide (CO₂) stimulation treatments
6. Hydraulic fracturing design and monitoring
7. Mobility control agents

MASTER

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SUMMARY OF TECHNICAL PROGRESS

West Welch Unit is one of four large waterflood units in the Welch Field located in the Northwestern portion of Dawson County, Texas. The Welch Field was discovered in the early 1940's and produces oil under a solution gas drive mechanism from the San Andres formation at approximately 4800 ft. The field has been under waterflood for 30 years and a significant portion has been infill drilled on 20-ac density. A 1982-86 pilot CO₂ injection project in the offsetting South Welch Unit yielded positive results. The recent installation of a CO₂ pipeline near the field allowed the phased development of a miscible CO₂ injection project at the South Welch Unit.

The reservoir quality is poorer at the West Welch Unit due to its relative position to sea level during deposition. Because of the proximity of a CO₂ source and the CO₂ operating experience that would be available from the South Welch Unit, West Welch Unit is an ideal location for demonstrating methods for enhancing economics of IOR projects in lower quality SSC reservoirs. This Class 2 project concentrates on the efficient design of a miscible CO₂ project based on detailed reservoir characterization from advanced petrophysics, 3-D seismic interpretations and cross wellbore tomography interpretations.

During the quarter, progress was made in both the petrophysical analysis and the tomography processing. The geologic model is dependent upon the petrophysical analysis and the seismic and tomography interpretations. The actual reservoir simulation cannot start until the geologic model is complete, although all the preliminary simulation work is being done.

PETROPHYSICAL ANALYSIS

The layer thicknesses are ready to be input into the reservoir simulator. Layer porosity and permeability values are nearing completion. Integration of tomography data will begin on completion of the geologic model for the simulator.

Permeability estimation from well log data was found to require three different methods. The method is determined by use of the normalized gamma ray, deep resistivity curve and effective porosity as follows: (1) if the normalized gamma ray is less than .25 and either the deep resistivity is less than 50 ohms or the effective porosity is less than .04, then permeability is estimated from a scaled cementation exponent using the Focke and Munn¹ equation, (2) if the deep resistivity is less than 50 ohms or the effective porosity is less than .04, and the normalized gamma ray is greater than .25, then permeability is estimated from a scaled cementation exponent using the Nugent² equation with a resistivity-derived porosity, and (3) if the porosity is greater than .04 and the deep resistivity is greater than 50 ohms, permeability is

found from a Modified Carman Kozeny³ equation. A flow chart of the logic is shown in Fig. 1.

The above procedure is found to give results at least as good as the agreement between plug and whole core-derived permeabilities when applied section by section over the entire gross interval. Figure 2 compares the permeability from each method to the whole core permeability for WWU 7916. The composite results are shown in the fourth (right) panel.

3-D SEISMIC INTERPRETATION

Integration of the tomography and 3-D seismic interpretation has begun using cross well compression wave and reflection seismic data from the tomography surveys to tie with the 3-D seismic information. Also, the closely spaced synthetic sonic logs being created from the tomograms⁴ will be tied to the 3-D seismic interpretation. The objective is to distribute the high resolution reservoir description obtained from the tomography areally using the 3-D seismic.

TOMOGRAPHY

Processing is essentially completed on all portions of the tomography data with only minor changes if any expected from a final review.

TECHNOLOGY TRANSFER

During the quarter, presentations were made by team members at a second all day seminar November 6, 1995 at the CEED/Petroleum Industrial Alliance Facility between Midland and Odessa, Texas that presented the results to date of the West Welch project. Five different team members made presentations concerning the engineering, petrophysic, geologic, seismic and tomographic aspects of the project. Included was an actual demonstration of the seismic attribute to log property conversion method using commercially available low cost software on a PC. An abbreviated version of the seminar was presented in-house to 32 professionals at Oxy's Bakersfield office.

The seismic attribute to log property conversion method was presented to the Society of Exploration Geophysicists in Bakersfield, California and published in the Rocky Mountain Association of Geologists' "High Definition Seismic Guidebook - 1995" published in December 1995.

Two posters were presented during the technical session at the Bureau of Economic Geology's Fall Industrial Associates meeting for the Reservoir Characterization Research Lab in Carlsbad, New Mexico. One poster covered seismic estimation of log properties and the other showed examples of the tomography work being done.

Two technical papers were written for submission to the Society of Petroleum Engineers (SPE) Permian Basin Oil and Gas Recovery Conference to be held in March, 1995, covering the passive seismic and hydraulic fracturing results (SPE 35230) and the permeability estimation methods (SPE 35160).

REFERENCES

1. Focke, J.W. and Munn, D., Cementation Exponents in Middle Eastern Carbonate Reservoirs, *SPE Formation Evaluation*, June 1987.
2. Nugent, W.H., Letters to the Editor: The Log Analyst, 1984, v.25, No. 2 p.2-3.
3. Hinterlong, G.D., and Taylor, A.R., Application of Reservoir Characterization and Advanced Technology to Improve Recovery and Economics in a Lower Quality Shallow Shelf Carbonate Reservoir, DOE Contract No. DE-FC22-94BC14990, *Quarterly Report*, July 1- September 30, 1995.
4. Hinterlong, G.D., and Taylor, A.R., Application of Reservoir Characterization and Advanced Technology to Improve Recovery and Economics in a Lower Quality Shallow Shelf Carbonate Reservoir, DOE Contract No. DE-FC22-94BC14990, *Quarterly Report*, March 1- June 30, 1995.

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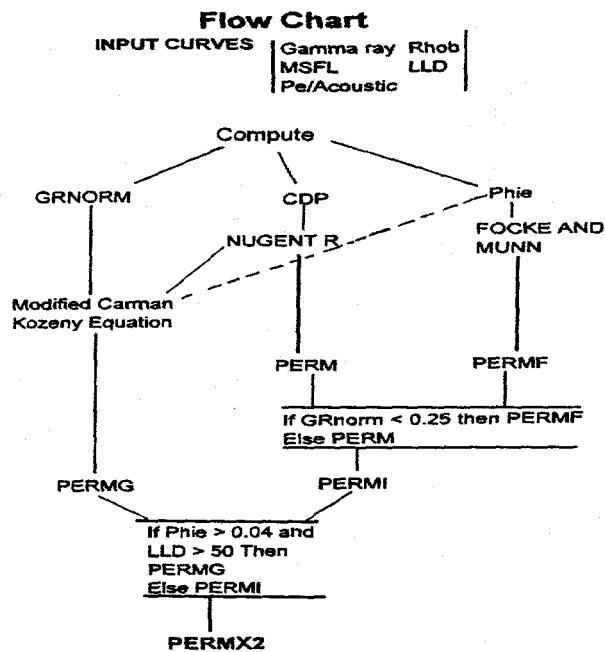


Figure 1. Flow chart for permeability computation.

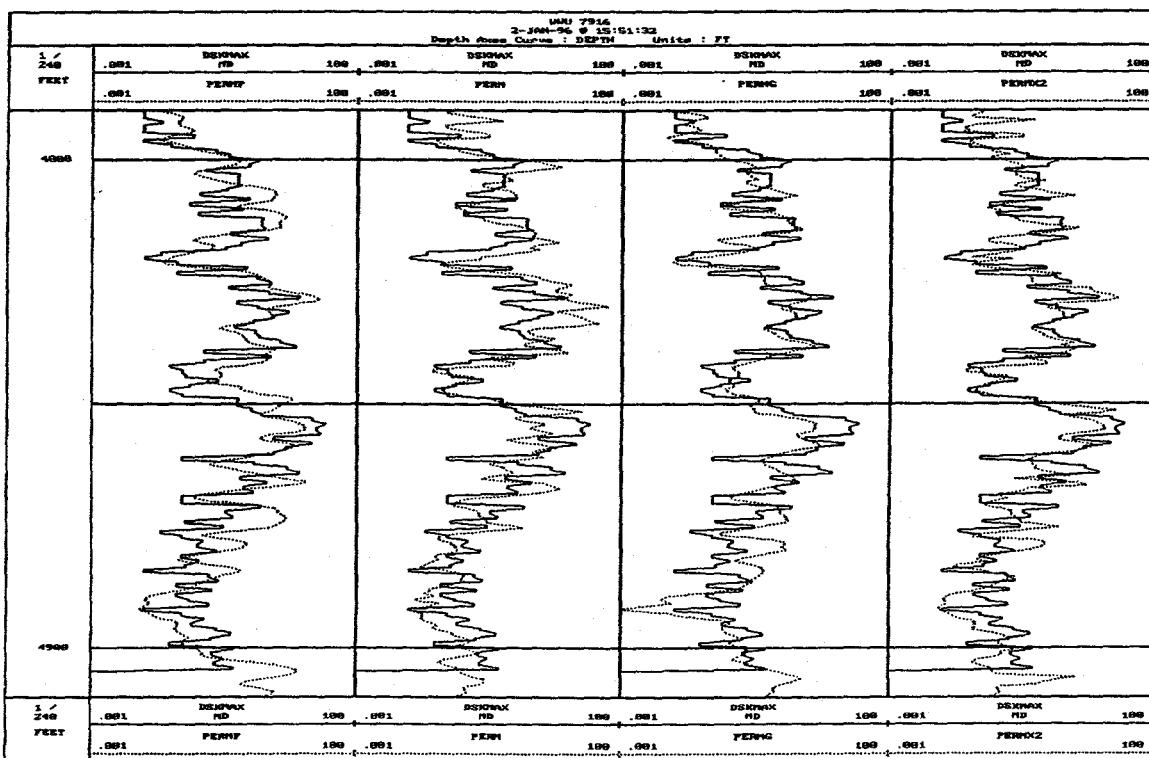


Figure 2. Whole core permeability (solid lines) vs. Computed permeabilities (dashes lines)