**Report Title:** Application of Reservoir Characterization and Advanced Technology to Improve Recovery and Economics in a Lower Quality Shallow Shelf San Andres Reservoir

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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

SUMMARY OF TECHNICAL PROGRESS

West Welch Unit is one of four large waterflood units in the Welch Field 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. 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 at the West Welch Unit is poorer than other San Andres reservoirs due to its relative position to sea level during deposition. Because of the proximity of a CO$_2$ source and the CO$_2$ 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 CO$_2$ project based on detailed reservoir characterization from advanced petrophysics, 3-D seismic interpretations and cross wellbore tomography interpretations.

During the quarter, cross well seismic work continued, using the revised processing software. The validity of the seismic-guided mapping was confirmed by the drilling of a well. Revised CO$_2$ performance projects were run using the enhanced geologic model in which the seismic data had been incorporated. Facilities for supplying and distributing CO$_2$ to the area were designed and bids solicited for the materials and construction.

3-D SEISMIC INTEGRATION

The seismic data over the project area have been used to generate porosity and porosity thickness maps for the two main pay intervals. Several wells were drilled outside the project area based on the latest seismic-guided porosity maps. The porosity logs showed an average porosity within 1/2 a porosity unit of the predicted value from the seismic-guided mapping. The mapping has identified additional locations just south of the project area that could be developed.

CROSS WELL SEISMIC

The quality of seismic data gathered from the fifteen line survey varies greatly between lines and along individual lines. The effort this quarter has focused on lines 1,2,7,9,11,12, and 13 which contain the best data. Three of these lines are from the north pattern and 4 from the south pattern. Rotating the phase along individual trace segments to compensate for the random orientation of the receivers consumed most of the quarter. The revised sections on the seven lines are showing realistic-looking seismic anomalies with 8-10 ft vertical resolution.

Synthetic seismograms were generated from sonic and density logs on WWU3210, 4852, and 7916. The synthetic seismograms were used to check the correlation of the cross well reflectivities.

NUMERICAL SIMULATION

The quarterly report for the first quarter of 1997 described the changes that resulted when the seismic-integrated model was used in the simulator for history match in place of the base geologic model. More accurate interwell reservoir characterization of the seismic-integrated model resulted in good agreement on total
fluid with the historical waterflood performance without the use of net/gross pay modifiers. The oil/water ratio match was improved by changing the mix of rock types to modify the relative permeability relationships. This change increased the overall residual oil saturation to waterflood. Higher oil saturation and the larger pay volume resulting from elimination of net/gross pay modifiers resulted in a larger volume of oil available as a CO₂ target.

The revised model was used to forecast CO₂ performance which projected an increased recovery compared to prior efforts. A larger volume of CO₂ will be required to realize the higher recovery. The performance forecast also showed a significant drop in production rate in the early life of the CO₂ flood. This comes about as a result of reducing injection pressures to stay below formation fracture gradient. To prevent this drop from occurring, injection rates have been cut back during this quarter to allow reservoir pressures to stabilize at a lower pressure prior to CO₂ injection. As a result of lower injection pressures, total fluid production dropped from 6,790 barrels per day to 6,417 barrels per day in only 48 hours with no measurable change in oil rate.

AREA PREPARATION AND CONSTRUCTION

The reduction in injection pressure mentioned under Numerical Simulation was achieved by temporarily shutting in all 18 active injector wells in the project area. The wells were returned to injection at rates which kept the surface pressure below the target established by utilizing results of 7-step rate tests that have been run recently. In addition, producing wells WWU4846 and 4832 were worked over. Pre-workover injection surveys were run on WWU4807w and 4816w.

WWU4854 was completed during the quarter to complete the south injection pattern (Figure 1). Well logs from WWU4854 along with previous fracturing work³ were used to create a fracturing model for design of the fracture treatment for this well.

CO₂ supply and distribution systems were designed and material specifications completed. The specifications were used to solicit bids for the materials. Successful bidders were selected and materials ordered. Construction bid packages were completed and mailed to five construction firms.

OXY operations, reservoir and facilities engineers used the information from the simulation model to design facilities. The model provided rates and pressures for each row of injection wells. A minimum and maximum injection rate and a maximum bottomhole injection pressure were specified for each injection well. The line sizing and wellhead fittings were then specified to keep the pressure differentials to less than 20 psi per mile and thus keep velocities to a minimum. Pressure losses from vaporization are to be avoided by keeping line pressures above the CO₂ critical pressure.
Each injection well assembly is comprised of a line blind (for changing to and from water and CO₂ injection) a line strainer turbine meter and manual choke assembly. Where the piping could be exposed to water, stainless steel was used instead of carbon steel. Additionally, supply meter locations use A333-Grade 3 or 6 piping due to the low temperatures expected during blowdown and depressurization.

TECHNOLOGY TRANSFER

During the quarter, George Watts made a presentation at the 1997 Southwest Section AAPG Convention in San Angelo, Texas. The paper, authored by George Watts, Greg Hinterlong and Archie Taylor, was titled “Seismic Description of a Complex Carbonate Porosity System,” Welch Field, Permian Basin, Texas and will be published in the meeting proceedings.

REFERENCES


Figure 1  Location of the new well #4854.