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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 (CO_2) 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 CO_2 injection project in the offsetting South Welch Unit yielded positive results. Recent installation of a CO_2 pipeline near the field allowed the phased development of a miscible CO_2 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 this quarter, interpretation and integration of the crosswell seismic data progressed, development of the south expansion area continued and CO_2 injection was expanded to a total of 13 wells.

3-D SEISMIC INTEGRATION

Drilling began on two new wells in the south expansion area that is based on seismic-enhanced mapping. These wells will be completed in the second quarter. The five wells drilled last quarter were completed, with initial production totaling about 110 BOPD. The results to date are being reviewed before additional wells are drilled. Wells may be drilled for water injection if performance data show the pressure support is needed.

CROSS WELL SEISMIC

Work continued on analyzing and developing processing procedures for interwell seismic data. Additional software improvements provided reflection profiles that merged the source gathers with the receiver gathers. Seven of these reflection profiles, which provided structural definition between the wells, were completed prior to the end of the quarter. Also, a migration algorithm for interwell reflection profiles has been developed and tested and the results look good. Final migrated section for all 15 lines of cross well seismic data are expected in the next quarter.

The relationship between shear velocities and compressional velocities was investigated as a method for identifying rock types. Shear waves travel through the rock matrix and are not affected by fluid movement in contrast to compression waves, which are affected by both rock matrix and fluid properties. Differences in the relationship between shear and compression wave velocities should highlight different rock types. A plot of cross well shear velocities versus compressional velocities for the total cross well data set is shown in Figure 1.

The initial attempt at rock typing used polygons to identify groups of points located in the same area on the plot. Figure 1 shows a "horn" outlined by a polygon. The data forming this "horn" corresponds to an oolitic section identified in the core of the #4852, which is also the source well for the south cross well seismic lines. Earlier work involving the use of well log and core transforms[1] to calculate permeability noted that this interval gave erroneous high permeability values and was probably an unaccounted for rock type. However, the problem was not considered to be significant since it was only seen in one small interval in one core. In Fig. 2, this rock type is represented by the lightest shade. This cross well line shows this interval or rock type thickening to the south and representing a larger part of the pay interval then originally assumed.

Figure 3 includes the data for the south lines only and shows the separate linear trends which are apparently different rock types. Additional investigation using this method of identifying flow units will be ongoing.

NUMERICAL SIMULATION

The seismic-enhanced model predicted that CO_2 injection rates would reach 10 MMCFD during this quarter. Although the actual rates matched the predicted rates for the first 4 months of injection, during the last two months, CO_2 injection rates have fallen below the rates predicted by seismic-enhanced model, but are above the predictions of the base geologic model. Also, the base geologic model predicted CO_2 production rates (breakthrough) over 1 MMCFD at the end of 6 months. To date the project produces no measurable CO_2 volumes, which agrees with the seismic-enhanced model predictions.

The fracture growth model that has been developed and successfully tested in new wells, indicates that a 400 ft fracture in an injector will grow out of zone and result in CO_2 losses. Smaller treatments, which would keep CO_2 from being lost out of zone, were investigated for improvement in areal sweep efficiency. Simulations of shorter fractures have shown increased oil recovery, even when a 100 ft fracture half length is represented by high permeability along three east-west grids including the well block. The smaller fractures showed reserve increases of about 20,000 barrels of oil for each injector fracture treated. In contrast, the larger (400 ft) fractures increased reserves by about 100,000 barrels per injection well treated.

AREA PREPARATION AND CONSTRUCTION

CO_2 is currently going into 12 of the injection wells in the project area. Well #4803 was converted to CO_2 injection after building reservoir pressure with water injection. Well #4838 was converted to CO_2 injection but would not take CO_2 at acceptable rates and was put back on water injection, prior to workover, to reduce well control problems. A step rate test was run on the #4801 to determine if the parting pressure continued to decline to the south as noted in previous tests. The test on the #4801 showed a parting pressure similar to the #4805, which is in the next injection row to the north.

The CO_2 injection system was extended south to the last row of injectors and injection should begin during the second quarter. Average CO_2 injection rates in the project area for the quarter were:

January	5227 mscfd
February	6650 mscfd
March	5959 mscfd

Well #4830 was hydraulically fractured based on the fracture model for the area. Prior production was 2 BOPD and 35 BWPD with post fracture production of 15 BOPD and 43 BWPD. Two other producing wells (#4820 and #4824) were reactivated. The five new wells drilled in the south expansion area were stimulated resulting in increased production of about 110 BOPD.

Three new separators were ordered to allow the gathering system to operate at the higher surface pressures expected with increased CO_2 volumes.

TECHNOLOGY TRANSFER

Archie Taylor presented the integrated well logging methods[1] at the DOE-sponsored logging symposium held in Denver, January 13, 1998. Two papers[2,3] covering the project simulation work were presented at the SPE Permian Basin Oil and Gas Recovery Conference in March, 1998. George Watts presented a paper[4] and poster session at the AAPG SWS convention on March 29,1998.

REFERENCES

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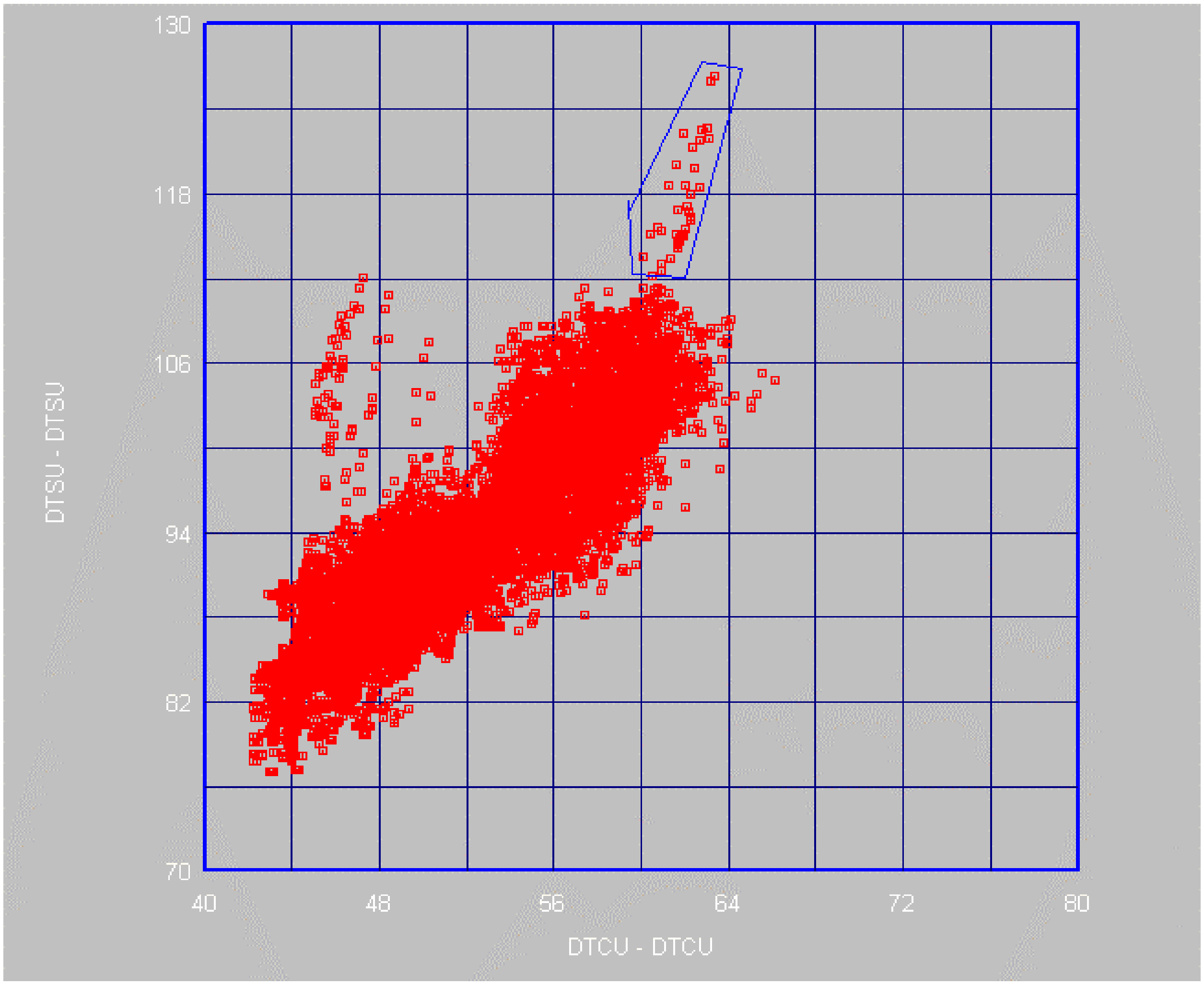

Figure 1. Shear wave travel times (DTSU) versus compressional wave travel times (DTCU) for the total cross well seismic data set gathered.

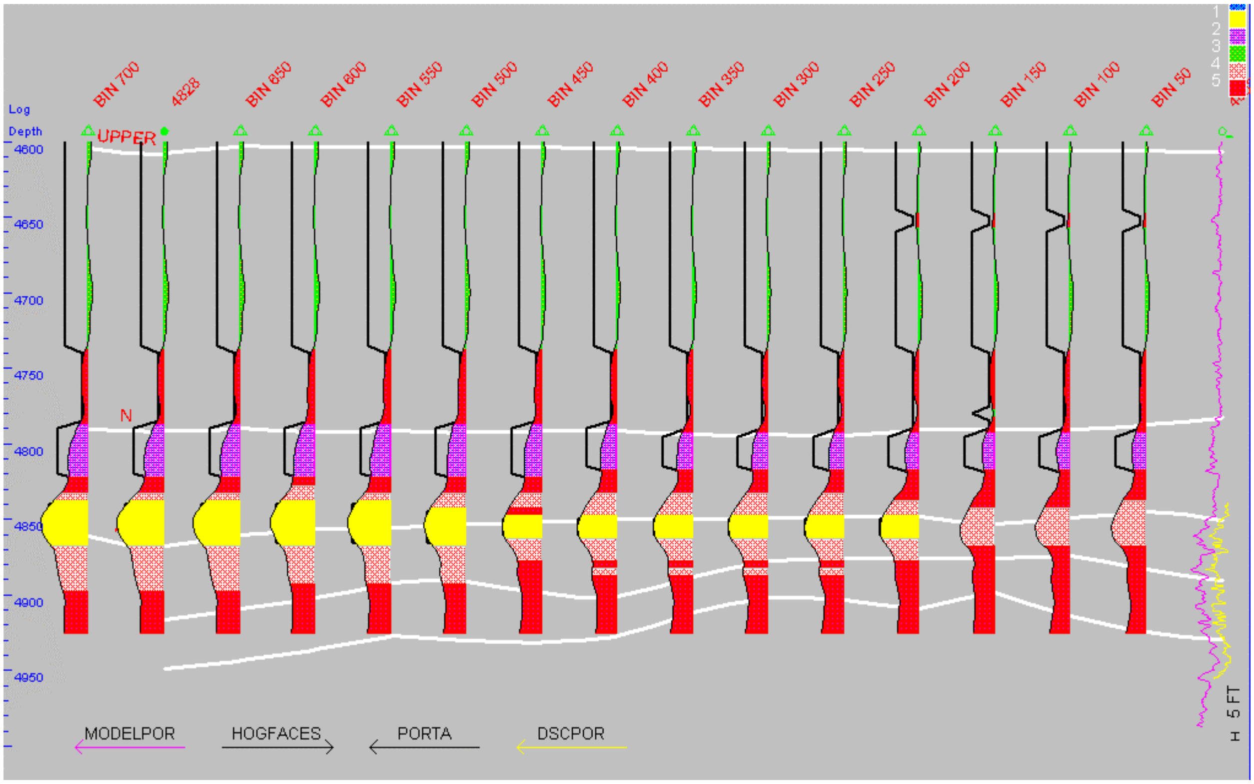

Figure 2. Rock types from cross well seismic for the south line from the 4852 source well (right) to the 4828 (left).

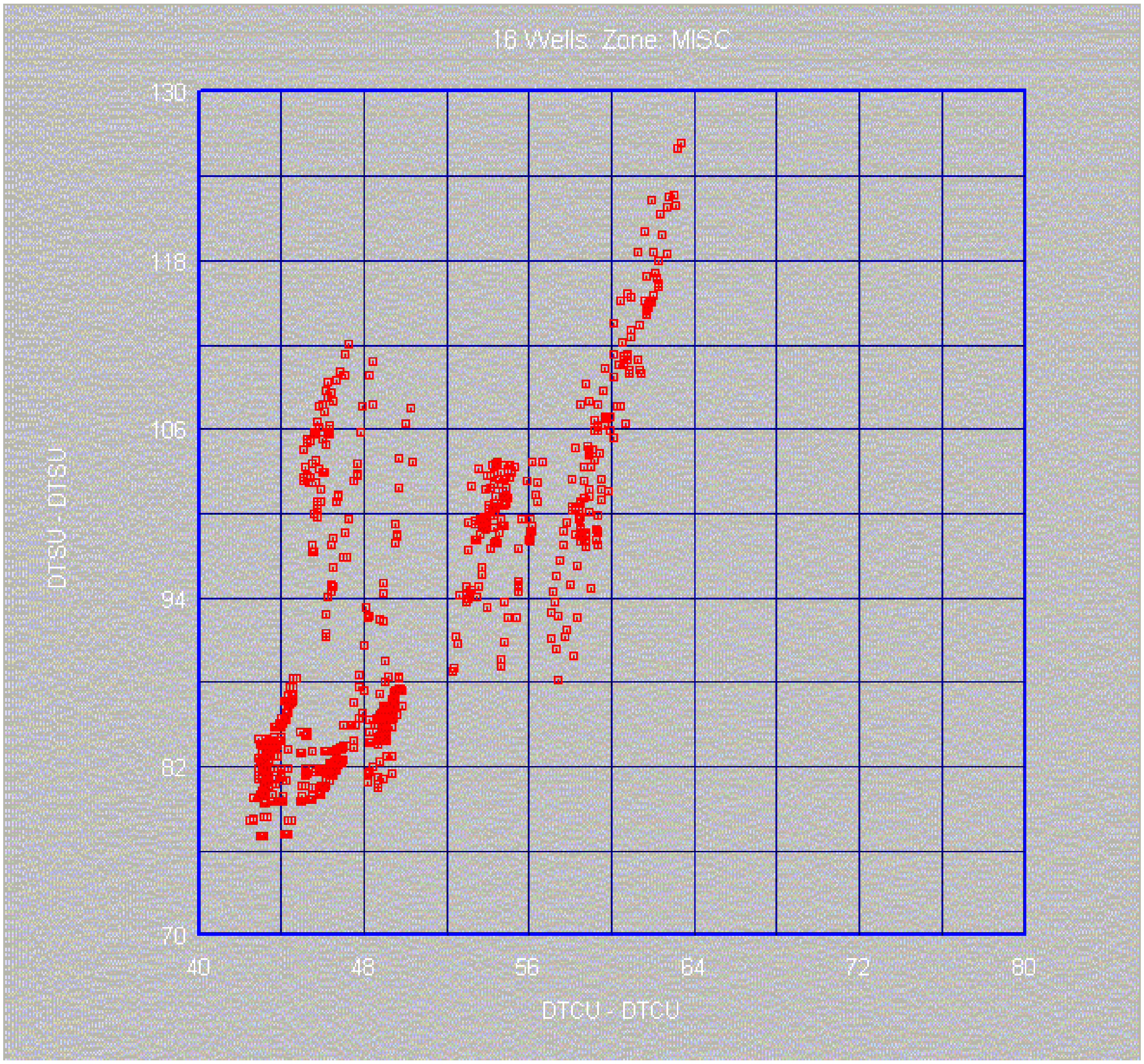

Figure 3. Cross plot of the south line crosswell compression (DTCU) and shear (DTSU) wave travel times.