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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DISCLAIMER

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. Crosswell 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 crosswell tomography interpretations.

During the quarter the difference between the detail porosity profiles derived for the three interwell seismic surveys were used to show the increase in CO_2 saturation as a function of time. The reservoir processing rate has been increased by the effort to maximize CO_2 injection.

INTERWELL SEISMIC

In the second quarter of 2001, Advanced Reservoir Technologies (ART) integrated results from the original baseline interwell survey (3Q94) with the first monitor survey (4Q99) and the second monitor survey (1Q01) to get a four dimensional representation of the outward advance of CO2 in the reservoir from the 4811 injector. The monitor survey locations, which were identical lines for both, are shown by Figure 1. ART's approach required processing the shear and compressional tomogram data to derive detailed porosity distributions. For a given survey line, the change in porosity over time reflects an increase in CO2 saturation. The change in CO2 saturation can only be scaled in relative not absolute value. The technique utilized has been discussed in the last several quarterly reports.

The difference between two surveys along the same line shows in two dimensions exactly where the saturation changes have occurred. This is illustrated along the line from the source well 4852 to 4843 by Figure 2, which is the difference between the baseline survey and the first monitor survey, and by Figure 3, which is the difference between the first and second monitor surveys. Injector 4811 is located at the left axis and producer 4843 at the right axis. The darker grey is the CO2 saturated reservoir. Note that CO2 movement between the two monitor surveys occurred in the bottom of the reservoir. Figure 4 is the saturation representation at the time of the second monitor survey, i.e. the sum of Figures 2 and 3.

This line was chosen because it clearly shows that CO2 from injector 4811 had preferentially moved in a southeast direction at the time of the first monitor survey. The second monitor survey shows that the CO2 is beginning to fill the reservoir hydrocarbon pore volume in every direction sampled, not just in the preferential direction. Well tests indicate that significant CO2 breakthrough occurred in 4843 during the first half of 1999, while the tomography results indicate that CO2 saturation reached 4843 between the first (4Q99) and second (1/01) monitor surveys. However, the saturation results are qualified by the fact that data was not acquired along the 4852-4843 line during the original baseline survey. Baseline data was modified from an offsetting line to create a pseudo-baseline survey for 4852-4843. The results using the pseudo-baseline appear reasonably consistent with results using only the actual monitor surveys. Also the survey line is from the 4852 source well and not from the 4811 injector to 4843.

3-D SEISMIC INTEGRATION

No activities involving 3-D seismic were undertaken during the quarter.

NUMERICAL SIMULATION

It is anticipated that the modeling requirements developed in the first quarter of 2001will be incorporated in the simulation during the third quarter of 2001. Several future scenarios will be modeled, including various slug sizes and different WAG schedules.

FIELD DEMONSTRATION PHASE

A total of 328 mmcf (3.6 mmcfpd) of CO2 was injected into six wells in the CO2 focus area during the second quarter of 2001. The total volume of CO2 injected through June 2001 is 3.7 bcf in the focus area and 4.7 bcf in the total project area since initiation of injection in October 1997. Overall oil production is lower that the last quarter because of the reduction in CO2 injection in the fourth quarter of 2000 due to drilling the 4853 horizontal lateral and in the first quarter of 2001 for acquisition of the interwell seismic monitoring survey data. The CO2 focus area injection and production performance for the second quarter of 2001 is shown on Table 1.

In the ongoing effort to maximize the CO2 input rate, the surface injection pressure limits were recalculated using recent bottom hole pressure survey results on all six wells. As a result, May and June had the highest injection rates to date for the focus area. The reservoir's hydrocarbon pore volume (HCPV) is now being processed by CO2 at a rate of 0.4% per month. A total of 12.1% of the HCPV within the focus area has

been processed through June 2001. At this rate it will take about seven months to process 15% of the HCPV that is considered minimum for evaluating the process. Two of the six inverted 7 spot injection patterns have already processed more than 15% of the HCVP. Since the project is scheduled to terminate on September 30, 2001 a short extension may be requested from the DOE if sufficient project funds are left to operate for several more months. Injectivity profile surveys will be run in all six injectors during the third quarter in an effort to improve injector efficiency.

A horizontal lateral was drilled due north from the 4853 wellbore and completed in the 1Q01 as reported. The well path passed midway between to sets of CO2 injectors- 4810-4806 and 4809-4811. Initial well tests indicated a good oil rate, which was soon overwhelmed by the breakthrough of CO2 into the wellbore. 4853 was shut in during the second quarter of 2001 because problems at the gas plant reduced its capacity. A pressure fall off test was conducted on injector 4810 in an effort to determine if it was in direct communication with the 4853 lateral. Two hundred thirteen (213) hours into the test 4853 was opened for two hours. A pressure transient analysis of the data using curve matching techniques shows that the slope of the pressure derivative changes between 220 and 230 hours into the test (Figure 5). This indicates that 4810 is in communication with the 4853 lateral. What this means in quantitative terms is not known, but neither the injection pressure performance or the pressure falloff data suggest a direct channel. In view of the large volume of CO2 that 4853 is capable of producing, other injectors probably contributing CO2 to 4853.

Remedial operations were conducted on two producers, 4842 and 4846 in May 2001 to remove any “skin” around the wellbore. The basic procedure was to jet wash the perforation and treat the wells with scale converter and 4000 gal acid. The initial production increases were on the order of 15 to 20 bopd for each wells, but had decline by the end of the reporting period. The most recent test data showed 5 bopd increase for 4842 and a 7 bopd increase for 4846. The gas volume increase several fold, particularly on 4842. These two wells were selected for remedial work because they were two of only three out of nine direct offsets to the six CO2 injectors that hadn’t experienced increase gas (C02) and/or oil production. It definitely appears that gas breakthrough has occurred on 4842 and is possibly starting to occur on 4846. The performance of both wells will have to be studied for a longer period of time to determine if oil production in either well is responding to C02 injection.

Producer 4827 was entered in April 2001 to repair a tubing leak. The well was also treated for scale and acidized with 3000 gal. Larger sucker rods were installed to increase the lift capacity. The well went from 6 bopd and 33 bwpd to 0 bopd and 350 bwpd. Apparently the earlier plugback from a lower zone failed during the remedial operations.

The only definitive change in producer response to CO2 injection in this quarter has been a significant increase in gas on 4842 . There is possible oil response starting on 4829 and 4848 and a possible gas increase on 4846. If additional test data confirm the response in 4829, it will be the first diagonal offset to the injectors that has responded. Normally, the gas increase on 4842 and possibly 4846 would be considered CO2 breakthrough along a more permeable layer. Since both wells were worked over, the increase may be due to removal of the skin damage around the wellbore. The current response to CO2 is shown on Figure 5.

TECHNOLOGY TRANSFER

No technology transfer activities have taken place this quarter.

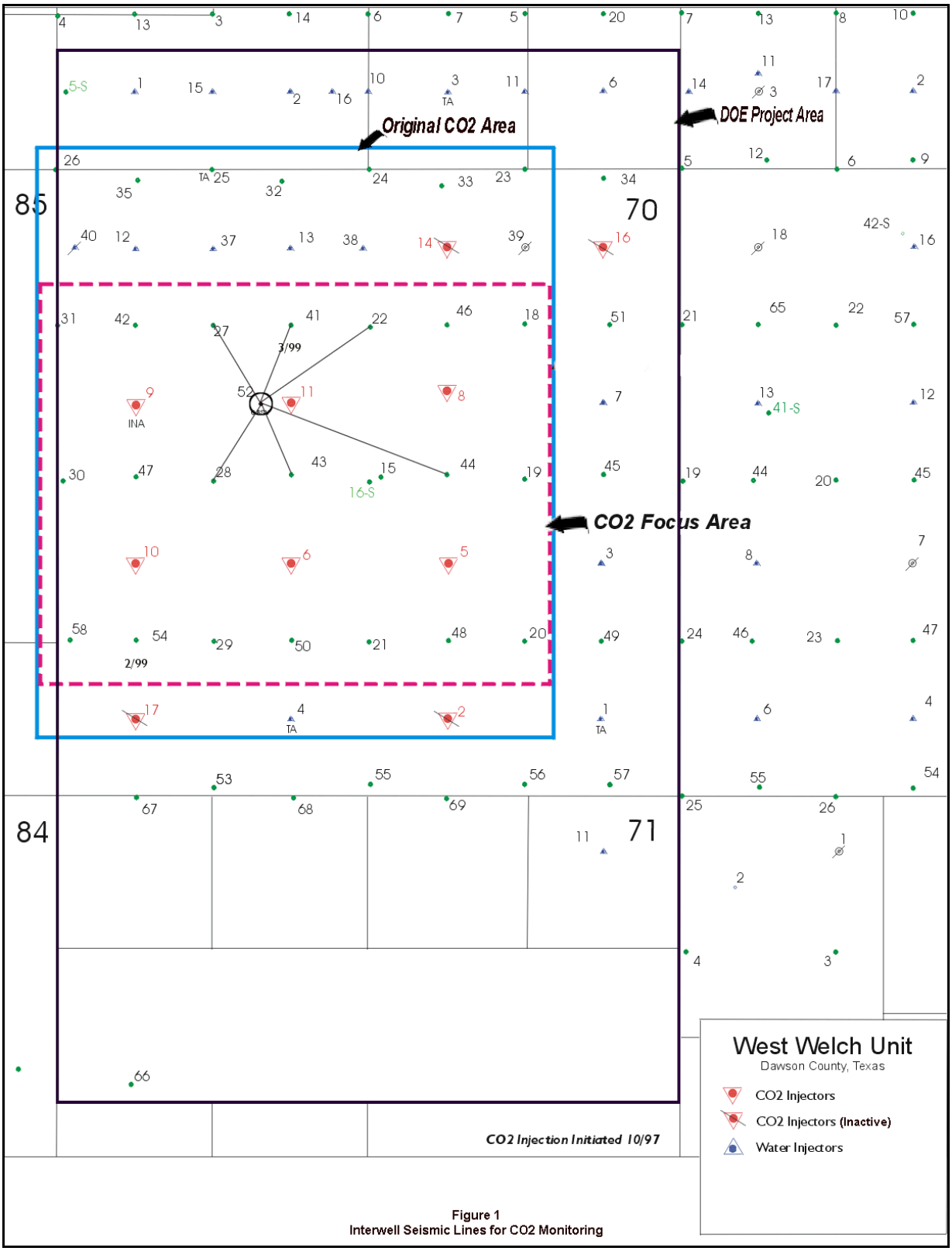

Figure 1
Interwell Seismic Lines for CO2 Monitoring

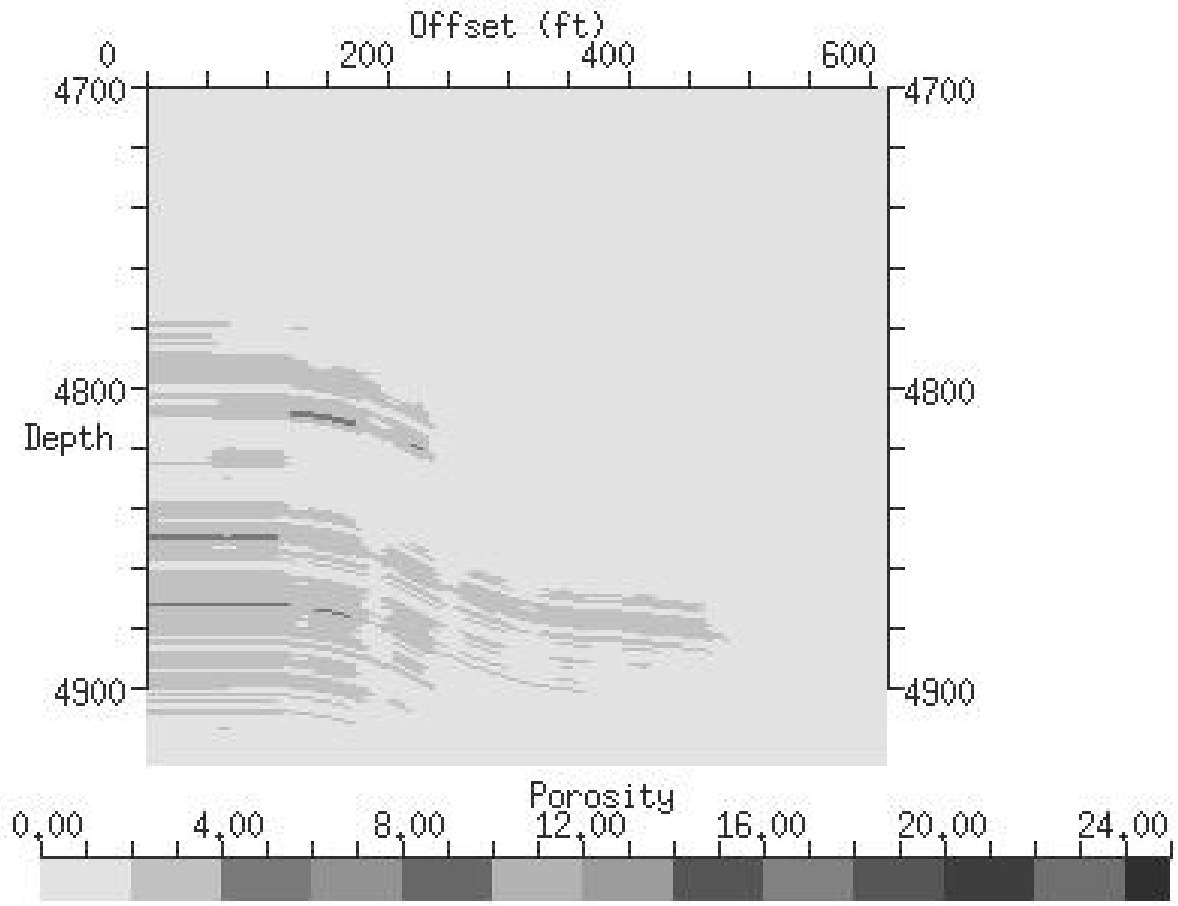

Fig. 2 - Changes in CO2 Saturation Between 3Q94 and 4Q99 Along Survey Line 4852-4843.

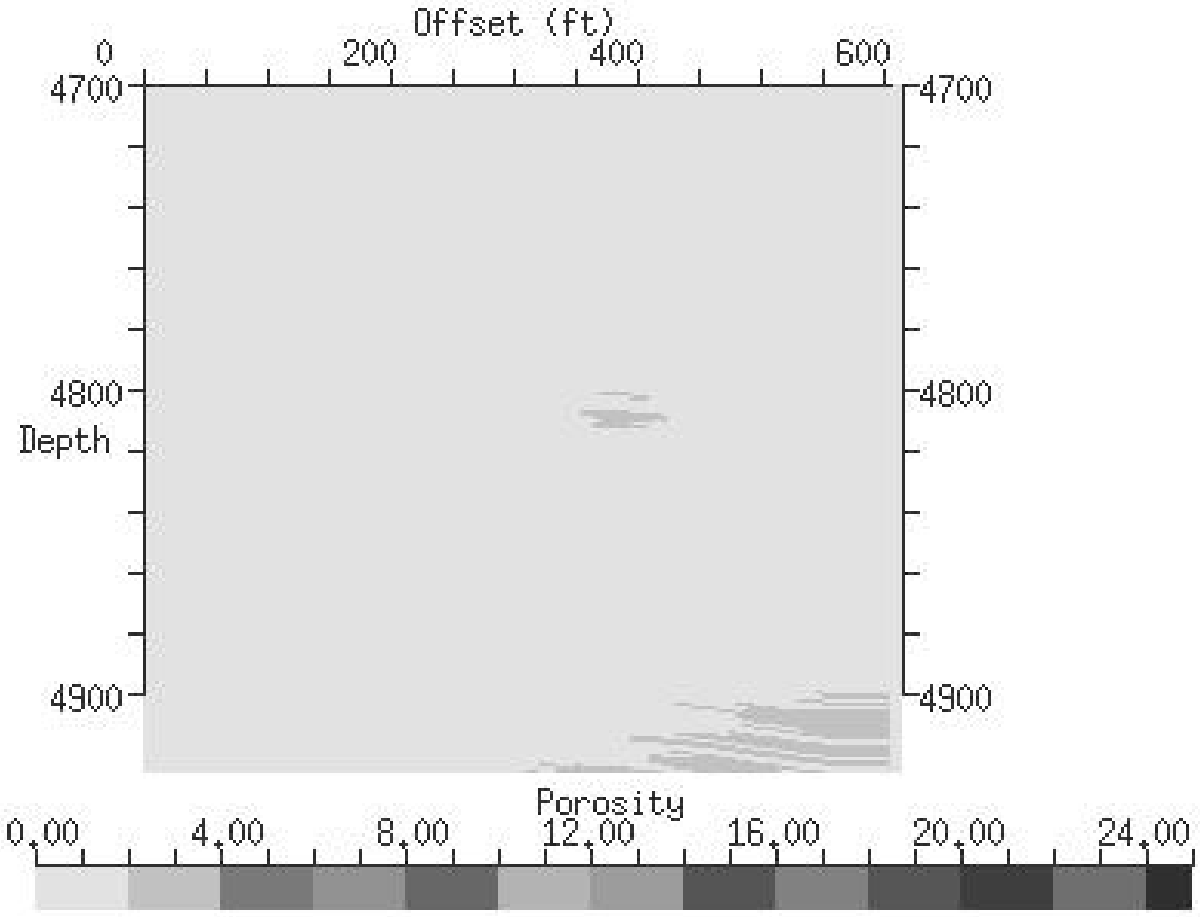

Fig. 3 - Changes in CO2 Saturation Between 4Q99 and 1Q01 Along Survey Line 4852-4843

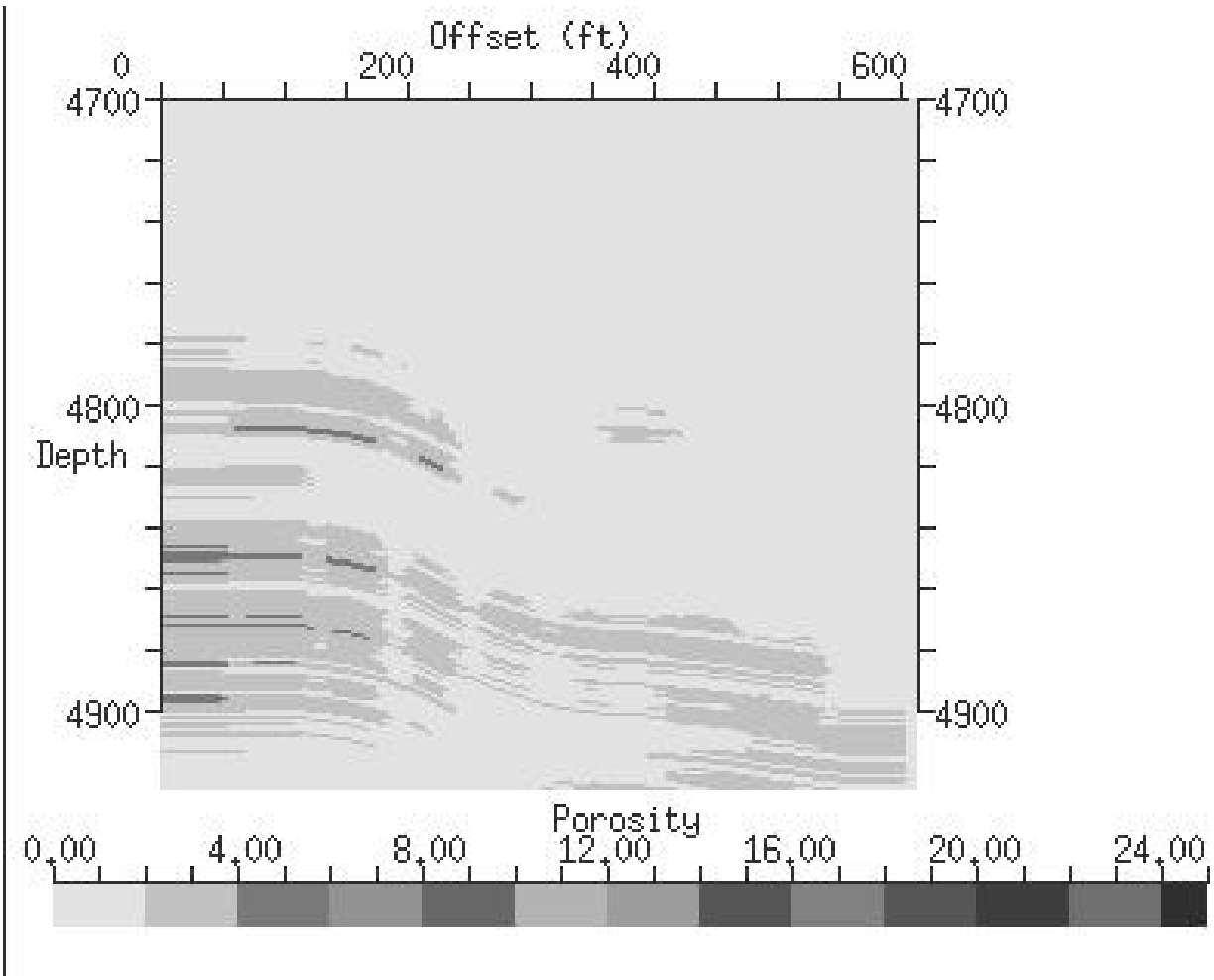

Fig. 4 - CO2 Saturation Representation as of 1Q01 Along Survey Line 4852-4843

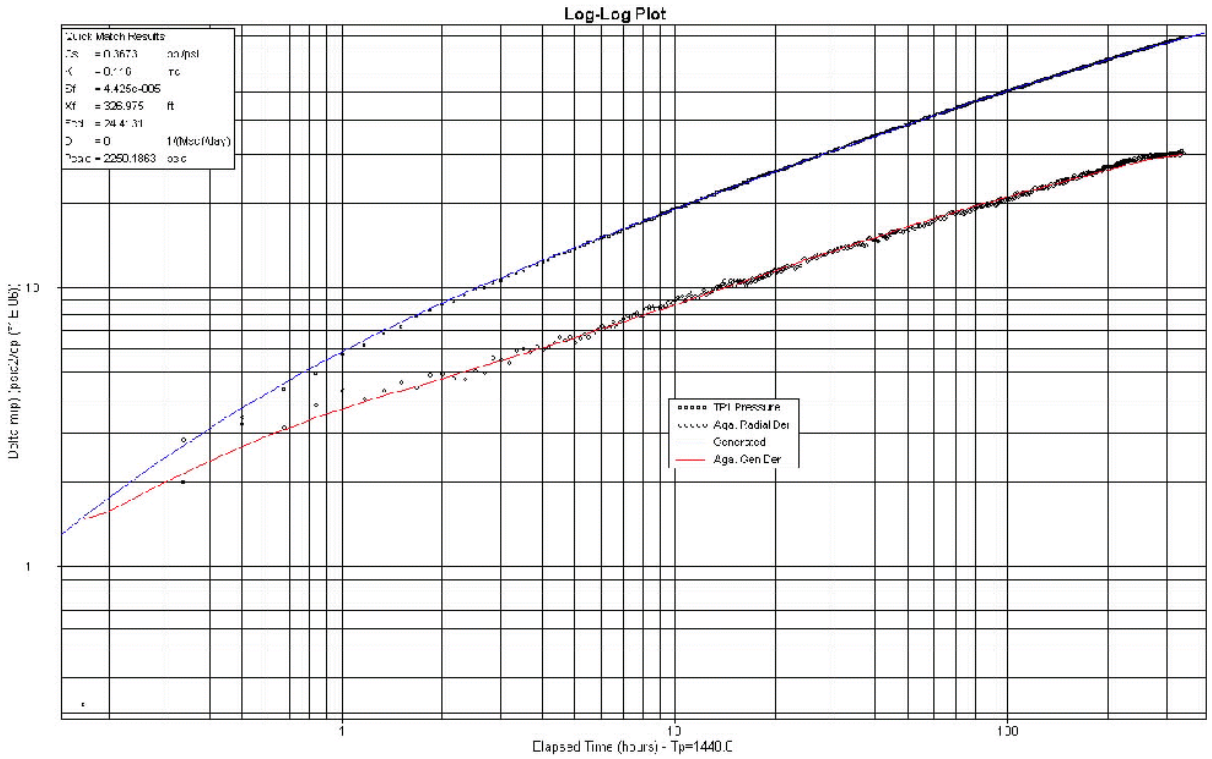

Fig. 5 - Injector 4810 - Pressure Transient Analysis of Pressure Falloff Test

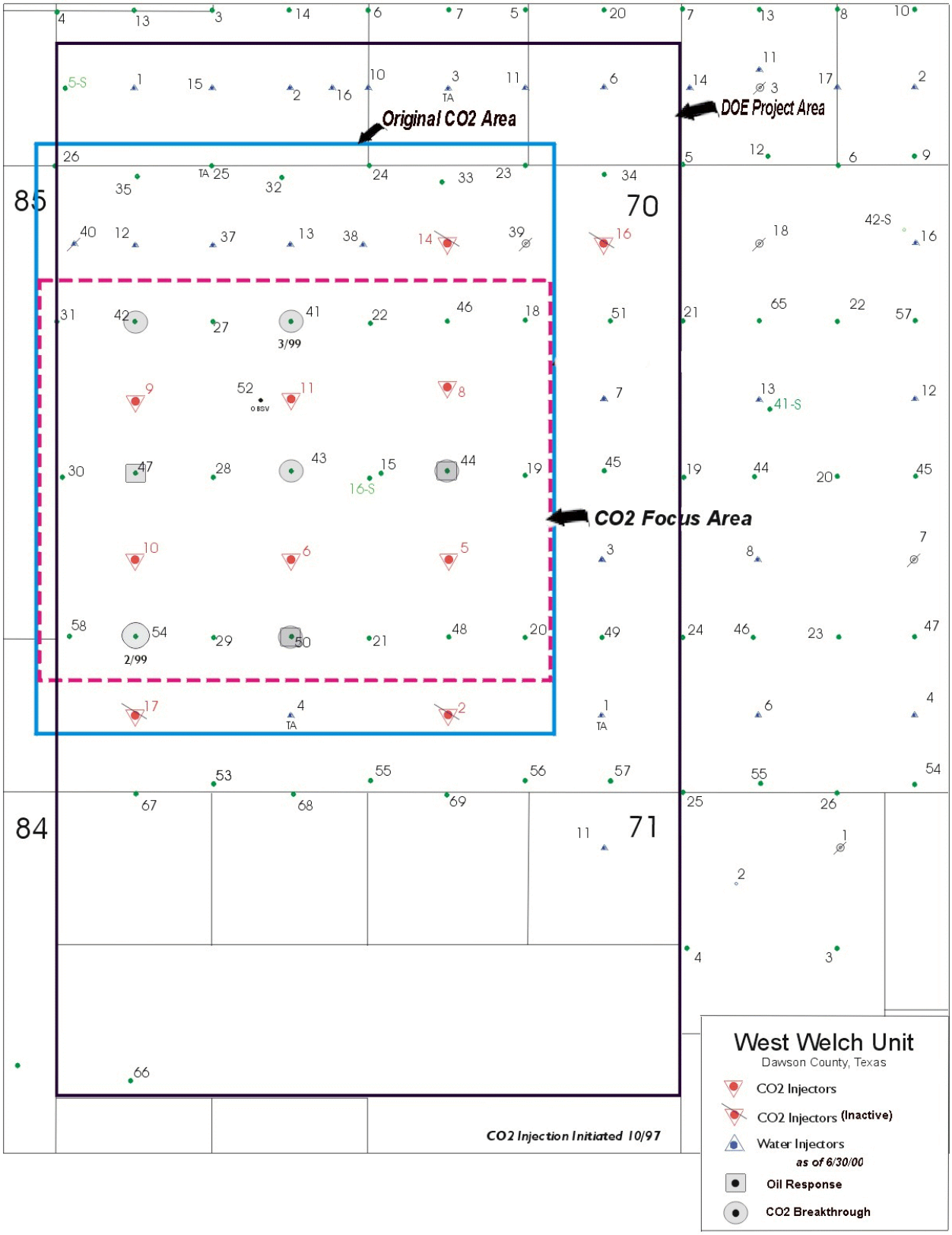

Fig. 6 - Response to CO2 Injection As Of Second Quarter 2001

Table 1

CO2 Focus Area Performance
Second Quarter - 2001
West Welch Unit DOE Project
Dawson County, Texas

		Apr	May	Jun	2nd Qtr
Injection					
	Average CO2 injection rate (mcfd)	3216	3624	3969	3603
	# of Injectors on CO2	6	6	6	6
	Average rate per injector (mcfd)	536	604	662	600
	% HCPV injected	0.3%	0.4%	0.4%	1.1%
	Cum % HCPV injected	11.3%	11.7%	12.1%	12.1%
	Average water injection rate (bwpd)	0	0	0	0
	# of Injectors on water	0	0	0	0
	Average rate per injector	0	0	0	0
	Water+CO2 % HCPV injected	0.3%	0.4%	0.4%	1.1%
	Water+CO2 Cum % HCPV injected	13.0%	13.4%	13.8%	13.8%
Production					
	Base oil production (bopd)	129	128	127	128
	Actual oil production (bopd)	163	164	172	166
	Incremental oil production (bopd)	34	36	45	38
	Gas production (mcfd)	546	589	633	589
	Gas production as % injection	17%	16%	16%	16%
	Base WOR	13	13	13	
	WOR	5.2	4.8	5.1	5.0