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

Quarterly Technical Report

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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 (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 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 this quarter variograms built from the porosity and permeability profiles between wells created by integrating core, log and crosswell seismic data were used to generate a spatial distribution of the reservoir's petrophysical properties. This allowed the construction of a 3-D reservoir model. CO2 injection was increased significantly with the addition of three injectors.

CROSSWELL SEISMIC

Industry uses geostatistical procedures for combining "hard" and "soft" reservoir data to derive spatial statistics for the interwell distribution of reservoir properties in geologic models. The interwell area can be sampled indirectly by pressure transient and performance analysis, but vertical resolution is low and results are nondirectional. Surface seismic data sample the reservoir directly but both the vertical and lateral resolutions are often too low for use in numerical simulation. A preferred approach is to take closely spaced measurements of porosity and permeability on outcrops of the reservoir formation. The drawback is that outcrops are weathered and may not be truly representative of the reservoir rock. Crosswell seismic data offer the ability to derive spatial statistics from direct sampling of the interwell area with high resolutions. Within the West Welch project area, the interwell survey lines radiated out from two central wells, giving a good variation in azimuthal direction which allows the reservoir anisotropy to be determined.

During the second quarter of 1999, spatial variograms were created for all of the porosity and permeability distribution cross-sections that had been previously established as discussed in the 4th quarter 1998 and 1st quarter 1999 reports. These variograms yield a measure of the probability of the occurrence of any value of porosity or permeability as a function of distance away from each point in the reservoir along a particular azimuthal direction.

The total database used included core and log data at each well in addition to the interwell seismic data. The spatial dip was removed from the interwell data and a Kriging approach used to distribute porosity and permeability value between or beyond control points to generate a 3-D model of the reservoir. This model is useful for examining variation in porosity and permeability within a single lithologic unit. Spatial dip was then restored, creating a full 3-D reservoir model, which reflects all of the "hard" data and interpolates between control points consistent with the data. Figures 1 and 2 show east-west cross sections from the reservoir model for porosity and permeability distribution, respectively.

3-D SEISMIC INTEGRATION

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

NUMERICAL SIMULATION

No simulation work was conducted during the second quarter.

FIELD DEMONSTRATION PHASE

CO2 injection began in October 1997 and through June 1999 a total of 2.7 BCF of CO2 had been injected into the project area. The monthly CO2 injection rate is shown on Table 1. The significant increase in injection rate in June results from the addition of three injectors for a total of nine. The model assumed 17 injectors so the field demonstration phase has significantly under-injected in comparison to the numerical simulation. Consequently, actual production has underperformed the model predictions.

Through June 1999 only three wells - 4843 (12 bopd), 4844 (8 bopd) and 4846 (5 bopd) - have shown a sustained increase in oil production attributable to CO2 injection. These three wells plus two others have experienced a significant decrease in the WOR. All 30 producing wells are currently producing measurable volumes of gas. Gas production averaged 451 MCF/D in April, 846 in May and 521 in June. The CO2 content of the total produced gas steam was sampled in April (89.94 mole %) and June (81.61 mol. %).

AREA PREPARATION AND CONSTRUCTION

There was no construction, stimulation or workovers done in the DOE project area during the second quarter of 1999.

TECHNOLOGY TRANSFER

No formal technology transfer activity occurred during the quarter.

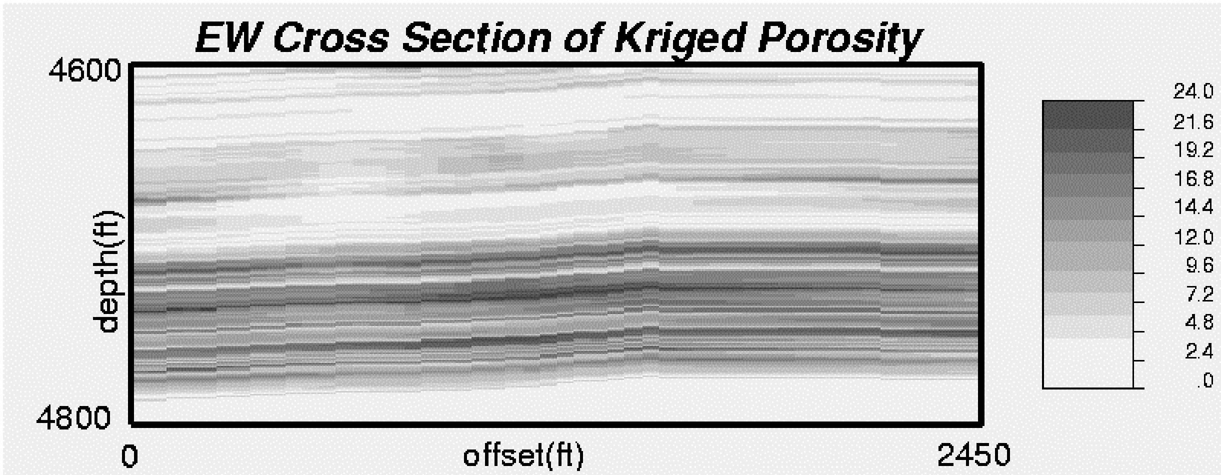
EW Cross Section of Kriged Porosity
4600
depth(ft)
4800
0
offset(ft)
2450
24.0
21.6
19.2
16.8
14.4
12.0
9.6
7.2
4.8
2.4
.0

FIG. 1

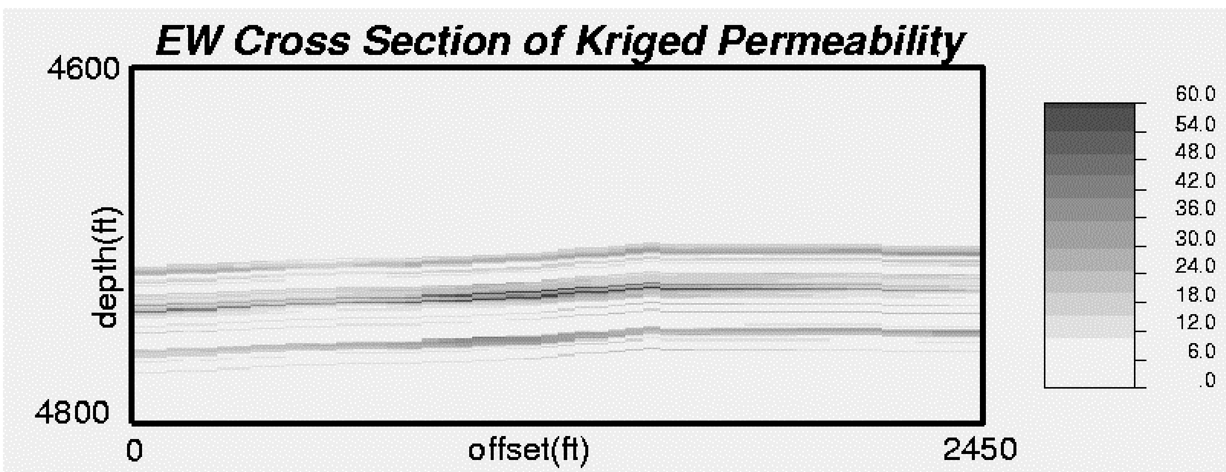
EW Cross Section of Kriged Permeability
4600
depth(ft)
4800
0
offset(ft)
2450
60.0
54.0
48.0
42.0
36.0
30.0
24.0
18.0
12.0
6.0
.0

FIG. 2

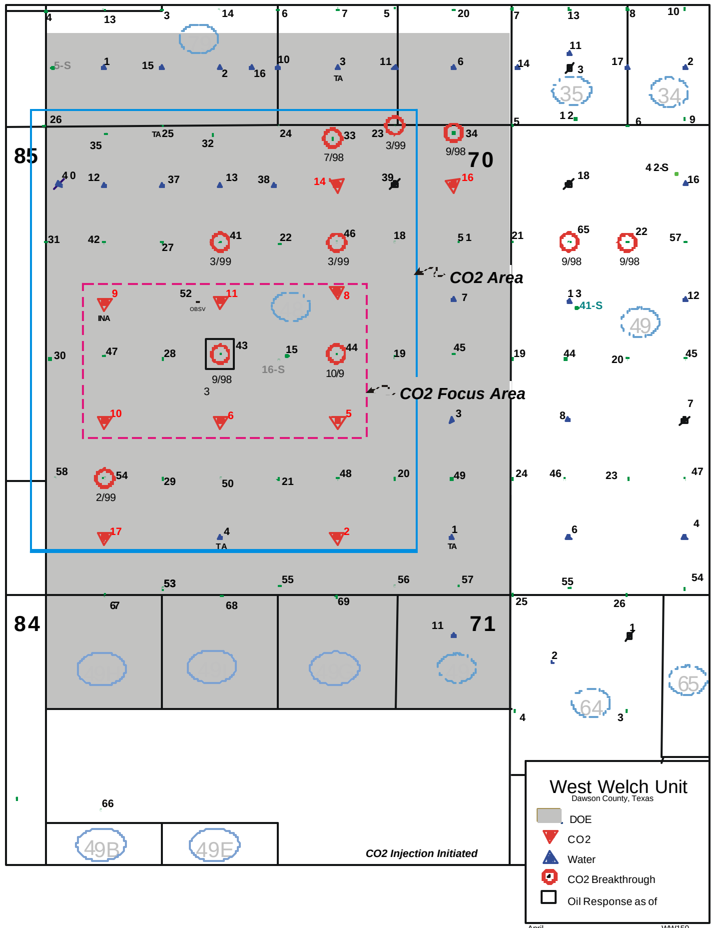
85
70
84
71
CO2 Area
CO2 Focus Area
CO2 Injection Initiated
West Welch Unit
Dawson County, Texas
DOE
CO2
Water
CO2 Breakthrough
Oil Response as of

FIG. 3

Table 1
CO_2 Injection History
DOE Demonstration Project
West Welch Unit

Month	Avg. MCFD	# of Injectors	Comments
Oct-97	2187	9	
Nov-97	3906	9	
Dec-97	4599	9	
Jan-98	5227	9	
Feb-98	6650	10	Added 4803. Tried to inject into 4838
Mar-98	5854	10	
Apr-98	5445	10	
May-98	4967	10	Dropped 4812 & 4809, added 4802, 4817
Jun-98	5437	10	
Jul-98	5381	10	
Aug-98	5801	10	
Sep-98	5630	10	
Oct-98	4530	10	
Nov-98	2242	9	Dropped 4807, cut back overall injection for economic reasons
Dec-98	2347	9	
Jan-99	2209	9	
Feb-99	2570	6	Started sour injection. Dropped 4802, 4803, 4816, 4817
Mar-99	2864	6	
Apr-99	2686	6	
May-99	2702	9	
Jun-99	3416	9	