QUARTERLY TECHNICAL PROGRESS REPORT
(Second Quarter)

**ADVANCED OIL RECOVERY TECHNOLOGIES FOR IMPROVED
RECOVERY FROM SLOPE BASIN CLASTIC RESERVOIRS,
NASH DRAW BRUSHY CANYON POOL, EDDY COUNTY, NM**

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Objective

The overall objective of this project is to demonstrate that a development program based on advanced reservoir management methods can significantly improve oil recovery. The demonstration plan includes developing a control area using standard reservoir management techniques and comparing the performance of the control area with an area developed using advanced reservoir management methods. Specific goals to attain the objective are: (1) to demonstrate that a development drilling program and pressure maintenance program, based on advanced reservoir management methods, can significantly improve oil recovery compared with existing technology applications, and (2) to transfer the advanced methodologies to oil and gas producers in the Permian Basin and elsewhere in the U.S. oil and gas industry.

Summary of Technical Progress

This is the second quarterly progress report on the project. Results obtained to date will be summarized.

Description of Project Work

Management and Project Planning

Three planning sessions of the geological, engineering, simulation, and management project teams were held during the quarter. As a result of these meetings, a project plan for the reservoir characterization/simulation team was developed.

Consolidation of interests and buyout of small interest owners has been initiated. A block of interests representing approximately 23% of the working interest owners have been consolidated. This will aid in the unitization process and simplify management of the project.

Geology

Compilation of data for the purposes of mapping and calibration was undertaken. Logs were correlated within the field to establish an initial stratigraphic and structural framework for the basal Brushy Canyon sands in the Nash Draw Unit.

The basal Brushy Canyon has been subdivided (by prior work) into four mappable stratigraphic units. These units have been designated the "J", "K", "K-2", and "L" sands. All are productive in the area and fall within the scope of this project.

For the purposes of mapping and comparison, various log data have been compiled for each sand. These data include gross interval isopach thickness, ϕ_h values (net thickness for porosity >14%), and core porosity vs. log porosity data. The data were then used to prepare the following initial suite of maps:

- 5 Structure maps ("J", "K", "K-2", "L", and top of Bone Spring Lime)
- 5 Gross Interval Isopach Maps ("J", "K", "K-2", "L", and top of Bone Spring Lime)
- 4 Net porosity maps =14% ϕ_D ("J", "K", "K-2", "L"), where ϕ_D =Density Porosity
- 4 ϕ_h maps 12% or greater ϕ_D ("J", "K", "K-2", "L")

These maps will serve as the basis for geological modeling in the field. The reservoir simulation group will use the maps to develop a preliminary geologic framework for their modeling. The calibration of core data to log data will determine what are "pay" quality sands. This data will help define the net available reservoir within each of the primary pay zones. It will also help to establish parameters for pay in other logs where core data are not available.

The geophysical group is looking at the maps as an aid to help develop a seismic model. Once the 3-D seismic is processed, the geological and geophysical models can be combined and refinements made. Discussions with the geophysical group have begun concerning depositional environments, seismic attributes, and mappability of the individual sands.

Pilot Area

Detailed geologic mapping within the proposed injection pilot area was started. The Nash #1, #5, #6, #10, and #14 wells were posted on a cross-section. Having previously established the gross interval correlation for the sands from well-to-well, a more detailed mapping approach has been taken. The "K", "K-2", and "L" sands were subdivided in the following manner:

"K" sand:	K_A	"K-2" sand:	$K-2_A$	"L" sand:	L_A
	K_B		$K-2_B$		L_B
	K_C		$K-2_C$		L_C
	K_D				L_D

A gross isopach map has been generated for each of the subunits in the pilot area. This will begin to help in developing cells for the purpose of reservoir simulation. Core and log data are being added to help define pay intervals within each of the subunits. The results from the pilot area will then be expanded throughout the rest of the field. The detailed correlation and mapping has shown that each of the gross sand intervals is actually a composite of multiple, stacked "micro" reservoirs. Additional work will be done in an attempt to correlate these "micro" reservoirs from well-to-well.

Production Analog

Preliminary data gathering has begun in the portion of the Loving East analog area. This field was chosen because the geologic and reservoir characteristics are similar to the basal Brushy Canyon in the Nash Draw Unit. Mapping will begin early in the second quarter of 1996.

Engineering

The third data well, the Nash Draw #25 located 500 ft. FEL and 165 ft. FSL of Section 14, was drilled in February. It encountered a well-developed "K" sand, high water saturations in the "K-2" sand, and a thin "L" sand with only four feet of net pay. Prior to fracturing, a bottomhole pressure buildup test was performed to determine permeability and formation damage. Assuming 40 ft of net pay, this test indicated a permeability of 0.81 md. This well is being completed and should be on production by mid April, 1996.

The "data base" has been brought up-to-date with the addition of digitized logs, digitized core data, and production and decline curves updated through February 1, 1996. Preliminary calibration of the production volumes has been initiated and anomalies are being resolved. The simulation team has received the first copy of the data base and is processing the data into the reservoir simulator.

The full core analysis and SEM data has been reviewed in detail. The relative permeabilities indicate that the permeability to water at the residual oil saturation may be too low to make water injection a practical method of pressure maintenance. A modification to the statement of work was made to eliminate the second core and substitute additional fluid swelling tests to determine the effectiveness of gas injection for pressure maintenance. These tests will be performed during the next quarter.

The Analog Area has been identified and preliminary data acquisition has been initiated. The area being reviewed is Section 14-T23S-R28E in the East Loving Brushy Canyon Pool. This section has sixteen Brushy Canyon producers with cumulative production ranging from 51,000 to 168,000 bbl of oil, which provides a wide variety of well types and structural positions for analysis. Well logs, production plots, and preliminary mapping have been completed.

Vertical Seismic Profiles

Two vertical seismic profiles (VSPs) were recorded in the Nash Draw No.25 well. One Litton 315 vibrator was positioned 255 ft southeast of the well (127° azimuth) to produce zero-offset VSP data, and a second Litton 315 vibrator was stationed 2,178 ft. north of the well (349° azimuth) to create a far-offset VSP. One advantage of VSP data recording is that the image produced can be displayed as either a function of seismic two-way traveltime, so that it can be correlated with surface-recorded 3-D seismic data, or as a function of stratigraphic depth to better correlate with wireline-measured log and core data. The Nash Draw far-offset VSP image is displayed in Fig. 1 in a depth format to illustrate this latter VSP-imaging option.

The log-interpreted depths of the tops of the "J", "K", "K-2", and "L" reservoirs in the No.25 well are 6598, 6639, 6737, and 6765 ft., respectively, where all depths are measured relative to KB. Two of these reservoirs, "K" and "L", are of particular interest at the No.25 well because the "K" reservoir was well developed, but the "L" reservoir was not. The depth positions of the "K" and "L" reservoirs are labeled in the VSP image in Fig. 1, together with the position of the Bone Spring Limestone, which is immediately below the "L" Sandstone.

An important insight provided by these VSP data is that the closely spaced "K" and "L" reservoirs are defined as separate seismic features when the illuminating wavelet has a bandwidth of at least 8 to 96 Hz. The VSP image shows that the "K" reservoir creates a reasonably strong reflection peak at the No. 25 well, whereas the "L" reservoir generates a weaker reflection trough. Seismic modeling will be required to establish if there is a definitive correlation between reservoir properties of the "K" and "L" units and seismic reflection amplitude. However, seismic modeling at Nash Draw is handicapped because only one sonic log is available for calculating synthetic seismograms.

The reflection character of both the "K" and "L" events, as it appears at the well (the right most trace of the image), changes significantly about 100 ft. north of the well (the 5th and 6th trace from the right side of the VSP image), which implies that some type of variation in the reservoir system occurs at this location. Again, seismic modeling, or the careful integration of geologic control with 3-D seismic interpretation, will be required to establish the stratigraphic and rock-property messages implied by such variations in seismic facies. The VSP image also shows that the reflection trough associated with the "L" reservoir has a slightly greater amplitude (brightens) at location A about 200 to 300 ft. north of the well, and that at location B about 500 to 650 ft. north of the well, the amplitudes of both the "K" reflection peak and the "L" reflection trough become noticeably stronger. These reflection amplitude variations are direct indicators of stratigraphic changes, or facies changes, or both, within the "J", "K", "K-2", and "L" reservoir systems. The interpretation challenge is to establish a definitive correlation between areal distributions of these variations in seismic reflection character and areal maps of geologic and engineering properties of the reservoirs. These variations in the reflection amplitude of the VSP image are an early indication that considerable changes in 3-D seismic reflection attributes will occur across this heterogeneous reservoir system.

The far-offset VSP data were processed so that the stacking bins used in the image construction had a horizontal width of only 20 ft. Consequently, the trace spacing in the image displayed in Fig. 1 is 20 ft. Much of the lateral variation in reflection waveform character that occurs in this image is due to the fact that the VSP stacking bins (that is, the trace spacings in the image) have a small width. The stacking bins that were to be created in the original 3-D seismic geometry, which was sent out for bids, covered an area measuring 110 x 110 ft. In such a geometry, each 3-D seismic trace would thus have been equivalent to the trace that would be created by summing five adjacent traces in the VSP image in Fig. 1. In the 3-D image resulting from this acquisition geometry, the stratigraphy extending 870 ft. north of the No.25 well would be defined by only eight traces; whereas, that same stratigraphy is defined by 44 traces in the VSP image in Fig. 1.

One important result of this initial VSP imaging effort is that it revealed that smaller stacking bins would have to be created in the 3-D seismic data volume if the 3-D data are to show lateral changes in the reservoir that are of the size seen in the VSP images. Consequently, as a result of the VSP

work, the Nash Draw 3-D seismic grid has been redesigned to produce acquisition bins measuring 55 x 110 ft. During data processing, a trace interpolation will be done in the source line direction to create interpretation bins measuring 55 x 55 ft.

A key conclusion of this vertical wavetest is that high quality seismic data can be recorded at the Nash Draw field. Essentially all of the signal components of each test wavelet survived the downward trip to the targeted stratigraphy at a depth of 7,000 ft.

Reservoir Characterization/Reservoir Simulation

Activities of the Reservoir Characterization/Simulation Team for the first quarter of 1996 were focused on preparations for the evaluation of three alternative enhanced recovery methods for the field pilot which is planned for the last quarter of 1996. Three methods are currently under consideration: (1) immiscible lean gas injection, (2) waterflooding, and (3) CO₂ injection.

The majority of the effort for this quarter was devoted to the development of a geological model for the Unit. An effort was also made to inventory and assess the completeness of the data available to support the modeling work. Finally, there was an expenditure of time to install the project's two new computers (a SGI Indigo2 with High Impact Graphics and a Pentium 166 PC).

The most important technical decision taken during the quarter was the decision to initiate the simulation of the pilot with the present geological interpretation of the Nash Draw Unit prepared by the project geology team. This interpretation exists in the format of maps of Unit attributes for five zones: "J", "K", "K-2", "L", and the interval between the bottom of "L" and the top of the Bone Spring sand. For each of these "sands", the following attributes have been mapped: (1) top of structure, (2) gross isopach, (3) porosity-thickness, and (4) net porosity.

These maps have been digitized for input into the Stratigraphic Geocellular Model (SGM). SGM permits full three-dimensional representation of the Nash Draw Unit. In turn, it supports spatial statistical analysis and the geological component of reservoir simulation. An example of one of the digitized maps, the top of the "J" sand in 3-D, is illustrated in Fig. 2.

The future availability of 3-D seismic data will permit the development of a second generation geological model. Such data may support the use of sophisticated linear estimation methods like co-kriging and stochastic simulation. The present model will be based on the use of kriging to estimate reservoir properties.

The team envisions the pilot simulation model to be a full-field model from inception. The unstructured gridding options available in the flow simulators under consideration will be exploited to coarsen the flow model away from the pilot. Although the present interpretation of the Unit has identified only five significant lithological units, the simulation model is expected to exhibit additional vertical segmentation in order to treat gravity effects.

3-D Seismic

Permitting and surveying for the 3-D seismic program are approximately 80% completed. The final 3-D seismic program design is almost complete and the 3-D shoot planned for mid May, 1996.

Technology Transfer

A Working Interest Owner's meeting was held on February 23, 1996, to bring owners up-to-date and to start the organization of a technical committee. A preliminary membership list of the technical committee was agreed upon and is being finalized.

A list of potential members for the Liaison Committee has been prepared and is being sent to prospective members. Final organization of the Liaison Committee should be completed in the next quarter.

Mr. Bruce Stubbs will present a Poster Session on May 15 and 16, 1996 at the Shallow Shelf Carbonate Workshop being held in Midland, Texas. The workshop is being coordinated by DOE, BDM, and the Center for Energy and Economic Diversification.

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FIG. 1 Interpretation of VSP image. The positions of the closely spaced K and L reservoirs and the high-amplitude Bonespring Limestone reflector are labeled. An important message provided by these VSP data is that the K and L reservoirs are associated with different and distinguishable waveform features if the illuminating wavelet has a signal bandwidth of at least 8-96 Hz. The wavelet trough associated with the L reservoir increases in amplitude at offset locations A and B. The wavelet peak that correlates with the K reservoir increases in amplitude at location B only. These amplitude variations infer where each reservoir system undergoes stratigraphic and/or facies changes. Seismic modeling needs to be done to establish what specific alterations in the reservoirs cause these observed variations in VSP reflection amplitude.

Nash Draw Brushy Canyon
Top of "J" Sand

FIG. 2