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ADVANCED RESERVOIR CHARACTERIZATION IN THE ANTELOPE SHALE TO ESTABLISH THE VIABILITY OF CO_2 ENHANCED OIL RECOVERY IN CALIFORNIA'S MONTEREY FORMATION SILICEOUS SHALES

Quarterly Technical Progress Report
April 1, 1998-June 30, 1998

By
Michael F. Morea

Report Issue Date: July 31, 1998

Performed Under Contract No. DE-FC22-95BC14938

Chevron USA Production Company
Bakersfield, California

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Advanced Reservoir Characterization in the Antelope Shale to Establish the Viability of CO_2 Enhanced Oil Recovery in California's Monterey Formation Siliceous Shales

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Michael F. Morea

October 1999

Work Performed Under Contract No. DE-FC22-95BC14938

Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

Gary Walker, Project Manager
National Petroleum Technology Office
P.O. Box 3628
Tulsa, OK 74101

Prepared by
Chevron USA Production Company
P.O. Box 1392
Bakersfield, CA 93302

TITLE: **ADVANCED RESERVOIR CHARACTERIZATION IN THE ANTELOPE SHALE TO ESTABLISH THE VIABILITY OF CO2 ENHANCED OIL RECOVERY IN CALIFORNIA'S MONTEREY FORMATION SILICEOUS SHALES**

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Government Award for Budget Period # 1 **$2,334,048**

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Anticipated Completion Date for Budget Period # 1: **March 31, 1999**

DOE Project Manager: **Gary Walker, National Petroleum Technology Office**

Principal Investigator: **Michael F. Morea**

Contractor Name and Address: **Chevron USA Production Company, P.O. Box 1392, Bakersfield, California 93302**

Objective

The primary objective of this research is to conduct advanced reservoir characterization and modeling studies in the Antelope Shale reservoir. Characterization studies will be used to determine the technical feasibility of implementing a CO_2 enhanced oil recovery project in the Antelope Shale in Buena Vista Hills Field. The Buena Vista Hills pilot CO_2 project will demonstrate the economic viability and widespread applicability of CO_2 flooding in fractured siliceous shale reservoirs of the San Joaquin Valley. The research consists of four primary work processes: Reservoir Matrix and Fluid Characterization; Fracture Characterization; Reservoir Modeling and Simulation; and CO_2 Pilot Flood and Evaluation. Work done in these areas is subdivided into two phases or budget periods. The first phase of the project will focus on the application of a variety of advanced reservoir characterization techniques to determine the production characteristics of the Antelope Shale reservoir. Reservoir models based on the results of the characterization work will be used to evaluate how the reservoir will respond to secondary recovery and EOR processes. The second phase of the project will include the implementation and evaluation of an advanced enhanced oil recovery (EOR) pilot in the United Anticline (West Dome) of the Buena Vista Hills Field.

Summary of Technical Progress

Project work in Phase 1 is now completed. Based on our results, we will not be proceeding with a Phase 2 field trial in Buena Vista Hills. Although we had numerous technical successes (i.e., high resolution crosswell seismic, mineral model based saturation algorithm) and completed a detailed reservoir characterization, we could not overcome the siliceous shale's very low oil saturation and heterogeneity at Buena Vista Hills.

Reservoir characterization work has demonstrated to us that under the right conditions, CO_2 is a potentially viable enhanced recovery process for siliceous shales. Therefore we have requested and received approval for a time extension to March 31, 1999 (no additional funding) to study, at our own expense, the feasibility of moving the Phase 2 pilot to a more promising reservoir: the Belridge Diatomite at Lost Hills Field, about 30 miles north of Buena Vista Hills. Our studies should be completed within the next few months. At that time we will decide if we will submit a detailed proposal and budget for a Phase 2 CO_2 pilot at Lost Hills. If approved, a field trial would not commence until 1999.

During the 2nd Quarter, presentations were made at the Pacific Section AAPG Convention in Ventura, the AAPG Annual Convention in Salt Lake City, the SPE Regional Meeting in Bakersfield, and the SPWLA Annual Meeting in Keystone. Outlined below is a status report on the tasks that were performed during the 2nd Quarter of 1998. Lastly, the project remains well under budget.

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Task B. Preliminary Preparation for CO2 Injection

Task B.2. Initiate Fluid Characterization and Lab Displacement Tests

We have completed two sets of displacement experiments on a composite sandstone core and a mixed lithology core to evaluate the oil recovery potential of crossflow in a siliceous shale reservoir. The experimental data demonstrated that crossflow mechanisms recovered significant amounts of oil from very low permeability siliceous shale at 2500 psi, although very little oil was recovered at 600 psi. Analysis of the experimental data indicates that CO_2 crossflow not only recovered restored oil from the shale, but also recovered some of the original oil in the shale.

Task B.3. Develop Field Scale Compositional Simulation

The principal objective of this task was to determine the potential of CO_2 EOR at Buena Vista Hills; if potential existed, then simulate the recovery performance for a pilot project and for the full field. With the completion of the 3D earth model in spring 1998, we proceeded to investigate the flow characteristics of the reservoir. We used 3D streamlines and finite-difference formulations to investigate sweep and recovery performance of a quarter-pattern element model representative of the geology near well 653Z–26B. The results suggest rapid breakthrough, poor sweep and poor recovery performance for the Buena Vista Hills Antelope Shale. The simulation results do not warrant further effort in estimating pilot or full field potential. The primary factors impairing CO_2 potential at

Buena Vista Hills are low oil saturation and poor conformance caused by very adverse heterogeneity.

Task D. Technology Transfer

The following papers were presented at the May, 1998 AAPG Annual Convention, Salt Lake City, Utah:

Britton, A. W., and Morea, M. F., Acoustic Anisotropy Measurements in the Siliceous Shale, 653Z-26B Well, Buena Vista Hills Field, California.

Campagna, D. J., Amos, J. F., and Mamula, N., Influence of Structure, Reservoir Compartments, and Natural Fractures on Oil and Gas Production in the Southern San Joaquin Basin, California.

Morea, M. F., Zalan, T. A., Julander, D. R., Beeson, D. C., and Britton, A. W., Advanced Reservoir Characterization of the Siliceous Shale, Buena Vista Hills, California: Integration of Geological, Geochemical, and Petrophysical Data.

The following paper was presented at the 1998 SPE Western Regional Meeting, Gems Session, Bakersfield, CA:

Zalan, T. A., Morea, M. F., Julander, D. R., and Denoo, S. A., Integrated Formation Evaluation in California's Monterey Formation Siliceous Shales, Buena Vista Hills Field, California.

The following paper was presented at the 1998 SPWLA Annual Convention, Keystone, Colorado:

Zalan, T. A., Morea, M. F., Julander, D. R., and Denoo, S. A., Applying Integrated Formation Evaluation to Advanced Reservoir Characterization in California's Monterey Formation Siliceous Shales.

A booth was set up at the 1998 Pacific Section AAPG Convention, Ventura, CA:

Morea, M. F., Julander, D. R., Zalan, T. A., and Beeson, D. C., Advanced Reservoir Characterization of the Siliceous Shale, Buena Vista Hills, California. We had displays illustrating our data and interpretations, and a workstation showing our 3D visualization/geologic modeling and reservoir simulation.

Three expanded abstracts have been submitted to the 1998 Annual International Meeting, Society of Exploration Geophysicists to be held in New Orleans:

Langan, R. T., Julander, D. R., Morea M. F., Addington, C. M. and Lazaratos, S. K., 1998, Crosswell seismic imaging in the Buena Vista Hills, San Joaquin Valley: A case history.

Wang, G., Harris, J. M., Magalhaes, C., Julander, D. R., and Morea, M. F., 1998, Buena Vista Hills 3-D attenuation and velocity tomography.

Washbourne, J. K. and Rector III, J. W., 1998, Crosswell seismic in three dimensions.

Data from this project has been given to Southwest Research Institute, San Antonio, TX and included in their project:

Parra, J. O., Characterization of Fracture Reservoirs using Static and Dynamic Data: from Sonic and 3D Seismic to Permeability Distribution, BDM Subcontract No. G4S51-731, and Prime Contract No. DE-AC22-94PC91008.