REVIVING ABANDONED RESERVOIRS WITH HIGH-PRESSURE AIR INJECTION: APPLICATION IN A FRACTURED AND KARSTED DOLOMITE RESERVOIR

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ABSTRACT

The field operator, Goldrus Producing Company, has been unable to secure funding needed to continue the field demonstration phase of the project. Accordingly, we have temporarily halted all project activities until necessary funding is obtained. Goldrus is confident that funds can be acquired by third quarter 2005 at which time it will be necessary to request a project extension to complete the originally designed study.

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I. INTRODUCTION

The Bureau of Economic Geology and Goldrus Producing Company assembled a multidisciplinary team of geoscientists and engineers to evaluate the applicability of high-pressure air injection (HPAI) in revitalizing a nearly abandoned carbonate reservoir (the Barnhart Ellenburger field) in the Permian Basin of West Texas. The potential of HPAI for improved oil recovery from Barnhart field has been established in preliminary laboratory tests, studies and a reservoir pilot project. To assess the effectiveness and economics of HPAI technology more completely, we developed plans to integrate more detailed characterization of reservoir properties with laboratory modeling of flow and a field demonstration and monitoring program.

Characterization and modeling elements of the study employed geoscientists and petroleum engineers from the Bureau of Economic Geology and the Department of Petroleum and Geosystems Engineering (both at The University of Texas at Austin) to define controls on fluid flow in the reservoir as a basis for developing a reservoir model. Plans were to utilize this model to define a field deployment plan that Goldrus, the field operator, can implement by drilling both vertical and horizontal wells during the demonstration phase of the project.

We believe that high-pressure air-injection technology has the potential to significantly increase the flow of oil from deep carbonate reservoirs in the Permian Basin, a target resource that can be conservatively estimated at more than 1.5 billion barrels. Successful implementation of this technology in the Barnhart Ellenburger field could result in the recovery of more than 34 million barrels of oil that will not otherwise be recovered.

II. EXECUTIVE SUMMARY

The implementation of plans developed by The Bureau of Economic Geology and Goldrus Producing Company to demonstrate the effectiveness of high-pressure air injection (HPAI) in revitalizing a nearly abandoned carbonate reservoir in the Permian Basin of West Texas has been delayed because of the inability of Goldrus, the field operator, to secure needed funds to continue field development. Because of the current lack of funding, we have temporarily suspended activities on the project.

We believe HPAI can be shown to be an extremely effective means to recover the remaining oil in deep reservoirs like the Ellenburger at Barnhart field and that this technology has the potential to revolutionize oil recovery operations in the Permian Basin and other mature oil-containing basins in the United States. Accordingly, we feel that is important to keep the project active in the hopes that the operator can obtain necessary funds to continue. If it becomes apparent that the operator cannot obtain the necessary funds by the end of 2005, we will develop and propose an alternative plan to DOE for a continuation of this extremely important analysis of this potentially breakthrough technology.

III. REVIEW OF PROJECT OBJECTIVES

The primary objectives of the project are to develop, test, and document optimal methods for deploying high-pressure air injection (HPAI) technology to recover remaining hydrocarbons from an abandoned carbonate reservoir. Each of these will be accomplished in three phases of activity. The reservoir characterization phase (Phase 1) consists of (1) analysis of reservoir stratigraphy and facies, (2) characterization and modeling of reservoir matrix petrophysical properties, (3) characterization and modeling of reservoir fractures, and (4) characterization and modeling of the effects of HPAI on reservoir mechanical properties (deformation, strength, and fluid transport behavior) for both matrix and fractures. The demonstration phase (Phase 2) includes (1) deployment of vertical HPAI injector wells and horizontal oil-producing wells on the basis of stratigraphic, petrophysical, fracture, and rock mechanical models developed in Phase 1; (2) collection of additional reservoir data to further constrain and revise existing models; (3) field monitoring of the progress of HPAI using well tests; and (4) postmortem analysis and synthesis of the best strategies for deployment of HPAI well patterns. The third and final phase of the project (Phase 3, Technology Transfer) is devoted to compiling, reporting, and distributing the results of the completed project to industry.

IV. STATUS OF RESERVOIR CHARACTERIZATION (PHASE I)

Characterization activities have been suspended since fall of 2004. Objectives of the reservoir characterization phase of the project are to define the distribution of key

reservoir properties that control the distribution of remaining oil and the movement of injected air. Among the key issues that must be addressed are (1) the distribution of karst features and their impact on flow; (2) the distribution, abundance, and orientation of fractures and their impact on flow; and (3) the rock mechanics response of the Ellenburger to HPAI.

Summary of Geological and Petrophysical Progress (Tasks 1 to 4)

A critical discovery is that the Ellenburger reservoir at Barnhart contains abundant evidence of overprinting karst-related diagenesis. This was unexpected and means that a detailed understanding of karst process and products and their effect on reservoior heterogenetioty is needed to effectively design hydrocarbon recovery methodologies. We have developed techniques using wireline resistivity logs to define areas of karst development and to delineate the reservoir architecture. Further work can be done to refine geophysical techniques for imaging the distribution of karst pathways.

Summary of Laboratory Studies (Task 5)

Laboratory activities have been suspended since fall of 2004. Key completed work includes a laboratory simulation of fluid flow and oil recovery from high-pressure air injection (HPAI) in the Barnhart Ellenburger reservoir (Dhiraj, 2004). This study showed that the Barnhart reservoir is a good candidate for high-pressure air injection. Specifically, the study tested relative efficiencies of injector-producer pairs in varying types of possible reservoir architectures and with varying reservoir fluid compositions. The study also showed that horizontal wells may improve ultimate resource recovery from the reservoir.

V. STATUS OF FIELD DEMONSTRATION (PHASE 2)

A pilot study has been completed in the field and has demonstrated the feasibility of the technology to displace and recover hydrocarbons. A broader scale field demonstration has been delayed due to lack of funding.

VI. STATUS OF TECHNOLOGY TRANSFER ACTIVITIES (PHASE 3)

Technology transfer activities have been suspended along with all other project activities. A full list of published transfer reports in given in the appendix.

VII. SUMMARY

Project activities are currently suspended until the field operator can obtain additional funding to permit continuation of field demonstration activities. The operator, Goldrus operating company, has tentative commitments from major funding partners and feels that they will be able to secure funding later in 2005. If they are unable to do so we will propose alternative plans for continuing and completing the analysis of high pressure air injection technology in deep reservoirs of the Permian Basin.

APPENDIX 1: REPORTS, PAPERS, & PRESENTATIONS

Combs, D. M., Loucks, R. G., and Ruppel, S. C., 2003, Lower Ordovician Ellenburger Group collapsed Paleocave facies and associated pore network in the Barnhart field, Texas, *in* Hunt, T. J., and Lufholm, P. H., eds., The Permian Basin: Back to basics: West Texas Geological Society Publication No. 03-112, p. 397-418.

Combs, D.M., R.G. Loucks, and S.C. Ruppel, 2004, Lower Ordovician Ellenburger Group Collapsed Paleocave Facies, Associated Pore Networks, and Stratigraphy at Barnhart Field, Reagan County, Texas: Southwest Section AAPG, El Paso, Texas

Dhiraj, Dembla, 2004, Stimulating enhanced oil recovery (EOR) by high-pressure air injection (HPAI) in west Texas light oil reservoir: The University of Texas at Austin, Master's thesis, 123 p.

Gomez, L. A., Gale, J. F. W., Ruppel, S. C., and Laubach, S. E., 2001, Fracture characterization using rotary-drilled sidewall cores: an example from the Ellenburger Formation, West Texas, *in* Viveiros, J. J., and Ingram, S. M., eds., The Permian Basin: Microns to Satellites, Looking for Oil and Gas at all Scales: West Texas Geological Society Publication No. 01-110, p. 81-89.

Loucks, R. G., 2003, Understanding the development of breccias and fractures in Ordovician carbonate reservoirs, in Hunt, T. J., and Lufholm, P. H., The Permian Basin: back to basics: West Texas Geological Society Fall Symposium: West Texas Geological Society Publication #03-112, p. 231–252.

Ruppel, S. C., Loucks, R., and Kane, J., 2004, Report on the geology and petrophysics of the Ellenburger reservoir at Barnhart field, Reagan County, Texas: The University of Texas at Austin, Bureau of Economic Geology, Consultant Report prepared for Goldrus, 35 p.