TITLE: **IMPROVED OIL RECOVERY IN MISSISSIPPIAN CARBONATE RESERVOIRS OF KANSAS -- NEAR TERM -- CLASS 2**

Cooperative Agreement No.: DE-FC22-94BC14987

Contractor Name and Address: The University of Kansas Center for Research Inc.

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DOE Cost of Project: $ 3,169,252 (Budget Period 2 05/16/97 -- 07/30/99)

Principal Investigators: Timothy R. Carr (Program Manager)
Don W. Green
G. Paul Willhite

Project Manager: Daniel J. Ferguson, NPTO Tulsa, Oklahoma

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OBJECTIVES

The objective of this project is to demonstrate incremental reserves from Osagian and Meramecian (Mississippian) dolomite reservoirs in western Kansas through application of reservoir characterization to identify areas of unrecovered mobile oil. The project addresses producibility problems in two fields: Specific reservoirs target the Schaben Field in Ness County, Kansas, and the Bindley Field in Hodgeman County, Kansas. The producibility problems to be addressed include inadequate reservoir characterization, drilling and completion design problems, non-optimum recovery efficiency. The results of this project will be disseminated through various technology transfer activities.

At the Schaben demonstration site, the Kansas team will conduct a field project to demonstrate better approaches to identify bypassed oil within and between reservoir units. The approach will include:

- Advanced integrated reservoir description and characterization, including integration of existing data, and drilling, logging, coring and testing three new wells through the reservoir intervals. Advanced reservoir techniques will include high-resolution core description, petrophysical analysis of pore system attributes, and geostatistical analysis and 3D visualization of interwell heterogeneity.
- Computer applications will be used to manage, map, and describe the reservoir. Computer simulations will be used to design better recovery processes, and identify potential incremental reserves.

- Comparison of the reservoir geology and field performance of the Schaben Field with the previously described by slightly younger Bindley Field in adjacent Hodgeman, County.
- Drilling of new wells between older wells (infill drilling) to contact missed zones;
- Demonstration of improved reservoir management techniques, and of incremental recovery through potential deepening and recompletion of existing wells and targeted infill drilling.

SUMMARY OF TECHNICAL PROGRESS BUDGET PERIOD 2

Progress is reported for the period from 1 January 1998 to 31 March 1998. Work in this quarter concentrated on demonstrating the incremental recovery of additional mobile oil through targeted infill drilling (Task 2.1) and the potential of horizontal drilling. We also concentrated on preparations for three papers at the AAPG Annual Meeting in Salt Lake, Utah. The full-field reservoir simulation using a modified version of USDOE's BOAST 2 was completed with the addition of new infill wells. A summary of the results to be presented at AAPG is included as Appendix A.

Task 2.1 DEMONSTRATION OF RESERVOIR MANAGEMENT STRATEGY

During late 1996 and 1997, a total of fourteen infill locations were drilled or recompleted at the Schaben Demonstration Site. The locations were selected based on the results of the reservoir management strategy developed in Budget Period 1 (See previous quarterly for a list). All three major field operators (Ritchie Exploration, Pickrell Drilling and American Warrior) used the simulation results to evaluate multiple locations and select optimum locations. The history of each well has been evaluated and incorporated into the ongoing performance monitoring. The reservoir simulation provides excellent full-field and good individual history matches for all 50 previously existing wells. The simulation also provides an estimate of additional incremental oil as a result of targeted infill drilling (Figure 1).

Task 2.2 TECHNOLOGY TRANSFER

Technology transfer is an ongoing process that includes access to information through the Internet, almost daily inquires and formal presentations. Three extended abstracts covering a variety of topics are being prepared for the 1998 AAPG Annual Meeting in Salt Lake City Utah (Franseen and others; Guy and others, and Gerlach and others). We have worked to assure that the presentations provide complementary information and have similar formats.

Hands-on demonstrations and workshops focusing on PfEFFER were presented in Odessa Texas (Invitation of Phillips Petroleum Company, March 3-4) and at DOE (February 24, Tulsa, OK).

We continue to work with a number of Kansas's operators on application of the technologies developed as part of the Class 2 project. We are providing access to the digital data and results from the project through an on-line (Internet) accessible format (see Schaben homepage at http://www.kgs.ukans.edu/Class2/index.html).

REFERENCES

(Accepted) Franseen, E.K., Carr, T.R., Guy, W.J., and Beaty, S.D., Significance of Depositional and Early Diagenetic Controls on Architecture of a Karstic-Overprinted Mississippian (Osagian) Reservoir, Schaben Field, Ness County, Kansas: 1998 AAPG Meeting, Salt Lake City, Utah.

(Accepted), Guy, W.J., Byrnes, A.P., Doveton, J.H., and Franseen, E.K., submitted, Influence of Lithology and Pore Geometry on NMR Prediction of Permeability and Effective Porosity in Mississippian Carbonates, Kansas: 1998 AAPG Meeting, Salt Lake City, Utah.

(Accepted), Gerlach, P, and S. Bhattacharya, T. R. Carr, Application of Cost-Effective PC-based Reservoir Simulation and Management - Schaben Field (Mississippian), Ness County, Kansas

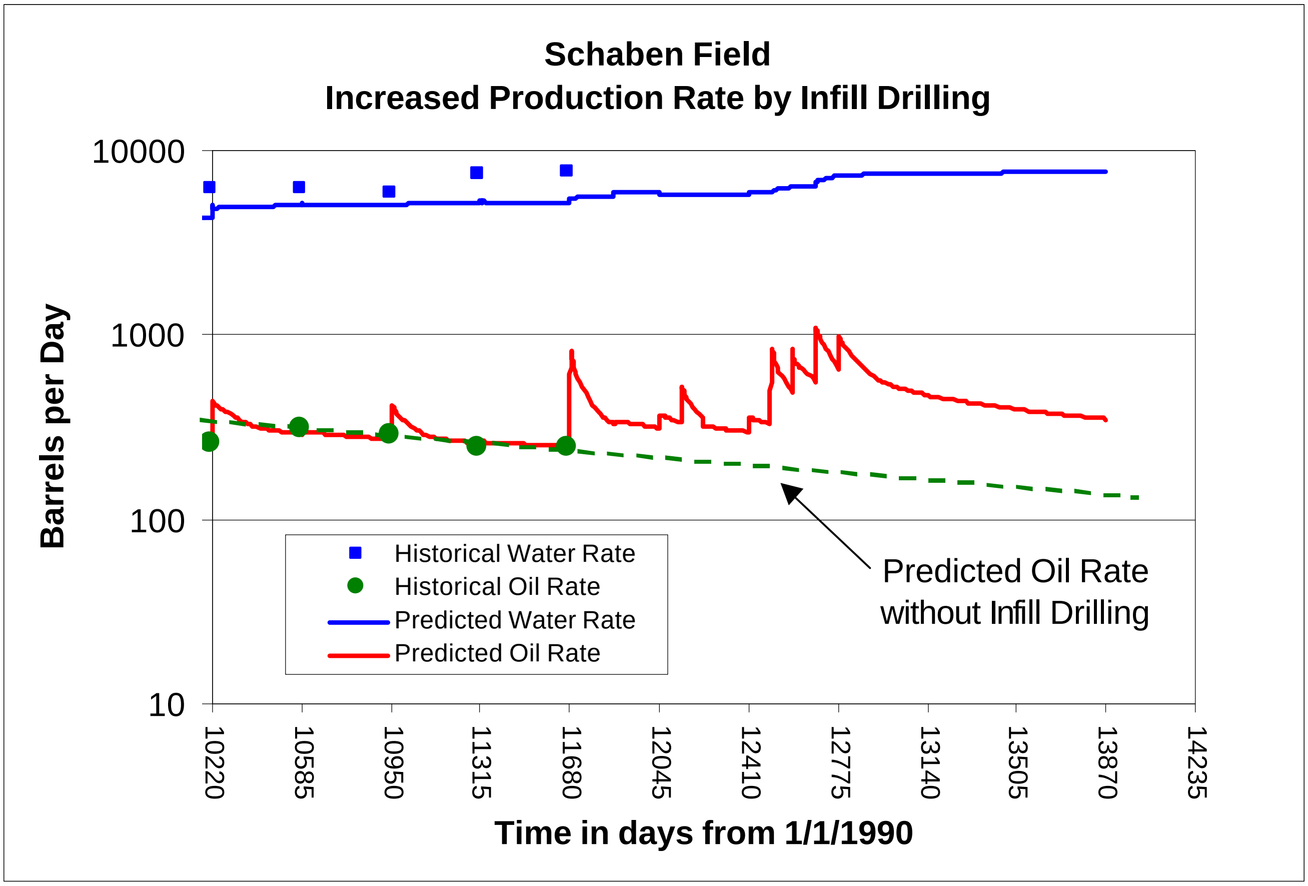

Figure 1.— Predicted and historical oil and water rates for the Schaben Field Demonstration Site showing the effect of infill wells and recompletions. Locations were selected using the reservoir description and simulation developed as part of the Class study.

APPENDIX A

Modified from: 1998, Gerlach, P, and S. Bhattacharya, T. R. Carr, Application of Cost-Effective PC-based Reservoir Simulation and Management - Schaben Field (Mississippian), Ness County, Kansas: 1998 AAPG Meeting, Salt Lake City, Utah.

In today's competitive economic climate, cost-effective production technology is required by producers of marginal petroleum reservoirs to continue to survive and prosper. Field management based on reservoir characterization and simulation studies can assist the producer in efficient exploitation of hydrocarbon reserves in marginal fields. In the past reservoir simulation and management was restricted to large oil companies and to producing fields considered "core assets". Today, PC-based reservoir simulation is economically and technically feasible for the small independent producer.

The objective of this study is to characterize and simulate a typical oil field producing from a Mississippian reservoir by using tools that are modern and cost-effective for small independent producers operating mature fields. General application of PC-based simulators such as BOAST3 to large-scale or full-field simulation has been restricted by hardware and software limitations. Recent advances in the computational speed and memory capabilities have drastically reduced the simulation run time. The development of powerful and “user-friendly” spreadsheet, relational database, girding and mapping software have provided the front and back-end tools to efficiently assemble and manipulate simulation input data and generate useful maps and charts.

Integrated reservoir characterization forms the foundation for the development of a descriptive reservoir model and provides the framework for simulation. The descriptive reservoir model integrated existing and newly acquired well. Simulation input parameters were generated from the reservoir model and used to simulate the reservoir performance of the Schaben field from discovery to 1996. Analysis of the reservoir performance and the distribution of the remaining mobile oil in place led to the identification of regions with potential for incremental oil recovery. The simulator was used to predict the performance of potential infill wells drilled in these areas.

The Schaben field simulation as part of a US Department of Energy Class 2 project, addressed a number of producibility problems in Meramecian and Osagian dolomite reservoirs in Kansas. Mississippian reservoirs are a major source of Kansas production and account for approximately 43% (21 MMbbls in 1994) of the state's annual production. The Schaben Field in Ness County was selected because it is representative of Mississippian oil fields in Kansas. Results from this study were used to design field management and future infill drilling plans in Schaben field. It is hoped that this study will provide a model for improving field management of similar reservoirs in Kansas and in the mid-continent.

INTRODUCTION

The Schaben Field is located in the upper shelf of the Hugoton Embayment of the Anadarko Basin and produces oil from dolostones and limestones of the lower Meramecian Warsaw Limestone and Osagian Keokuk Limestone (Mississippian) at depths of 4,350-4,410 feet. The Schaben simulation study area consists of six square miles within Schaben field and is located in Township 19 South--Range 21-22 West, Ness County Kansas. Schaben field, discovered in 1963, consists of 78 completed oil wells spaced primarily on 40-acre locations. Cumulative Schaben field production as of September 1996 was 9.1 million barrels of oil (BO), wells within the simulation study area have cumulatively produced 3,593,609 BO, with current (Sept. 1996) daily production totaling 141 BOPD from 29 wells.

Common reasons for non-optimal primary recovery include lack of production and geologic data, problems in drilling and completion design, inadequate reservoir characterization studies, and lack of information about productive potential of the field. Application of cost-effective reservoir description and management strategies can significantly extend the economic life of these mature fields and result in significant incremental reserves. Equally important is the wider application of the demonstrated technologies in similar fields throughout the northern Mid-continent.

RESERVOIR MODEL and VOLUMETRIC CALCULATIONS

Descriptive reservoir characterization entailed integration and creative application of existing data and new data from three wells. New core and log data provided insight into fundamental reservoir parameters (e.g., core plug NMR analysis to determine effective porosity). Integrated analyses of welllogs, core data and field mapping provided a better understanding of the complexities of an extremely heterogeneity of the reservoir. Determination of pore and throat size, irreducible water saturation, permeability, effective porosity, and movable oil are part of an integrated reservoir characterization. The descriptive reservoir model developed for Schaben Field provided a major component of the input data for reservoir simulation. (Reference 1,2,3,4)

Prior to the start of reservoir simulation, a volumetric study of the Schaben simulation study area was completed on a grid-by-grid basis. The volumetric calculations were performed to check if the different reservoir parameters such as effective porosity, net pay thickness, and water saturation in the effective porosity were able to support the observed historic production volumes. The resultant oil saturation values in the grid cells of the reservoir layer indicate the combination of reservoir parameters can with the historical production figures for the Schaben field.

BOAST 3 SIMULATION

The major premise of this simulation study was to enter eleven years of historical data and have the simulator predict and match the next 23 years of known field production data. At the field level, a good match between simulated and observed was obtained for both oil and water production rates during the 34 years encompassed by the historical and predictive periods (Figure A1).

A good match was also obtained for the simulated and observed cumulative oil and water production for the field from 1963 to 1995. After matches were obtained within acceptable tolerances for both oil and water at a field scale, attention was focused on the performance of the individual wells. The mismatch of water production in some of the wells may be due to inaccurate description of the reservoir properties surrounding these wells. The vertical permeability in the reservoir and aquifer layers, plays an important role in controlling the water production at each well. Several simulation runs were carried out with varied (decreased and increased) vertical permeabilities in the cells of the reservoir and aquifer layer surrounding wells with a poor history match. The results drastically improved the history match for water production. This process of local adjustment of the vertical permeability is now being applied on a well by well basis and should result in an acceptable individual well history match for the entire field.

COST-EFFECTIVE RESERVOIR MANAGEMENT

Oil saturation maps from simulation output at the end of 1973 (field life of 10 years) show areas of low oil saturation (<40%) have developed around most wells. The poor areal sweep efficiency of the reservoir, due to its heterogeneity, is demonstrated by the area between wells which have high oil saturation (>60%). At the end of 1996 (field life of 33 years) the simulation shows oil saturation around most wells to just above the irreducible oil saturation (between 31%-35%). However, significant pockets of high oil saturation (>60%) are still left unswept in between the drainage areas of surrounding wells.

The choice of location for infill (increased density) wells for efficient oil recovery in accordance with a cost-effective reservoir management plan requires the consideration of current oil saturation and pay height in the reservoir layer. Due to the difficulty of producing oil from zones with low oil saturation (<40%) and thin pay height (<20 ft.), those areas of the field at low oil saturation and thin pay height can be eliminated from consideration for infill drilling. Those areas of the field with the highest predicted infill drilling potential can be identified with a saturation-feet map. All grid cells on the reservoir layer with an oil saturation less than 40% or with a net pay thickness less than 20 feet were set to zero. The oil saturation layer and the pay height layer were then multiplied in a grid to grid operation to produce a saturation-feet map showing those areas of the field with best infill potential.

Figure A1. History match and performance prediction of Schaben field from Boast 3 simulation.

Based on the infill potential map and in consultation with Ritchie Exploration, operator of Schaben field, three infill-drilling sites were chosen. Subsequent simulation runs covering the ten year period of 1996 to 2006 were performed to predict the production rates for each of the three well locations and the effect on the oil saturation of the reservoir layer. The three new wells were simulated to produce with a flowing bottom hole pressure equal to that of the nearest well at the end of 1995. The daily production rate simulated for the Moore BCP #3 is calculated to produce a total of 47,200 bbls of oil and 227,600 bbls of water over a period of ten years (Figure A2). The simulator also predicts daily oil production above 10 bopd during the first 5 years. Predicted daily field production rate of oil and water with the addition of the three new wells indicates the addition of significant additional oil production.

CONCLUSIONS

1. Practical application of cost-effective technologies in reservoir simulation enables the small independent producer to map remaining hydrocarbon reserves in marginal fields.
2. Simulation results allow proper field management by targeting infill drilling in areas of best potential.
3. PC-based reservoir simulation is a practical reality for small independent producers with limited resources.
4. Procedures demonstrated in this study provide a guide for geologic modeling, simulating, and managing similar reservoirs in Kansas and in the mid-continent.

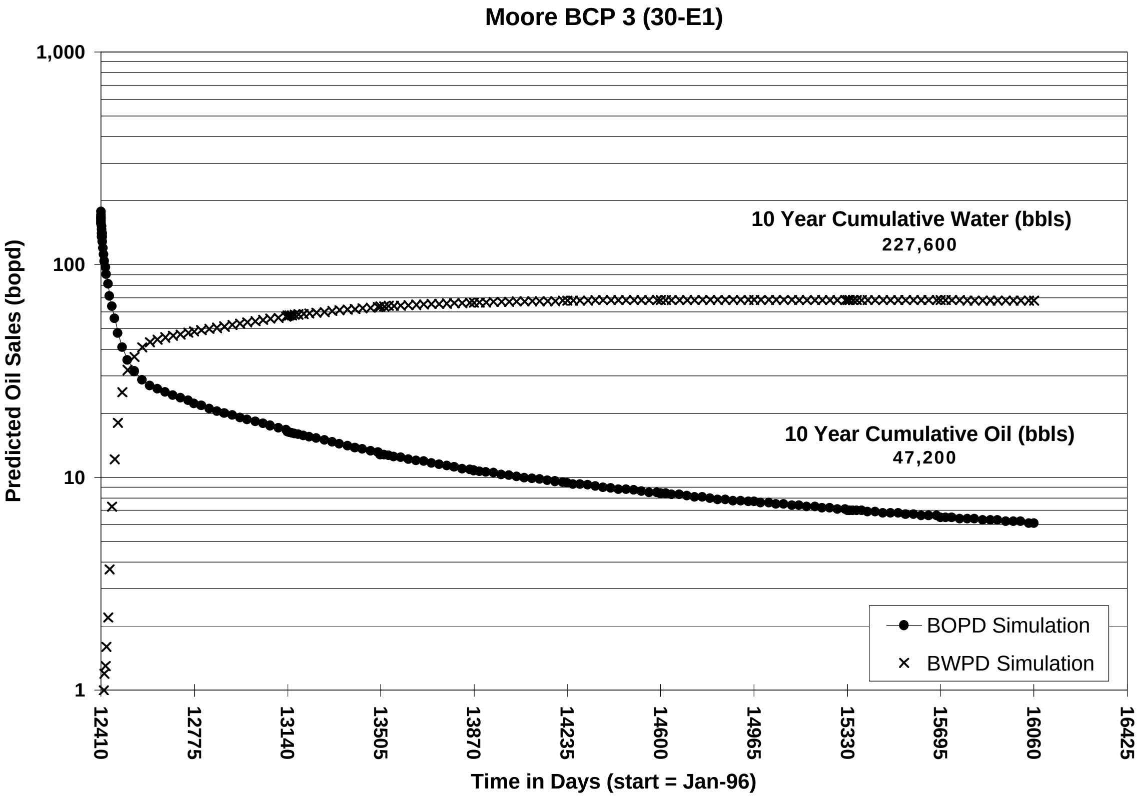

Figure A2. Performance prediction of Moore BCP #3 from Boast 3 simulation.

ACKNOWLEDGEMENTS

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