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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.

Date of Report: June 1, 1999

Award Date: September 16, 1994

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

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Reporting Period: April 1, 1998 -- June 30,1998

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 April 1998 to 30 June 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. The full-field reservoir simulation was completed with the addition of new infill wells. Horizontal well performance was also evaluated using BOAST VHS. Currently there are 14 horizontal wells evaluating predominately Mississippian reservoirs of Kansas. The interest in application of horizontal drilling technology in Mississippian reservoirs in Kansas is attributable to the results of the Class 2 study.

Task 2.1 DEMONSTRATION OF RESERVOIR MANAGEMENT STRATEGY

During late 1996 and 1997, a total of eighteen 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 Schaben reservoir simulation to evaluate multiple locations and select optimum locations used the Schaben reservoir simulation. The history of each well has been evaluated and incorporated into the simulation. 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).

In addition, the potential of horizontal wells, as a cost-effective method of recovering greater reserves, was evaluated at Schaben Field using BOAST-VHS. We used the Schaben simulation to further evaluate the cost-effectiveness of horizontal wells in Mississippian reservoirs of Kansas and the Mid-continent (Appendix A). This work has resulted in additional interest in horizontal technology in Kansas and two presentations/publications (Gerlach and others, in press; and Gerlach and others, submitted).

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 were presented at 1998 AAPG Annual Meeting in Salt Lake City Utah (Franseen and others; Guy and others, and Gerlach and others). We worked to assure that the presentations provided complementary information and had similar formats.

A presentation on cost-effective strategies for selection of reservoir targets for horizontal drilling in Mississippian reservoirs was presented at the North Midcontinent PTTC Horizontal Drilling Workshop (June 16, Wichita Kansas). This presentation has been invited and accepted for an AAPG Hedberg Conference entitled " International Horizontal Well Symposium: Focus on the Reservoir" (October 10-13, The Woodlands, Texas). Additional information on the conference and an online extended abstract (Gerlach and others, submitted) are available at <http://www.kgs.ukans.edu/PRS/AAPG/horizon.html>.

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

(in press), P.M. Gerlach, S. Bhattacharya, T.R. Carr, W. J. Guy, S. C. Beaty, and E.K. Franseen, PC based reservoir characterization and simulation of the Schaben Field, Ness County, Kansas: Proceedings of Midcontinent Platform Carbonates, Oklahoma Geological Survey Special Publication.

(submitted), P.M. Gerlach, S. Bhattacharya, T.R. Carr, Cost Effective Techniques for the Independent Producer to Evaluate Horizontal Drilling Candidates in Mature Areas: AAPG Hedberg Conference, International Horizontal Well Symposium: Focus on the Reservoir, (October 10-13, 1999, The Woodlands, Texas), <http://www.kgs.ukans.edu/PRS/AAPG/papers/gerlach.html>

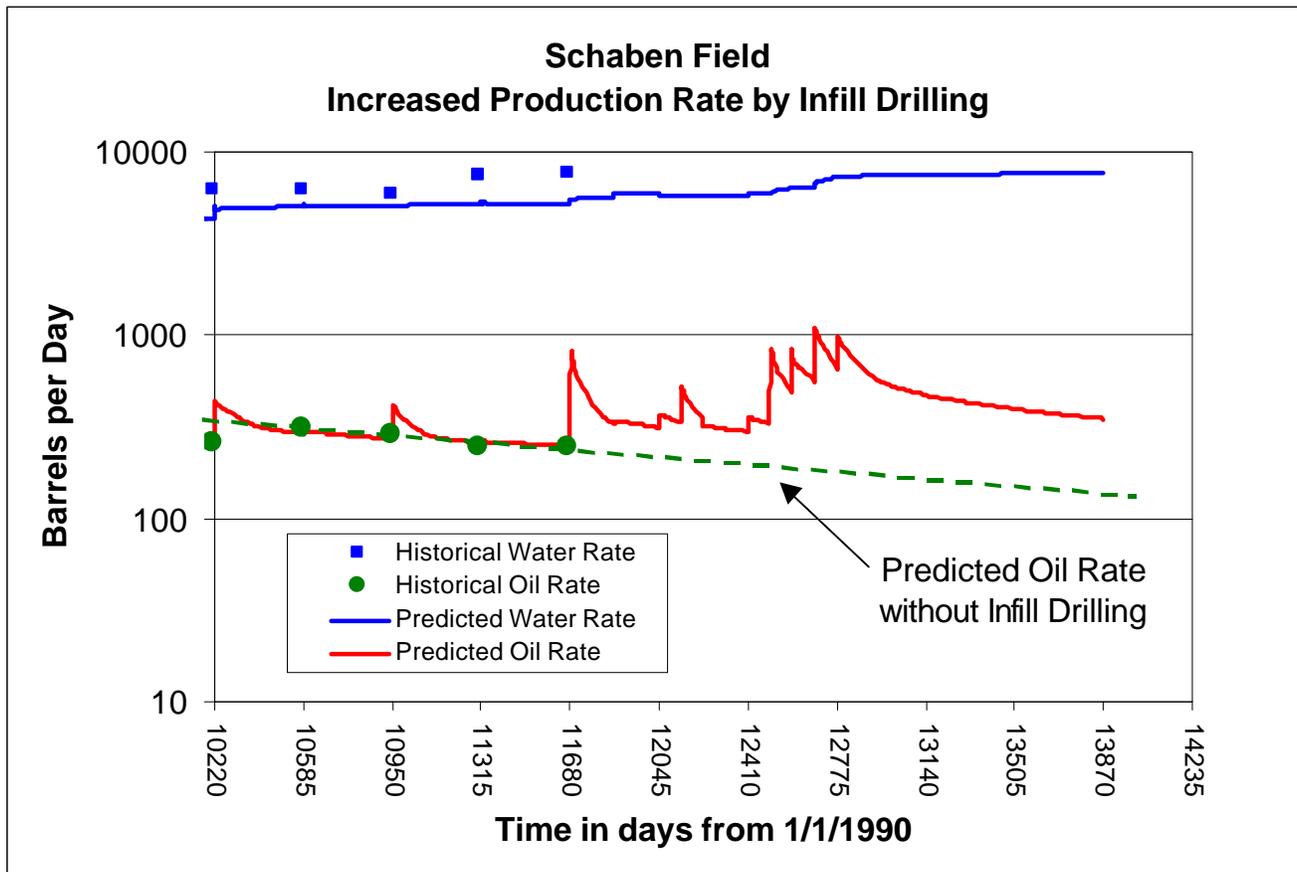


Figure 1. Predicted and historical oil and water rates for the Schaben Field Demonstration Site showing the effect of infill wells and recompletions. Locations were selected using the reservoir description and simulation developed as part of the Class study.

APPENDIX A

Modified from: P.M. Gerlach, S. Bhattacharya, T.R. Carr, Cost Effective Techniques for the Independent Producer to Evaluate Horizontal Drilling Candidates in Mature Areas: AAPG Hedberg Conference, International Horizontal Well Symposium: Focus on the Reservoir, (October 10-13, 1999, The Woodlands, Texas), <http://www.kgs.ukans.edu/PRS/AAPG/papers/gerlach.html>

Cost-Effective Techniques for the Independent producer to Evaluate Horizontal Drilling Candidates in Mature Areas

Introduction

Horizontal wells are a cost efficient tool for reservoir management that has not been widely adopted by small independent operators of mature oil fields. Horizontal drilling has been extensively applied as an exploitation and exploration tool in relatively under-exploited reservoirs such as the Austin Chalk and in structurally complex reservoirs. In recent years horizontal technology has been extended to incremental oil recovery in the mature oil fields of southeast Saskatchewan. Though the technological needs in many mature onshore reservoirs are unique, the overall reservoir management objectives and requirements for commercial success are similar to those elsewhere.

Application of horizontal drilling in Kansas has been limited to 28 wells. In Kansas results have been mixed with a few significant successes (Figure A1). Operator concerns for appropriate economic return, and difficulty in identifying candidate reservoirs have been the principal factors restricting application of horizontal drilling technology. Recent declines in cost factors have brought horizontal drilling technology within the economic reach of small independent producers. The remaining barrier to wider application of horizontal technology by the small independent is cost-effective approaches to target a horizontal well. We present several low-cost approaches that can be used to evaluate a potential horizontal well. These cost-effective screening techniques apply at the field scale, the lease level, and the well level. The techniques discussed enable the small independent producer to quickly and efficiently evaluate reservoir candidates, and predict performance of horizontal well application.

Kansas is a mature petroleum producing province with many marginal oil and gas fields operated by over 3,000 independent oil producers. As a result of operational and depositional-diagenetic heterogeneities most of these fields have recovery efficiencies of less than 30% original oil in place (OOIP). This low recovery efficiency results in significant remaining oil in place (ROIP). Operators can use horizontal technology to add new reserves by exploiting the ROIP in their existing fields, and to more efficiently recover known oil and gas reserves.

Operational heterogeneities are inherent in field development practices and results in significant ROIP. Examples of operational heterogeneities include inadequate drainage due to excessive well spacing, openhole/partial completions, bypassed attic oil, thin pays, and water coning. Depositional-diagenetic reservoir heterogeneities due to vertical and lateral variability of petrophysical properties create compartments in the reservoir. These types of heterogeneities are a function of original depositional architecture and the subsequent diagenetic overprint. Examples include highly variable pore geometry of carbonate rocks, anisotropic permeability in fractured reservoirs, and stratified flow units.

Cost-effective screening tools

The primary screening tool for identifying candidate reservoirs is "quick-look volumetric" calculations. This method uses only one well per unit area (e.g., quarter section) to identify pay height, porosity, and saturation to compute OOIP. These reservoir properties can be estimated from public domain data and computed using simple log analysis programs. PFEFFER, a low cost integrated log analysis tool developed by the Kansas Geological Survey, is used to identify well flow units, associated petrophysical and reservoir properties, and potential for production. Cumulative production per quarter section is then divided by OOIP to calculate recovery efficiency. The mapping

of recovery efficiency across the field identifies target areas for further study. Regions with low recovery efficiency are those most likely to yield additional or incremental hydrocarbon reserves.

Monthly Oil Production

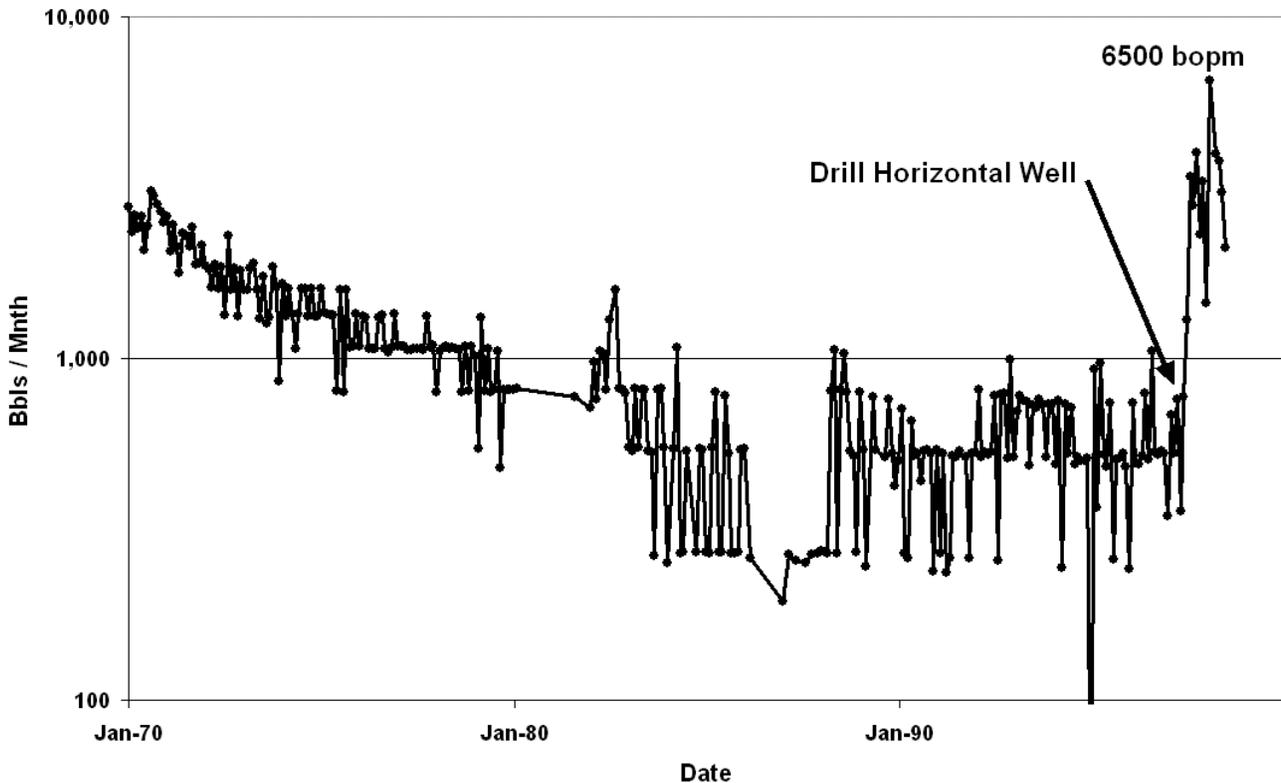


Figure A1. Effect of Horizontal well on oil production in the Wieland West Field, Hodgeman County Kansas.

Detailed volumetric calculations at the lease level can be used to further evaluate potential target areas. Information from all wells on a lease is used to calculate and compare recovery efficiency between adjacent leases and adjacent wells. Mapping well production, normalized by petrophysical parameters, can approximate sweep efficiency between wells. Well production is normalized by dividing cumulative production by the product of payheight, hydrocarbon saturation, porosity, and horizontal permeability. NMR measurements on selected core plugs in reservoirs with significant micro-porosity are used as a cost-effective approach to separate total porosity from effective porosity. Permeability data can be estimated from well tests or by using porosity-permeability crossplots developed from core plug studies. Areas with low normalized production values suggest high reservoir heterogeneity and less effective sweep.

Following volumetric screening, the next step in the candidate selection process is identifying of the cause of poor recovery efficiency. The causes can be many-fold, but in Kansas the most prevalent are stratified thin pays, attic oil, excessive well spacing, coning due to strong water drive, and fractured reservoirs. ROIP in stratified thin pays can be identified by comparing initial rates of production and cumulative production between wells with similar payzone properties but different completion procedures. Attic oil is a common result of well spacing or lease boundaries coinciding with the structural axis of a payzone. First derivative maps show the change in the structural dip and can be used to identify the attics of a structure with undrained reserves. A simple method to determine excessive well spacing is to compare estimated ultimate production between primary vertical wells and infill vertical wells in an analog field. Analysis of lease total fluid production through time is a quick and cost effective method to suggest water break-through as a result of coning.

The final step in the candidate selection process is reservoir simulation to accurately identify ROIP on a grid cell by grid cell basis. Boast4, a freeware black oil simulator, was used to history match the

performance of the Schaben Field, (Ness County, Kansas). Remaining hydrocarbon saturation-feet map (Figure A2) from this simulation was used to select areas with greatest potential for infill drilling. Boast VHS (vertical-horizontal-slant) simulation was used to predict and compare the performance of infill vertical and horizontal wells.

Conclusions

The Kansas Geological Survey has been working to develop and transfer cost-effective technologies to evaluate a potential horizontal target. We believe that small independents can successfully apply horizontal drilling technology to recover additional oil and gas in mature areas. Our approach recommends low-cost techniques to understand reservoir heterogeneity, to evaluate recovery potential at the field, lease and well scales, and to characterize and simulate candidate reservoirs.

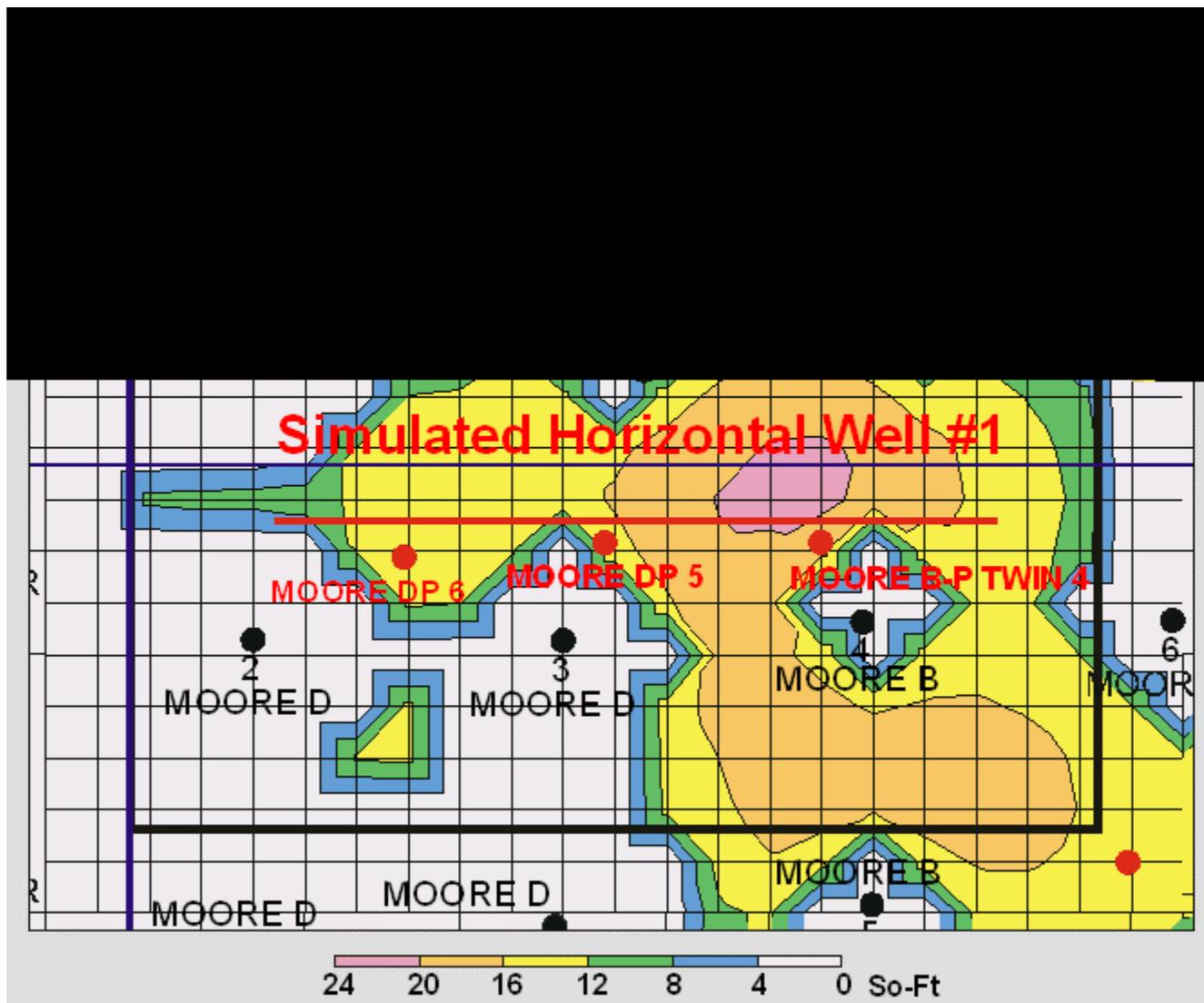


Figure A2. Remaining hydrocarbon saturation-feet map with possible vertical and horizontal infill locations base on the reservoir characterization and simulation at Schaben Field.