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

Cooperative Agreement No.: DE-FC22-93BC14987

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 1 09/18/94 -- 09/17/96)

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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

Progress is reported for the period from 1 September 1995 to 31 December 1995. Work in this quarter has continued to concentrate on reservoir characterization (Task 1.2), with an acceleration of technology transfer efforts (Task 1.3). The remaining well is now permitted and is scheduled to spud during the February.

### Task I.1 -- Acquisition and Consolidation of Available Data (Target Completion Date: 4/2/95). Delayed Completion (12/30/95).

Acquisition and consolidation of existing geologic, digital log, and production data is complete. After protracted permitting problems, the third and final new well is permitted and scheduled to be drilling in February. Sampling using a minipermeameter at 0.25 foot spacing in cores from both new wells shows that the vertical heterogeneity of the reservoir is much greater than depicted by either electric logs or traditional core plugs sampled at a 1.0 foot interval (Fig. 1). The minipermeameter results are being tied to the core description and are being used to generate permeability variograms for geologic reservoir modeling. Selected core samples have been sent out for NMR examination in order to get a better understanding of variations in pore geometry and effective porosity. Subject to hole conditions and tool availability we are still working on running a magnetic resonance imaging log (MRI) in the final well.

The completion of this task has continued to be delayed by a contentious operator, but only one well remains and should be drilled this quarter.

### Task I.2 -- Reservoir Characterization (Target Completion Date: 3/3/96).

A geologic reservoir characterization for the northern part of the Schaben Field (in and around 30-19S-21W) has been prepared for an initial reservoir simulation. When the first pass reservoir simulation is complete we will evaluate the results and make appropriate modifications to the geologic model.

Analysis of data from the remaining new well along with development of a descriptive reservoir model will continue. Engineering analysis and initial simulation efforts are underway and results should be available during the coming quarter.

### Task I.3 -- Technology Transfer (Target Completion Date: 8/4/96).

Technology transfer continues to increase and is well underway. Abstracts have been prepared and presentations are scheduled for a number of professional meetings and workshops. These include: the Platform Carbonates Workshop to be held in Norman, Oklahoma (3/96); SIPES National Meeting in Dallas, Texas (3/96); the AAPG/SEPM Carbonate Reservoir Session at the National AAPG meeting (5/96); BDM Class II workshop in Midland Texas (5/96); and the GCSEPM conference on Advanced Wireline and Geophysical Technology in Houston, Texas (12/96). Papers are associated with the Platform Carbonates

Workshop and the GCSEPM conference. Selected abstracts for presentations are attached (Appendix).

We will continue our work with Kansas operators on application of the technologies developed as part of the Class II project. We are working to provide BDM with access to the digital data from the project, and to place the data into an on-line (Internet) accessible format.

APPENDIX

Selected Abstracts

Abstract for Invited Talk/Panel Discussion at Society of Independent Petroleum Earth Scientists (SIPES) National Convention, March 20 -- 23, Dallas, TX

**The Role of the Public Sector in Providing Cost-Effective Technology to the Petroleum Independent: A Kansas Example**

CARR, TIMOTHY R., Kansas Geological Survey, University of Kansas, Lawrence, KS

To remain competitive, independent oil operators require the highest level of appropriate technology, and the highest quality data. Major technical challenges to independent operators are; geologic and engineering uncertainty, lack of knowledge of existing technology, lack of high quality data, and the lack of confidence that existing technologies can improve operations. In the last few years, the University of Kansas and the Kansas Geological Survey have attempted to address these technical challenges by a renewed commitment to improve technology and data transfer. Improvements include changes both in organizational structure, research directions, and in the process of technology transfer.

Research efforts in Kansas have focused on developing tools that leverage existing data through cost-effective application of technology. Examples include: use of well logs within interpretation systems designed for analysis of 3D seismic data ("Pseudoseismic"); a spreadsheet computer program to implement traditional and innovative log analysis (PfEFFER); and techniques for acquisition of high-resolution seismic data.

Changes in the technology transfer process are moving away from the one-on-one consultations, paper publications and dusty files, and toward providing high-speed large-volume conduits for digital data and technology among operating companies, service companies, consultants and public sector entities. The Internet has provided just-in-time accessibility to fundamental well, reservoir, and geographic data (such as e-logs, production volumes, and digital map data), to petroleum related data compilations (such as field studies, regional maps and bibliographies), and to the latest research ideas. The virtual resource center provides a flexible and efficient method to disseminate data and technology to a geographically dispersed high technology industry.

Abstract for National AAPG Convention AAPG/SEPM Session on Carbonate, May 19 -- 22, 1996, San Diego, CA

**Enhanced Carbonate Reservoir Model for an Old Reservoir Utilizing New Techniques: The Schaben Field (Mississippian), Ness County , Kansas**

CARR, TIMOTHY R., WILLARD J. GUY, EVAN K. FRANSEEN, and SAIBAL BHATTACHARYA, Kansas Geological Survey, University of Kansas, Lawrence, KS

The Pennsylvanian-Mississippian unconformity is a major stratigraphic event in Kansas that truncates rocks ranging from Precambrian to Mississippian. Many of the 6,000 fields in Kansas are located immediately beneath this unconformity. One example, Schaben Field located in Ness County, Kansas, has produced approximately 9 million barrels since it was discovered in 1963. Production is from the Mississippian (Osagian) cherty dolomites beneath the unconformity. The field was initially developed on a regular forty-acre spacing, but recent drilling has demonstrated the potential for additional targeted infill drilling.

To develop an enhanced reservoir model for the Schaben field modern core, log, and well data were integrated with the existing data. New techniques such as "Pseudoseismic" and the "Super" Pickett plot were used to leverage the existing data and provide tools for analysis and 3D visualization. The pseudoseismic approach uses well-logs within a standard 3D seismic visualization system to provide a detailed macroscale view of karst patterns. The petrophysical analyses using the "Super" Pickett plot were used to recognize subtle trends and patterns for each of multiple reservoir intervals. Visual and petrographic examination of core from the field confirms karst development and indicates multiple stages of fracturing, brecciation, and dissolution features that were important in controlling and modifying development of reservoirs. The resulting multiple stage karst reservoir model for the Schaben Field emphasizes the opportunities provided by both vertical and lateral reservoir compartments due to well-developed karst. The understanding of the reservoir heterogeneities resulting from the paleokarst model at Schaben field emphasizes the importance of integrating available data with new techniques to provide a predictive tool for discovery of additional pay within existing subunconformity fields in Kansas.

Abstract for 1996 GCSEPM Research Conference on Stratigraphic Analysis using Advanced Geophysical, Wireline and Borehole Technology for Petroleum Exploration and Production, December 8 -- 11, 1996, Houston, Texas. Paper to be submitted.

# PSEUDO-SEISMIC TRANSFORMS OF WIRELINE LOGS: A SEISMIC APPROACH TO PETROPHYSICAL SEQUENCE STRATIGRAPHY

***John F. Hopkins, and Timothy R. Carr***

Stratigraphic interpretation from wireline logs is typically drawn from multiple log traces or from crossplots of log data. Both techniques can readily depict vertical changes in lithology or reservoir quality, but lateral relationships are not readily visualized. Significant improvement in the geologic interpretation of wireline log data can be achieved through transformation and treatment of the transformed data as "seismic" traces for the purposes of processing, interpretation and display. This combination of wireline logs with a seismic interpretive approach is labeled pseudo-seismic. The pseudo-seismic transform can combine data from multiple logging tools generating a convolved 'crossplot log' for each well. A well-designed transformation of wireline log data across multiple wells maximizes both spatial and compositional information contents, and provides a readily interpretable image of the subsurface geology. Various filters and transformations can be applied to emphasize different aspects of the subsurface geology.

The transformed wireline log data are loaded into a computer workstation and interpreted as a set of 2D pseudo-seismic traces or as a 3D pseudo-seismic volume. Use of interpretation and visualization packages developed for seismic data offers flexibility in displaying and picking horizons, and increased efficiency of sequence stratigraphic interpretation. The treatment of wireline logs as a data volume permits comprehensive and cost effective sequence stratigraphic analysis of data sets that were previously considered intractable.

Examples from western Kansas, at both the regional and field scale, illustrate the utility and efficiency of sequence stratigraphic interpretation using the pseudo-seismic approach. The pseudo-seismic approach to the analysis of wireline log data from multiple wells opens new dimensions in log interpretation and provides significant insight into complex stratigraphic geometries associated with lithology, reservoir quality, and fluids.

Abstract for Workshop on Platform Carbonates in the Southern Midcontinent, March 26 -- 27, Oklahoma City, Oklahoma. Paper to be submitted.

# A NEW LOOK AT THE RESERVOIR GEOLOGY OF THE MISSISSIPPIAN SCHABEN FIELD, NESS COUNTY, KANSAS

CARR, Timothy R., GUY, Willard J., FRANSEEN, Evan K., BHATTACHARYA, Saibal, BEATY, Scott, and FELDMAN, Howard R.; Kansas Geological Survey, University of Kansas, Lawrence, KS

As part of US Department of Energy funded reservoir studies, research units at the University of Kansas have expanded their commitment to address the technical challenges faced by independent oil and gas operators. Our efforts focus on Kansas reservoirs and developing tools that leverage existing data through cost-effective application of advanced technology. An example of this approach to reservoir studies is Schaben Field, Ness County, Kansas. Since discovery in 1963, Schaben Field has produced approximately 9 million barrels from the Mississippian (Osagian) cherty dolomites beneath the Pennsylvanian-Mississippian unconformity. This unconformity is a major stratigraphic event in Kansas truncating rocks ranging from Precambrian to Mississippian. The field was initially developed on a regular forty-acre spacing, but recent drilling has demonstrated the potential for additional infill drilling. However, a detailed reservoir model is required to efficiently target infill drilling and evaluate the potential for other advanced recovery methods.

An enhanced reservoir model for the Schaben field is based on integrating modern core, log, and well data with the existing data of variable quality. New techniques such as "Pseudoseismic" and the "Super" Pickett plot leverage existing data and provide tools for analysis and 3D visualization. Pseudoseismic uses well-logs within a standard 3D seismic visualization system to provide a detailed macroscale view of reservoir patterns. At Schaben the "pseudoseismic" approach was used to recognize and map previously unknown small faults and subtle stratigraphic heterogeneities within reservoir units. The "Super" Pickett plots were used to recognize subtle trends and patterns for each of multiple reservoir intervals. Petrophysical analyses indicate that the reservoir is vertically stratified, of variable lithology (limestone, dolomite, and chert), and has high BWV (Bulk Water Volume). Petrophysical results were tied into newly acquired core data to provide the detailed documentation of reservoir heterogeneity. Original depositional facies excerpts an important control on later dissolution, cementation and dolomitization patterns. Highest quality reservoir units are associated with dolowackestone-packstones with abundant moldic, vuggy and intercrystalline porosity. Carbonate mudstones and chert horizons contribute to complex vertical and lateral compartmentalization within the Schaben Field. Karst associated with the overlying unconformity results in a fracture and breccia overprint that variably producibility of individual horizons.

The resulting multiple stage reservoir model for the Schaben Field emphasizes the opportunities provided by both vertical and lateral reservoir compartments. Compartmentalization is the result of a complex depositional and diagenetic history overprinted by a well-developed karst. The understanding of the reservoir heterogeneities resulting from the paleokarst model at Schaben field emphasizes the importance of integrating available data with new techniques to provide a predictive tool for discovery of additional pay within existing subunconformity fields in Kansas.