DOE/BC/14425

**ESTABLISHMENT OF AN OIL AND GAS DATABASE FOR INCREASED
RECOVERY AND CHARACTERIZATION OF OIL AND GAS CARBONATE
RESERVOIR HETEROGENEITY**

Contract No. DE-FG22-89BC14425

**Geological Survey of Alabama
Tuscaloosa, Alabama**

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Objective

The objectives of this project are to augment the National Reservoir Database (TORIS database) and to increase our understanding of geologic heterogeneities that affect the recoveries of oil and gas from carbonate reservoirs in the State of Alabama and to identify those resources that are producible at moderate cost. These objectives will be achieved through detailed geological, engineering, and geostatistical characterization of typical Jurassic Smackover Formation hydrocarbon reservoirs in selected productive fields in the State of Alabama. The results of these studies will be used to develop and test mathematical models for prediction of the effects of reservoir heterogeneities in hydrocarbon production.

Summary of Progress

Work to date has focused on the completion of Subtasks 1, 2, and 3 of this project as stated in Annex 1 to the Memorandum of Understanding between the United States Department of Energy (DOE) and the State of Alabama, through the Geological Survey of Alabama (GSA) and attachments to said Annex.

Subtask 1

Subtask 1 has been completed and a topical report detailing this subtask has been submitted to DOE. Subtask 1 included the survey and tabulation of available reservoir engineering and geological data relevant to the Smackover reservoir in southwestern Alabama. These data were submitted to DOE via magnetic computer tape in a format compatible with the national reservoir database (TORIS database). Data are being added and/or updated into the database as necessary and this will continue throughout the project.

Subtask 2

Subtask 2 comprises the geologic and engineering characterization of Smackover reservoir lithofacies. This has been accomplished through detailed examination and analysis of geophysical well logs, core material, well cuttings, and well-test data from wells penetrating Smackover reservoirs in southwestern Alabama. From these data, reservoir heterogeneities, such as lateral and vertical changes in lithology, porosity, permeability, and diagenetic overprint, have been recognized and used to produce maps, cross sections, graphs, and other graphic representations to aid in interpretation of the geologic parameters that affect these reservoirs. Geological and engineering research pursuant to this subtask has focused on descriptions of core material and petrographic thin sections and computer entry of pertinent data, including available core analyses as well as digitization of geophysical well logs. The ultimate goal of this research is a comprehensive characterization of all Smackover fields in the state. This characterization of Smackover fields will continue throughout the project.

All Smackover cores archived at the GSA have been inventoried and their condition and coverage evaluated. These data have been organized into computer databases that are updated regularly. More than 22 whole cores have been slabbed to facilitate description. The Smackover core inventory at the GSA is being enhanced by the addition of all new cores cut from Smackover rocks penetrated by wells within the State and by a vigorous program to acquire cores stored in other repositories.

Cores from 19 Smackover fields (Barnett, Big Escambia Creek, Bucatunna Creek, Chappell Hill, Chatom, Churchula, Gin Creek, Hatter's Pond, Healing Springs, Little Escambia Creek, Little River, Lovetts Creek, North Choctaw Ridge, North Wallers Creek, Stave Creek, Toxey, Turnerville, Uriah, and West Barrytown) have been described and graphic summaries of the core descriptions have been integrated with other data to generate reservoir characterizations for these fields. Depositional and diagenetic sequences have been interpreted and summarized for each core. Petrographic thin-section studies have been made on 7 of the 19 fields listed, in order to supplement and extend interpretations made from core descriptions. Two hundred ninety-nine thin sections have been described, 295 have been made but not yet described, and 46 have been selected but not yet made. A comprehensive record, in the form of an annotated file of 35-mm color slides, is being compiled from all thin sections examined. Paragenetic sequences have been reconstructed for most of the 19 fields described. Twenty-six thin sections have been point counted in order to estimate the relative proportions of particle and pore types making up the reservoirs.

Capillary pressure data are being collected on samples taken from selected cores from Smackover fields. These data will supplement the petrographic and geophysical data. To date, 9 capillary pressure analyses have been run, and 91 other samples have been prepared for analysis. In addition, image analysis using petrographic thin sections and scanning electron microscopy will be used to study the shapes and sizes of pores. Preliminary work needed to design appropriate image-processing techniques is now underway. This type of analysis and description will be carried out on all 46 Smackover fields for which core material currently is available.

Geophysical log suites for all 70 Smackover fields in Alabama were studied, and a type log for each field has been selected for digitization. Type logs of 51 Smackover fields have been digitized; type logs for the remaining 19 fields have been selected and will be digitized in the next quarter. The log suites that are being digitized include three induction curves, an SP curve, a gamma ray curve, a PEF curve, a caliper curve, a density curve, and a neutron curve. In addition, well-log data have been used to construct structure maps and structural cross sections for all 70 Smackover fields in Alabama. These maps and cross sections, which were generated by computer drafting techniques, are now complete. Oil samples from 27 Alabama Smackover fields not previously analyzed have been sent to the United States Geological Survey in Denver for geochemical analyses. These geochemical data will be integrated with the oil analyses from the fields previously studied and therefore will serve to enhance the existing geochemical database for Smackover oils in Alabama. All available commercial core-analysis data (porosity and permeability) for Smackover fields in the State have been entered into a computerized database. Entry of these data for wildcat wells is being completed at present. These data are being used for statistical analyses and to generate Dykstra-Parsons coefficients for the Smackover fields. Net pay, average porosity, and average water saturation values for 55 Smackover fields have been reviewed and revised as necessary.

Preliminary results of Smackover geological and engineering characterization (detailed in a recent topical report submitted to DOE) suggest that Smackover reservoirs may be placed on a gradient of diagenetic alteration, from slightly altered reservoirs that preserve much of their primary fabric, to pervasively altered reservoirs that have lost all vestiges of their primary fabric. This classification is useful because reservoir petrophysical properties are in part a function of intensity of diagenetic alteration. Also, whereas the petrophysical characteristics (e.g., permeability) of slightly altered reservoirs depend primarily on characteristics inherited from the depositional environment, highly altered reservoirs have petrophysical characteristics that derive mainly from the twin diagenetic processes of leaching and dolomitization. Dolomitization has a profound effect on fluid flow characteristics of a reservoir where it is not fabric selective. By contrast, fabric selective dolomitization has little effect on rock petrophysics.

In a more quantitative way, it appears that Smackover fields in southwest Alabama may be grouped into reservoir types on the basis of similarities in (1) depositional setting, (2) rock fabric, (3) pore types, (4) permeability values, (5) relationships between porosity and permeability, and (6) structural and geographic setting. Congruent variation in the 6 parameters listed may permit development of a heuristic classification of Smackover reservoirs in Alabama. This simply means that informed assessment of relatively accessible data, such as depositional setting, rock fabric, and structural and geographic setting may permit reliable prediction of relatively inaccessible data, specifically reservoir heterogeneity. This is one of the main goals of this study. This approach seems promising because many of the variables used in the geologic modeling of reservoir heterogeneity are the same as the ones discussed here.

The following example (Figure 1) shows that important petrophysical parameters such as permeability and pore type have similar values in some fields, and dramatically different values in others. Because this variation is congruent with variation in depositional setting, rock fabric, structural setting, and other relatively accessible variables, it seems likely that a field classification using these variables will permit prediction of reservoir petrophysics and reservoir heterogeneity. The following 3 fields, Gin Creek, Bucatunna Creek, and Lovetts Creek, are compared on a graph of porosity vs. log of permeability, and on a series of histograms of porosity types (data from point counts of thin sections). The first 2 fields exhibit dramatic similarities, whereas Lovetts Creek looks distinctly different. The first 2 fields are in close geographic proximity to one another, and have similar depositional and diagenetic characteristics. Lovetts Creek field is located in an entirely different structural setting, and also differs in depositional and diagenetic characteristics.

Subtask 3

Subtask 3 includes the geologic modeling of reservoir heterogeneities for Smackover reservoirs. This research has been based primarily on the evaluation of key geologic and engineering data from selected Smackover fields. These data represent important parameters influencing heterogeneity in Smackover fields and include porosity and permeability measurements from core-analysis data, porosity measurements from geophysical well logs, number of reservoir intervals within a field, thickness of reservoir intervals within a field, continuity of reservoir intervals within a field and petrographic data (porosity types, distributions, diagenetic alterations, etc.) for cores and core chips. Ten fields were used in this analysis; these fields were selected to represent the geologic diversity of Smackover reservoirs in the study area and to provide a good geographic distribution within the area. The ten fields are Chappell Hill, North Choctaw Ridge, and Sugar Ridge fields in Choctaw County, Chatom and Copeland fields in Washington County, Stave Creek field in Clarke County and West Bend field in Clarke and Choctaw Counties, Vocation field in Monroe County, Fanny Church field in Escambia County, and Churchula field in Mobile County. Using the data outlined above, an equation was derived that yields a hierarchical heterogeneity ranking for the fields. This ranking methodology is simple and uses data that are readily available for all Smackover fields.

Subtask 3 also requires that GSA host an annual public conference targeted at Alabama oil and gas operators for the purpose of transferring data and results of the project. The first of these conferences was held September 18-19, 1990, at the University of Alabama in Tuscaloosa, Alabama. Forty individuals representing industry, state and federal government agencies, and academia attended the meeting. At this conference, research team members from GSA and the University of Alabama gave eight presentations of research findings. Attendees were asked to comment on and critique the research effort; overall, comments were quite favorable regarding the work to date and future research plans. A list of attendees and the agenda for the conference are attached to this quarterly report.

Detailed topical reports of the results of Subtasks 1, 2, and 3 have been completed and submitted to DOE for review.

Significant Accomplishments

Significant accomplishments to date include the completion of Subtasks 1, 2, and 3 of the project and the completion of comprehensive topical reports of the results of these subtasks. In addition, significant progress toward the development of detailed predictive geostatistical and petroleum engineering models for the Smackover reservoir at Churchula field has been accomplished.

Conditional stochastic simulation using a fractal simulation program being developed as a part of this project is progressing ahead of schedule. Several test simulations have been run on the Alabama Supercomputer Network's Cray XMP supercomputer. This network has been interfaced with the University of Alabama, Department of Physics and Astronomy's VAX computer in order to use the IRAF astronomical image-processing package to produce false-color images for individual realizations of the geostatistical reservoir simulation. In the test simulations run to date, porosity values at two wells are held fixed and porosity values in interwell areas are predicted. Thus, the simulated values of these interwell porosities are conditional on the boundary values for the two wells. Simulations of multiple well systems will be run in the near future.

Conditional stochastic simulation of the reservoir at Churchula field has as its immediate goal the three-dimensional petrophysical modeling of the reservoir. The implications of this approach extend far beyond the boundaries of Churchula field, however. Proper integration of geological models into the conditional stochastic simulation will permit geologically realistic petrophysical prediction. This could then be coupled with the geological and engineering classification of reservoir types described earlier in this quarterly report, to permit generalization of petrophysical models derived from conditional stochastic simulation from one field to another, at least at some level.

Petroleum engineering studies to date have focused on completing the data base for Churchula field for use in reservoir engineering analyses, including reservoir simulation.

Significance to EOR Research Plan

The completion of Subtasks 1, 2, and 3 of Annex I and the research progress made toward geostatistical and engineering reservoir modeling are integral to the evaluation of EOR methodologies appropriate to a particular Smackover hydrocarbon reservoir. No EOR project can be totally successful without a full understanding of reservoir compartmentalization resulting from geologic heterogeneities within the reservoir interval. The distribution of heterogeneities within a reservoir can be understood only through detailed petrographic analysis of reservoir lithofacies (core description, thin-section petrography, etc.) combined with analysis of all available reservoir-engineering oriented data (core-derived measurements of porosity and permeability, capillary-pressure analysis, geophysical well-log analysis, etc.). The results of Subtasks 1 and 2 research provide us with these basic analyses necessary to gain an understanding of the Smackover reservoirs in southwestern Alabama. The results of Subtask 3 allows us to place reservoirs into a hierarchical ranking scheme of reservoir heterogeneity, which gives a relative means by which to rate reservoirs in terms of those most likely to contain unswept or uncontacted mobile oil and, therefore, be likely candidates for infill drilling or EOR.

Progress in geostatistical and engineering reservoir modeling is significant to the EOR research plan in that these models will provide stochastic and deterministic predications, respectively, of reservoir geometry, compartmentalization, and fluid-flow pathways. These data are extremely important to the design of EOR methodologies and to the infill drilling strategy within a field.

Figure 1: Example of petrophysical similarities and differences among three Smackover fields in Alabama

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RELATIVE ABUNDANCE OF PORE TYPES FOR THREE SMACKOVER FIELDS

**DOE SMACKOVER RESERVOIR HETEROGENEITY WORKSHOP
GEOLOGICAL SURVEY OF ALABAMA/
UNIVERSITY OF ALABAMA
SEPTEMBER 18-19, 1990**

Day 1-September 18, 1990

8:30-10:00 AM-- Welcome and Background Information--Ernest Mancini,
Robert Mink, Nick Tew, Steve Mann-Geological Survey of
Alabama

Regional Geology--Nick Tew (GSA)
Smackover Source Rocks and Oil Geochemistry--Ernest
Mancini (GSA)
Hydrocarbon Trends and Production--Robert Mink (GSA)
Smackover Core Descriptions and Petrography--Steve
Mann (GSA)

10:00-11:15 AM-- Discussion and Break

11:15-11:30 AM-- TORIS Database--Henry Moore (GSA)

11:30 AM-Noon-- Discussion

Noon-1:30 PM-- Lunch

1:30-2:00 PM-- Reservoir Heterogeneity--Joe Benson-University of
Alabama

2:00-3:30 PM-- Discussion and Break

3:30-4:00 PM-- Field Characterization--David Kopaska-Merkel (GSA)

4:00-5:00 PM-- Discussion and recess

Day 2-September 19, 1990

8:30-9:00 AM-- Core testing and log digitization--Peter Clark (UA)

9:00-10:00 AM-- Discussion and break

10:00-10:30 AM-- Geostatistics--Jen-Ho Fang (UA)

10:30-11:30 AM-- Discussion

11:30-12:00 AM-- Wrap-up

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