ANNUAL REPORT

***“BASIN ANALYSIS OF THE MISSISSIPPI INTERIOR SALT BASIN
AND PETROLEUM SYSTEM MODELING OF THE
JURASSIC SMACKOVER FORMATION,
EASTERN GULF COASTAL PLAIN”***

Submitted to

U.S. Department of Energy

By

**Department of Geological Sciences
The University of Alabama**

August 24, 2000

Report Title

“Basin Analysis of the Mississippi Interior Salt Basin and Petroleum System Modeling of the Jurassic Smackover Formation, Eastern Gulf Coastal Plain”

Type of Report

Annual Report for Year 4

Reporting Period Start Date

August 23, 1999

Reporting Period End Date

August 22, 2000

Principal Author

Ernest A. Mancini (205/348-4319)
Department of Geology
Box 870338
202 Bevill Building
University of Alabama
Tuscaloosa, AL 35487-0338

Date Report was Issued

August 24, 2000

DOE Award Number

DE-FG22-96BC14946

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Table of Contents

	Page
Problem	1
Project Description	1
Project Objectives	1
Research Accomplishments.....	1
Year 1	1
Year 2	3
Year 3	4
Year 4	6
Application and Utility of Project Results	7
Conclusions	7
Table 1. Publications and Presentations	9

ANNUAL REPORT

Problem

Oil and gas producers in the Eastern Gulf Coastal Plain maintain that the accessibility of oil and gas information is the single-most important factor to assist them in finding new hydrocarbon discoveries and in improving production from established fields in the Mississippi Interior Salt Basin.

Project Description

The Eastern Gulf of Mexico remains an underexplored region containing numerous sedimentary basins with a host of siliciclastic and carbonate formations having a high potential for hydrocarbon accumulations. To date, comprehensive basin analysis and petroleum system modeling studies have not been performed on any of the basins in this region. Further, small- and medium-sized companies are drilling the majority of the exploration wells in this region. These companies do not have the resources to perform basin analysis or petroleum system modeling studies nor do they have resources to do information searches through the voluminous amount of public data available at information repositories in the region.

Project Objectives

The project objectives are improving access to information for the Mississippi Interior Salt Basin by inventorying data files and records of the major information repositories in the region, making these inventories easily accessible in electronic format, increasing the amount of information available on domestic sedimentary basins through a comprehensive analysis of the Mississippi Interior Salt Basin, and enhancing the understanding of the petroleum systems operating in the Mississippi Interior Salt Basin.

Research Accomplishments

Year 1

An industry advisory committee consisting of Dave Cate (Pruet Production Company), Tom McMillan (Smackco, Ltd.), Julius Ridgway (Ridgway Energy, Inc.), Robert Schneeflock

(Paramount Petroleum), Harry Spooner (Spooners Energy, Inc.) and Terry Tigrett (Moon-Hines-Tigrett Operating Company) has been constituted.

The inventory of public data available for the Mississippi Interior Salt Basin has been completed. The inventory consisted of past and current petroleum geology research projects at the major research institutions in the region and at the geological surveys and oil and gas regulatory organizations in the area. Service companies and state agencies were contacted for listings of wells, logs, cores and cuttings, production data, and other drilling and production information and seismic data.

The information has been made available in electronic format through the Web site of the Eastern Gulf Region of the Petroleum Technology Transfer Council (EGR) and through the respective state agencies. In addition, links to commercial entities with oil and gas information and data are available through the EGR Web site. Base maps illustrating commercially available seismic reflection data have been identified, compiled and are available in electronic format.

Because much of the oil and gas information and data are not available in an electronic format, researchers on this project continue to work with state agencies in Mississippi, DOE and PTTC to make this information available electronically. This effort is a major undertaking and beyond the scope of this project.

To accomplish the objectives of this project, researchers have used oil and gas information and data available in the commercial domain for the basin analysis and petroleum system modeling components of this project.

The oil and gas public data available for the Mississippi Interior Salt Basin have been compiled and published (DOE/BC/14946-3). The report includes a bibliography, a listing of state agency reports and documents, a listing of theses and dissertations, a base map illustrating available seismic reflection data, a listing of well cores and cuttings and a listing of selected field studies. The report includes information from the Alabama Geological Survey, the Alabama Oil and Gas Board, the Mississippi Office of Geology, the Mississippi Oil and Gas Board, the Florida Geological Survey, and the Louisiana Geological Survey. Theses and dissertations from

the following universities are included in the report: University of Alabama, Auburn University, Mississippi State University, University of Mississippi, University of Southern Mississippi, Louisiana State University, University of Southwestern Louisiana, Northeast Louisiana University, Florida State University and the University of Florida.

Workshops were held in Tuscaloosa, Alabama on September 26, 1997, and in Jackson, Mississippi on November 6, 1997, to transfer the information compiled during Year 1 of the project and to discuss with producers the research plan for Year 2 of the project.

During the first year of the project, two underdeveloped hydrocarbon plays have been identified. The salt dome play in the central portion of the Mississippi Interior Salt Basin is estimated to have the potential to add 50 to 75 million oil equivalent barrels of new reserves. An underdeveloped reef play in the Upper Jurassic Smackover Formation along the northern extent of the basin has also been identified.

Year 2

Part 2 of the project is to provide a comprehensive analysis of the Mississippi Interior Salt Basin in Years 2 and 3 of the project and to transfer effectively the research results to producers through workshops and topical reports. Workshops were held in Tuscaloosa, Alabama on March 3, 1998, and in Jackson, Mississippi on March 4, 1998, to transfer the knowledge gained from Year 2 of the project and to discuss with the producers the research plan for Year 3 of the project. Topical reports on the tectonic and depositional histories and the burial and thermal histories of the Mississippi Interior Salt Basin were initiated.

The regional base map for the oil and gas fields, land grid map, field and reservoir production tabulation and well location and formation top database have been prepared. The well database consists of over 3,000 oil and gas wells that penetrated Jurassic strata in the Mississippi Interior Salt Basin area. To interpret the tectonic and depositional histories of the basin, five regional cross-sections consisting of 48 key wells have been drawn. Subsurface structure maps and isopach maps have been constructed on key stratigraphic horizons. A biostratigraphic study of two composite wells proved inconclusive. Well log patterns, well cuttings and core

descriptions have been used for sequence stratigraphic analysis. Depositional sequences have been interpreted for the Jurassic, Cretaceous and Paleogene strata in the basin. The structure and isopach maps have been compared to reconstruct the tectonic and depositional histories of the basin. The structural and stratigraphic framework of the basin was established as the Triassic and Jurassic and is a function of extensional rift tectonics and wrench faulting.

Mesozoic and Cenozoic strata in the basin were deposited as part of a seaward-dipping wedge of sediment that accumulated as a result of rift-related geohistory. The geologic section includes syn-rift redbeds and evaporites and post-rift siliciclastics, carbonates and evaporites.

Standard burial and thermal history software were acquired to determine the burial and thermal histories of each of the 48 wells utilized in the preparation of the regional cross-sections. Sediment accumulation and subsidence rate determinations were made for each of the wells. Oil and source rock analysis information has been tabulated, and oil gravities have been plotted on the regional base map. A vitrinite reflectance study produced limited results. Thermal alteration indices in combination with bottomhole temperature data were used in combination with the results of the vitrinite reflectance study to determine geothermal gradients. Bottomhole temperature and geothermal gradient data have been plotted on the regional base map.

Year 3

In Year 3, all tasks of Part 2 of the project were completed, except for the fluid flow task which we will continue into Years 4 and 5. A workshop was held in Tuscaloosa, Alabama on September 23, 1998, and a workshop was conducted in Jackson, Mississippi on July 21, 1999, to transfer the knowledge gained from the project and to discuss with the producers the research plan for Year 4 of the project. Presentations on research results of this project were made at the 1999 Annual Meeting of the American Association of Petroleum Geologists, at the 1999 Hedberg Research Conference of the American Association of Petroleum Geologists, at the 1999 DOE Oil and Gas Conference, and at the Annual Meeting of the Gulf Coast Association of Geological Societies. A paper on Part 2 of the project was published in the Transactions of the Gulf Coast Association of Geological Societies. Topical reports on the tectonic and depositional

histories and burial and thermal histories of the Mississippi Interior Salt Basin have been completed and submitted to DOE and placed on the EGR-PTTC Web site.

Burial and thermal history modeling for the basin was completed in Year 3. The tectonic and depositional histories of the Mississippi Interior Salt Basin form the foundation for interpreting the burial history of the basin. The burial history for 48 key wells in the cross-sections was determined using BasinMod® software. Information interpreted from the cross-sections, well logs, and other sources include biostratigraphic, paleoenvironmental, stratigraphic thickness of the units, lithologies, unconformities and faulting. Mean stratigraphic thickness, sediment accumulation rates and tectonic subsidence rates were determined using BasinMod® software. The burial history modeling is consistent with the rift-related geohistory of the basin. The greatest accommodation space was generated during the Jurassic. The deepest water depths occurred during the Late Jurassic, Early Cretaceous, Late Cretaceous and Late Eocene. These events correspond to global rises in sea level. Therefore, eustasy also contributed to the generation of accommodation space. Sediment accumulation acts to reduce available accommodation space. Sediment supply in concert with tectonics and eustasy are the principal controls on sediment accumulation and cyclicity in the basin.

The thermal history for key wells in the cross-sections was determined using BasinMod® software. The tectonics, depositional and burial histories of the basin form the foundation for interpreting the thermal history. Information utilized includes bottomhole temperature, present-day geothermal gradient, present-day heat flow, vitrinite reflectance, thermal alteration, Tmax, paleogeothermal gradient, paleoheat flow, thermal conductivity, total organic carbon and kerogen-type data. The thermal history modeling indicates that effective source rocks in the basin include Upper Jurassic Smackover carbonate mudstones throughout the basin area and Upper Cretaceous Tuscaloosa shales in the south-central portion (Perry sub-basin area) of the basin. Upper Jurassic and Lower Cretaceous shales are possible source rocks in the south-central portion (Perry sub-basin) of the basin given the proper organic facies. Tertiary shales have not been subjected to favorable burial and thermal histories required for petroleum generation in the

basin. These observations are consistent with previous studies. The generation of crude oil from source rocks in the Mississippi Interior Salt Basin is interpreted to have been initiated at a level of thermal maturity of 0.55% Ro (435°C Tmax, 2 TAI) and concluded at a level of thermal maturity of 1.5% Ro (470°C Tmax, 3 TAI). From thermal maturation profiles for wells in this study, the generation of hydrocarbons from Smackover carbonate mudstones is initiated at a depth of 8,000 to 11,000 feet during the Early Cretaceous and continuing throughout the Tertiary throughout much of the Mississippi Interior Salt Basin. Locally, hydrocarbon generation commenced at 7,000 to 8,000 feet from Tuscaloosa shales during the Tertiary in the area of the Perry sub-basin.

Year 4

In Year 4, petroleum system modeling of the Upper Jurassic Smackover Formation was initiated. A workshop on this work will be held on November 8, 2000 in Jackson, Mississippi to transfer the knowledge gained from the project and to discuss with the producers the research plan for Year 5 of the project. Presentations on research results of this project were made at the 2000 Annual Meeting of the American Association of Petroleum Geologists, at the 2000 DOE-NPTO Contractor's Review Meeting, at the 2000 International Geological Congress and will be made at the 2000 Annual Meeting of Gulf Coast Association of Geological Societies. Four manuscripts on Part 2 of the project have been accepted for publication in the Transactions of the Gulf Coast Association of Geological Societies. A topical report on underdeveloped plays and reservoirs in the basin has been completed and is included in the Appendix of this report.

Three major petroleum plays in and along the margins of the Mississippi Interior Salt Basin have been identified in this study. These structural plays include the basement ridge play along the northern margin of the salt basin, the regional peripheral fault trend play also along the northern margin of the basin near the updip limit of Louann Salt deposition, and the salt anticline play within the Mississippi Interior Salt Basin proper. Petroleum reservoirs have been delineated within these major plays.

The salt anticline play of the Mississippi Interior Salt Basin is downdip of the regional peripheral fault trend and is characterized by a progression of salt and salt-related features varying from updip to downdip as follows: (1) peripheral salt ridges, (2) low relief salt pillows, (3) salt anticlines, (4) turtle structures, and (5) piercement domes. These structural features form the majority of the petroleum traps in the basin. Combination traps, consisting of porosity and permeability terminations, also occur on these salt and salt-related features. Associated with the salt features are listric normal faults and graben systems.

To date, nine regional reservoirs are recognized within the Mississippi Interior Salt Basin anticline play. These are the: (1) Eutaw sandstone, (2) Tuscaloosa sandstone, (3) Dantzler sandstone, (4) Rodessa/Mooringsport/Paluxy sandstones, (5) Hosston/Sligo sandstones, (6) Cotton Valley sandstone, (7) Haynesville sandstone, (8) Smackover carbonate, and (9) Norphlet sandstone. Each of these reservoirs is underdeveloped in parts of the basin. Local reservoirs in the basin are the James Limestone, Selma Chalk, and Wilcox sandstone. Potential reservoirs in the basin include Lower Cretaceous carbonates and subsalt Eagle Mills sandstones; however, to date, these intervals have not been productive in the basin. Most of the oil production is from the Tuscaloosa, Eutaw, Rodessa/Mooringsport/Paluxy, and Smackover reservoirs, and the majority of the gas production is from Hosston/Sligo, Smackover, Tuscaloosa, and Eutaw reservoirs.

Application and Utility of Project Results

The lessons learned from this project have application in other regions where small- and medium-sized companies are the principal operators. New hydrocarbon and improved field recoveries will add to our domestic petroleum resource base and contribute to national energy security. Additional production will add to the economies of Mississippi and Alabama.

Conclusions

The project is on schedule, except the basin flow modeling will continue into Year 5.

A vast amount of the oil and gas data available in the public domain is not in an electronic format and will require a major effort to achieve this goal.

There is a great deal of oil and gas data available in the commercial domain at reasonable costs. Therefore, the basin analysis and petroleum system modeling studies will utilize data from the public and private sectors to be cost effective.

The first part of the basin analysis study has shown that the principal petroleum traps are salt and basement related. These traps may have a stratigraphic component. The key reservoirs are Jurassic carbonates (Smackover) and sandstones (Norphlet, Haynesville, and Cotton Valley) and Cretaceous sandstones (Lower Cretaceous, Tuscaloosa and Eutaw). Seal rocks include anhydrites (Buckner, Ferry Lake) and shales (Tuscaloosa).

The second part of the basin analysis study has shown that the burial history modeling for the basin is consistent with the rift-related geohistory of the region, with tectonic subsidence rates being greatest during the Jurassic resulting in maximum accommodation space during this time.

The thermal history modeling indicates that effective source rocks include Upper Jurassic Smackover carbonate mudstones throughout much of the basin and Upper Cretaceous Tuscaloosa black shales locally in the south-central portion of the basin.

Three major petroleum plays in and along the margins of the Mississippi Interior Salt Basin have been identified in this study. These structural plays include the basement ridge play and regional peripheral fault trend play along the basin margin and the salt anticline play in the basin proper.

Nine regional reservoirs within the Mississippi Interior Salt Basin anticline play have been recognized. These are the: (1) Eutaw sandstone, (2) Tuscaloosa sandstone, (3) Dantzler sandstone, (4) Rodessa/Mooringsport/Paluxy sandstones, (5) Hosston/Sligo sandstones, (6) Cotton Valley sandstone, (7) Haynesville sandstone, (8) Smackover carbonate, and (9) Norphlet sandstone. Each of these reservoirs is underdeveloped in parts of the basin. Local reservoirs in the basin are the James Limestone, Selma Chalk, and Wilcox sandstone, and potential reservoirs include Lower Cretaceous carbonates and subsalt Eagle Mills sandstone.

Table 1. Publication and Presentations

Papers

- Mancini, Ernest A., Sequence stratigraphy and chronostratigraphy of Upper Eocene and Lower Oligocene strata, eastern Gulf Coastal Plain, Gulf Coast Association of Geological Societies Trans. 50 (in press), 2000.
- Mancini, Ernest A., and Puckett, T.M., Sequence stratigraphy and petroleum potential of Lower Cretaceous strata, Mississippi Interior Salt Basin, Gulf Coast Association of Geological Societies Trans. 50 (in press), 2000.
- Bearden, Bennett L., Mancini, Ernest A., and Puckett, T.M., Salt anticline play in the Mississippi Interior Salt Basin, Gulf Coast Association of Geological Societies Trans. 50 (in press), 2000.
- Puckett, T. Markham, and Mancini, Ernest A., Microfossil characteristics of systems tracts in the Upper Cretaceous deposits of Mississippi and Alabama, Gulf Coast Association of Geological Societies Trans. 50 (in press), 2000.
- Puckett, T. Markham, B.L. Bearden, E.A. Mancini, and B.J. Panetta, Topical Report 3, Petroleum plays and underdeveloped reservoirs in the Mississippi Interior Salt Basin, Basin analysis of the Mississippi Interior Salt Basin and petroleum system modeling of the Jurassic Smackover Formation, eastern Gulf Coastal Plain, U.S. Department of Energy Report, 107 p., 2000.

Abstracts

- Mancini, Ernest A., Variability in components of the Upper Jurassic Smackover petroleum system, northeastern Gulf of Mexico, Am. Assoc. Petroleum Geologists Bulletin, 2000 Am. Assoc. Petroleum Geologists Annual Meeting Abstract Volume, p. A92, 2000.
- Mancini, Ernest A., and Puckett, T. Markham, Integrated lithostratigraphic and biostratigraphic approach to sequence stratigraphic analysis: Lower Cretaceous section, Mississippi Interior Salt Basin, Am. Assoc. Petroleum Geologists Bulletin, 2000 Am. Assoc. Petroleum Geologists Annual Meeting Abstract Volume, p. A92, 2000.
- Mancini, Ernest A., Basin analysis of the Mississippi Interior Salt Basin and petroleum system modeling of the Jurassic Smackover Formation, eastern Gulf Coastal Plain, DOE Oil Technology Program and Contractor Abstracts Volume, p. DCS-15, 2000.
- Mancini, Ernest A., Improved oil recovery from Upper Jurassic Smackover carbonates (Class II Reservoir) through the application of advanced technologies at Womack Hill Oil Field, Choctaw and Clarke Counties, Alabama, eastern Gulf Coastal Plain (Class Revisits), DOE Oil Technology Program and Contractor Abstracts Volume, p. DEMO-06, 2000.
- Mancini, Ernest A., and Puckett, T.M., Sequence stratigraphy of Lower Cretaceous strata, eastern Gulf Coastal Plain, USA, 31st International Geological Congress Abstract Volume, 2000.
- Mancini, Ernest A., Puckett, T.M., and Parcell, W.C., Integrated biostratigraphic and sequence stratigraphic framework: key to sedimentary basin modeling, 31st International Geological Congress Abstract Volume, 2000.

Presentations

- Mancini, Ernest A., American Association of Petroleum Geologists Annual Meeting, New Orleans, LA, 2000.
- Mancini, Ernest A., DOE Oil Technology Program Review Meeting, Denver, CO, 2000.
- Mancini, Ernest A., International Geological Congress, Rio de Janeiro, Brazil, 2000.